



**UNIVERSITY OF LEEDS**

**Aspects of imaging of the anterior region of the edentulous  
mandible prior to dental implant placement**

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The candidate confirms that the work submitted is his own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

The work in Part 1 of this thesis has appeared in publication as follows:

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### **Professor Paul Brunton**

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### **Professor Anne-Marie Glenny**

Advisor on systematic review methodology and member of review team

### **Mrs Lauren Wardle**

Research assistant for the questionnaire study - Compiled the sample frame, made telephone reminders and collected the post survey data

### **Mr Alessandro Ferrero**

Dental Technician – Jointly developed the dental simulation used in the before-after study and manufactured all the drillable models.

### **Mr Julian McKenny and Mr Nick Gould**

Website developers – wrote the software for the on-line survey used in the questionnaire study



## Abstract

### Objectives

To gain an understanding of the imaging prescription of implant practitioners when placing implants in the anterior edentulous mandible and to investigate the impact of cross sectional imaging on diagnostic thinking, treatment planning and patient outcome.

### Methods

- ❖ A web-based questionnaire presented two realistic clinical scenarios of edentulous patients. Participants were asked to prescribe imaging prior to implant placement.
- ❖ A systematic review was conducted to determine if pre-operative availability of cross-sectional imaging has an impact on diagnostic thinking, therapeutic impact or impact on patient outcome when placing dental implants in the anterior mandible.
- ❖ A before-after study of osteotomy preparation was undertaken using simulations of four edentulous mandibles, recording the incidence of perforations of the lingual surface. Participants were presented with conventional imaging in the “before” part of the study and conventional imaging with CBCT in the “after” part of the study. Two cases were regarded as “regular” and two as “challenging”.

### Results

- ❖ 169 dentists were surveyed with an 80% response. The results showed no agreement on prescription of imaging methods.
- ❖ The systematic review identified only five relevant studies. These were clinically diverse with high risk of bias.
- ❖ In the before-after study, there were no perforations in the regular cases either before or after the availability of CBCT. There were fewer perforations in the

challenging cases after the availability of CBCT but this difference was not statistically significant.

## **Conclusions**

- ❖ The imaging prescription of dentists when planning implant placement in the anterior edentulous mandible is chaotic.
- ❖ The systematic review found no evidence to support any specific imaging modality when planning implant placement.
- ❖ The before-after study provided very weak evidence that CBCT may be helpful in avoiding perforations in challenging cases.



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### **Conflicts of interest**

There are no conflicts of interest. Whilst Neoss Ltd generously loaned me an implant motor and associated instrumentation, they had no further involvement in the research. These studies did not involve the evaluation of any implant system.



## 1 Introduction

### 1.1 Edentulousness and implant supported dentures

Whilst tooth loss in the United Kingdom and other industrialised countries is in decline [1], there is equally a rise in the population and the proportion of those over 65 years.[2] The effect of this is that there is likely to remain a significant number of edentulous individuals in the population. Feine et al comment, "Complete maxillary and mandibular dentures have been the traditional standard of care for edentulous patients for more than a century".[3] This underestimates the history of dentures as the first are reported to have been made by the Etruscans around 700 BCE.[4] Many edentulous patients struggle to function leading to a decline in their quality of life.[5] This is particularly true of lower dentures where looseness and discomfort are common.[6]

The placement of two dental implants in the anterior mandible allows methods of additional retention to be used to support complete lower dentures. Implant retained overdentures dramatically improve patient satisfaction compared to conventional lower complete dentures. For example, Thomason et al carried out a randomised controlled study comparing a number of factors in a group of edentulous patients who were assigned to a conventional or implant retained overdenture group. Ability to chew, denture comfort and stability were all rated significantly higher in the two implant retained overdenture group. [7]

The McGill consensus of 2002 [3] and the York consensus of 2009 [5] both reviewed the place of mandibular two implant overdentures in the treatment of edentulism. The McGill group concluded, "There is now overwhelming evidence that a two implant overdenture should become the first choice of treatment for the edentulous mandible." [3] Similarly, the York group commented, "A two implant supported mandibular overdenture should be the minimum offered to edentulous patients as a first choice of treatment." [5]

Interestingly, there is disagreement about the quality of evidence to support these statements. The SBU, the Swedish Council on Health Technology Assessment, evaluated the evidence for mucosa supported prostheses, implant supported removable prostheses and implant supported fixed bridges in the treatment of the edentulous mandible.[8] The SBU reported in 2011 that, "The scientific evidence is

insufficient to appraise the effects of different treatment methods in patients with a toothless lower jaw". The explanation for this disagreement seems likely to be that the McGill and York consensus groups considered evidence at all levels, including expert opinion.[3, 5] The McGill group also took into account patient opinion. The SBU, however, only consider evidence of the highest quality. Whilst the McGill and York consensus documents both considered randomised controlled clinical trials, it must be that the rigorous application of quality criteria by the SBU excluded the same randomised controlled trials which were considered by the McGill and York groups. For example, the SBU investigation identified nine relevant studies which addressed the question of prosthetic rehabilitation of the edentulous mandible. All were rated as being of moderate or low quality.

## 1.2 Dental implant placement in the anterior mandible and management of surgical risks

Alveolar resorption following tooth extraction can leave the anterior mandible very shallow, narrow or knife edged. [9] This increases the risks of perforation of the lingual cortical plate during preparation for placement of dental implants. Perforation of the lingual cortical plate has the potential to traumatise lingual vessels causing severe bleeding and a life threatening upper airway obstruction.[10] There are many case reports in the dental literature.[11-28]

An appreciation of the form of the anterior mandible is required in order to avoid such complications. To assist with this, radiographic techniques are available to give a cross sectional image of the symphyseal region. Conventional tomography, MRI\*, Medical CT† or the later CBCT‡ can be used with specialist planning software to give true cross sectional images. It has been suggested that preoperative cross sectional imaging is advisable, or should be routine, to reduce the likelihood of such an event.[10, 29, 30] Nonetheless, a preoperative appreciation of the form of the anterior mandible may also be gained through conventional radiography. The lateral cephalogram records the superimposition of the lower left to lower right canine region and is considered to be an adequate representation of the form of the bone in the anterior mandible.[31] The

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\* MRI – Magnetic resonance imaging

† Medical CT - Conventional medical computed tomography

‡ CBCT - Cone beam computed tomography

transymphyseal view, described by Shelley and Horner [32] can be taken in general dental practice using conventional intra oral film and holders. The intention is to produce a similar view to that of a lateral cephalogram. It is, therefore, unclear whether the preoperative availability of cross sectional imaging, such as cone beam CT, has an impact on preoperative assessment, treatment or outcome in such cases.

### 1.3 Guideline documents

Clinical guidelines are defined by Field and Lohr as “Systematically developed statements designed to assist the clinician and patient in making decisions about appropriate healthcare for certain specific clinical circumstances”. [33] In radiology, such guidelines are termed selection (or referral) criteria. Whilst they are not intended to be prescriptive, selection criteria assist in the process of selecting the appropriate imaging pathway. [34]

Well prepared, evidence based, widely disseminated guideline documents are important public health measures. The risks of ionising radiation are established and well documented. Whilst the risks are small, epidemiological investigations have suggested that dental radiography presents an increased risk of brain, thyroid and salivary gland tumours [34, 35]. The benefits of imaging, therefore, must be balanced against the risks. One aspect of minimising these risks is the use of selection criteria to identify patients who are likely to benefit from a specific imaging modality.

Selection criteria for imaging prior to implant placement have been issued by several authorities. [36-42] Notwithstanding, guidelines on selection of images for dental implantology are often non-specific, stated in vague terms and open to wide interpretation. In some instances guidelines are directly contradictory. For example, in 2012 the American Academy of Oral and Maxillofacial Radiology (AAOMR) stated, "AAOMR recommends that cross-sectional imaging be used for the assessment of all dental implant sites and that CBCT is the imaging method of choice" [42] The European Association of Osseointegration take an opposing view and state that clinical assessment and conventional radiography may be sufficient. [40] The guidelines issued by the UK's Faculty of General Dental Practice in 2013 sum up the position as follows, "At present, there is a limited evidence base on which to formulate guidelines for the use of radiographs in implant dentistry" [34]

## 1.4 Assessment of the efficacy of diagnostic imaging

A number of authors have proposed models for the evaluation of diagnostic imaging. [43-45] Fryback and Thornbury presented a hierarchical structure in order to appraise the literature on the efficacy of diagnostic imaging.[46] These authors proposed six levels: technical efficacy, diagnostic accuracy efficacy, diagnostic thinking efficacy, therapeutic efficacy, patient outcome efficacy and societal efficacy. In this model, the lower levels represent technical and diagnostic efficacy whilst the higher levels relate to the impact of the technology. Many studies have been conducted to investigate technical efficacy and diagnostic accuracy efficacy of cross sectional imaging methods. [47-50] Nevertheless, in order to understand the impact of cross sectional imaging on preoperative assessment, treatment planning and outcome of dental implant therapy, studies should be performed at the other, higher, levels of efficacy. When considering imaging prior to dental implant placement, there are very few studies which address therapeutic efficacy and none have been identified which address the higher levels of efficacy.

## 1.5 Practice based research

The majority of dental implant placements in the United Kingdom are carried out in the independent practice environment. [51] Nevertheless, research is almost exclusively conducted in university schools of dentistry with hospital based dentists. For example, as part of the systematic review reported in this thesis, a rapid scoping exercise was carried out to identify studies which evaluated the impact of imaging methods on dental implant placement. (Section 4.6 page 137) Thirteen studies were identified.[52-64] Whilst the reports were not always explicit, it is most likely that all of these studies were carried out in a university hospital environment. In general, one would expect that dentists in independent practice and dentists in university hospital practice would have different training, experience, support staff, facilities and so on. It appears, therefore, that such research is most often being conducted with those who do not represent the majority of implant-placing dentists.

## 1.6 Questionnaire studies

Attitudes, opinions and practices of general practitioners can generally be determined in several different ways, both quantitative and qualitative. One method which is

commonly used when addressing large numbers of practitioners is the use of questionnaires.

### 1.7 Aims of this research

The overall aim of this research was to gain an understanding of the imaging prescription of implant practitioners when placing implants in the anterior edentulous mandible and to investigate the impact of cross sectional imaging on diagnostic thinking, treatment planning and patient outcome. The research was carried out amongst independent implant practitioners in the North West of England. The intention was to provide evidence that may be helpful in development of future guidelines and to reduce the risks of implant placement in the region by use of appropriate imaging.

#### Specific aims

- ▶ To undertake a narrative literature review to investigate the planning and execution of questionnaire studies of dentists and other health professionals with particular reference to dental radiography.
- ▶ To use the information gained from the narrative literature review to conduct a questionnaire study which investigates the custom and practice of independent dental implant practitioners in the North West of England when planning imaging methods prior to implant placement in the edentulous anterior mandible.
- ▶ To undertake a systematic review to assess the available evidence for the impact of conventional radiography and cross sectional imaging prior to dental implant placement in the edentulous anterior mandible.
- ▶ To develop a lifelike dental simulation of the anterior edentulous mandible which provides drillable models with corresponding images.
- ▶ To evaluate the impact of cone beam CT imaging on the incidence of perforation of the lingual cortical plate when placing dental implants in the anterior edentulous mandible, using a 'before-after' study design.



## 1.8 Outline of this thesis

Research objectives are addressed in this thesis as below:

Part 1 - Narrative literature review. The planning and execution of questionnaire studies of dentists and other health professionals with particular reference to dental radiography

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Part 2 - A questionnaire study to investigate custom and practice of imaging methods for the anterior region of the edentulous mandible prior to dental implant placement

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Part 3 – Systematic review. Conventional radiography and cross sectional imaging when planning dental implants in the anterior edentulous mandible to support an overdenture

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Part 4 - Development of a dental simulation for use in a before-after study

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Part 5 - A before-after study using a dental simulation to evaluate the impact of cone beam CT imaging when placing dental implants in the anterior edentulous mandible

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Conclusions for this thesis

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- 2 Part 1 - Narrative literature review. The planning and execution of questionnaire studies of dentists and other health professionals with particular reference to dental radiography**



## 2.1 Introduction

A narrative literature review was conducted to enable an investigation of the current prescription of dentists when prescribing imaging prior to implant placement in the edentulous anterior mandible,

### 2.1.1 Aim and objectives of this review

#### Aim

To undertake a narrative literature review to investigate the planning and execution of questionnaire studies of dentists and other health professionals with particular reference to dental radiography.

#### Objectives

1. Explore the conduct of questionnaire studies drawing on the wider dental and medical literature where this is considered relevant.
2. Identify questionnaire studies which address imaging prior to dental implant placement
3. Use the information gained from the narrative literature review to plan a questionnaire study which investigates the custom and practice of independent dental implant practitioners in the North West of England when planning imaging methods prior to implant placement in the edentulous anterior mandible.

## 2.2 Background

Surveys of dentists and other health professionals by questionnaire are a widely used research method. They can provide important, cost effective information on dentists' knowledge [65], attitudes [66], and practices [67]. They can be a key factor influencing planning and policy [68], [69]. In dental radiography, surveys have been used to assess a range of issues including the prescription of bitewing radiographs [70], prescription of radiographs prior to implant placement [71], radiographic practice in endodontics [72], the use of digital radiography [73], and radiation protection [74]. The number of surveys to which general dental practitioners are subjected is unknown. As early as 1993, however, Horner et al [75] drew attention to the, "saturation of GDPs by postal surveys in the area immediately surrounding a University Dental School". The authors commented further, "It is possible that GDPs were suffering from 'questionnaire fatigue' ". In addition to surveys by academic institutions, general dental practitioners regularly receive requests to complete commercial surveys. Therefore it is unsurprising that non-response is considered to be a shortcoming of many surveys [76].

Consequently, the applicability of survey findings to a population is of concern and studies have addressed the difficulty of raising response levels [77], [78], [79], [80]. Many authors have drawn attention to low response rates as sources of bias in surveys of health professionals [81], [82], [83]. For example Ho et al commented in 2007, "The main threat to the validity of survey findings arises from low response rates" [84]. Nevertheless non-response is only one component of survey error and a good response rate alone does not guarantee the validity of findings [85]. Further, it has been argued that non-response is only a source of error to the extent that responders and non-responders differ on the variables of interest [80]. Asch et al [83] comment, "Surveys with very low response rates may provide a representative sample of the population of interest, and surveys with high response rates may not."

In 1989 Groves [86] described four errors of sample surveys of which non-response is only one. These were reinterpreted by Dillman et al in 2009 [87] to take into account modern survey methods such as internet and email surveys. The four areas of concern in sample surveys were stated by Dillmann et al [87] as follows:

- ▶ Coverage

Coverage error occurs when the sample frame does not include everyone in the population.

- ▶ Sampling

Sampling error is the result of collecting data from only a subset, rather than the entire sample frame.

- ▶ Non-response

Non-response error occurs when the individuals who do not respond are different from those who do respond in a way that is important to the study.

- ▶ Measurement

Measurement error occurs when an individual's answer is inaccurate or imprecise

The literature review for part 1 of this study will examine these four areas in relation to published questionnaire surveys in the dental radiographic literature and, where appropriate, the wider dental and medical literature. There follows a review of questionnaire studies which have investigated the custom and practice of dentists in preoperative imaging of implant sites. (Section 2.7 page 43)

## 2.3 Coverage

Dilmann et al [87] state some key definitions:

The survey population; this consists of all of the individuals to which one wishes to generalise survey results. The sample frame; this is the list from which a sample is to be drawn in order to represent the survey population. Coverage error; this occurs when inaccuracies in the sample frame lead to members of the population having an unequal chance of being selected for the sample. The ideal situation is that every member of the survey population appears once on the sample frame with accurate contact details. This is termed full coverage. In this way, every member of the survey population will have the same chance as any other of being selected into the survey sample to receive a questionnaire.

### 2.3.1 Does the sample frame include all members of the survey population?

In 2001 Jenkins and Dummer [88] carried out a study entitled, "A study of endodontic treatment carried out in dental practice within the UK". This included the use of dental radiography. From the title of the paper the intended survey population can be assumed to be UK dental practitioners. Nonetheless, the sample frame consisted only of graduates of Cardiff Dental School. Furthermore there was no discussion in the paper of how addresses of Cardiff dental alumni were verified. It seems likely that a dental school list would have at least some non-current addresses and so those graduates could not have participated in the study. This would further compromise the sample frame. Therefore, even if the population of interest was taken to be Cardiff dental graduates, it is likely that coverage error still existed.

A more extreme example appears in a study by Hayakawa et al in 1999 [89]. A survey was carried out to assess opinions on the compatibility of current x-ray generators with intra-oral digital x-ray systems. The questionnaire was "posted in both English and in Japanese on an oral and maxillofacial radiology electronic bulletin board". The questionnaire was also mailed to "selected researchers and manufacturers in oral and maxillofacial radiology". The method of selection is not reported. The authors reported that the questionnaire was posted electronically to, "Those interested in Oral and Maxillofacial Radiology". Replies were received from 19 countries. The intended survey population could therefore be assumed to be "Those interested in Oral and Maxillofacial Radiology" worldwide. The sample frame in this case was users of an

electronic bulletin board via electronic mailing lists from one US and two Japanese universities and “selected researchers and manufacturers”. This approach led to a huge difference between the sample frame and the intended population of interest. Coverage error was therefore significant.

A common source of coverage error is to survey participants at a meeting or conference. Participants would be expected to form a special sub population of dentists who were available, interested and enthusiastic enough about the subject to attend a conference. For example Sakakura et al [90] in 2003 published a study entitled, “A survey of radiographic prescription in dental implant assessment”. They stated the objectives of their study as, “To survey the current radiographic prescriptions in dental implant assessment amongst dentists in Brazil”. The authors selected a random sample of 69 dentists attending a dental implant meeting held in São Paulo, Brazil. Whilst the random selection of subjects suggests good survey practice, the sample frame from which the sample was taken was very different from the survey population. The survey population was stated at the outset to be, “Dentists in Brazil”, but the sample frame was only those dentists attending one conference on one occasion. Other examples of this type of coverage error include a study by Ghasemi et al in 2008, “Restorative treatment threshold reported by Iranian dentists” [91]. Delegates at a conference were asked to plan treatment from bitewing radiographs. The sample frame was delegates at two major dental meetings in Tehran, Iran. Similarly in 2005 Ilguy et al published their study, “Survey of dental radiological practice in Turkey” [67]. The aim was stated as, “to determine the dentist's knowledge about dose reduction techniques, radiographic equipment and quality of dental radiographic service in general dental practice in Turkey”. Nevertheless the sample frame was those attending the 11th International Congress organized by the Turkish Dental Association.

By contrast, Salti and Whaites [92] in 2002 carried out a study of dental radiographic services in Syria. The objective was stated as, “To perform a radiographic survey of private dental clinics in Damascus, Syria”. The paper suggests that efforts were made to identify the total number of dentists in Syria and in Damascus. The authors identified those who work in government departments, the University of Damascus and for private companies. The remaining dentists were found to work in private dental clinics. The survey population was stated clearly as, “private dentists in Damascus”. The authors appear to have made substantial efforts to select a sample frame which was as close as possible to the survey population.

### 2.3.2 Is the source information current for the sample frame?

There are concerns in some studies that source data could be out of date and thus compromise the sample frame. Jenkins et al [88] and Kogon et al [93] used lists of graduates from Cardiff and Ontario dental schools respectively. There is a concern that such lists would have errors soon after graduation. Typically, contact details for graduates would only be updated where the graduates themselves had informed their Dental School or their Alumni Associations. Studies also often use the lists of national or specialist dental associations. For example Bjerklin [94] carried out a study to assess the influence of computed tomography on decision making by orthodontists. The source was the list of the Swedish Orthodontic Society. Similarly, Mileman [95] used the list of the Dutch Dental Association. Again it would be expected that some of the contact details would be incorrect or that some members would no longer be practicing. Even the UK General Dental Council register, as used by Stewardson [72], will have some inaccuracies. In these cases the accuracy of the contact details will depend on the members on the lists keeping the association or council informed of changes. Where contact details are incorrect, an individual will have a zero chance of being included in the sample.

### 2.3.3 Could the sample frame include duplicates?

Kay and Nuttall carried out a study of restorative decisions based on bitewing radiographs [96]. The source for the sample frame was the Glasgow yellow pages telephone directory. These are published annually and so may contain a number of errors. Furthermore, it is not unusual for UK dental practitioners, in particular associates, to work in more than one practice. It is very possible, therefore, that the sample frame could be compromised by duplicate entries if taken from the yellow pages directory. For example, if some individuals are included twice, then they will have twice the chance of being selected for the sample than the individuals whose names are included once.

In 2003 Tugnait et al [97] carried out a survey to investigate radiographic equipment and techniques used in general dental practice in England and Wales. The list of dentists was generated by the UK's Dental Practice Board<sup>§</sup>. This list would include some dentists multiple times if they worked in more than one dental practice. This

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<sup>§</sup> Dental Practice Board or DPB – The UK Government body responsible for remuneration of general dental practitioners working in the National Health Service in England and Wales.



situation is not uncommon. The authors demonstrate awareness of this problem and report, "A population of dentists was created in which each dentist appeared just once". The method by which duplicates were removed is not described by the authors.

#### 2.3.4 Does the sample frame include ineligible individuals?

It is possible that a sample frame may include ineligible individuals who are outside the intended survey population. For example, Stewardson in 2002 [72] carried out a study to assess endodontic practice in recent graduates including the use of dental radiographs. The sample frame was taken from the General Dental Council register for the year 2000. The study assessed the practice of dentists at one and four years post qualification. Inevitably some registrants would not be working in clinical dentistry or would be working in situations where endodontics was not carried out such as oral medicine or orthodontics. Similarly, studies which use lists of graduates from dental schools will include some graduates who are in non-relevant branches of the profession or may have left the profession altogether [88], [93].

In Tugnait et al's study [97] the UK's Dental Practice Board generated a random sample of 800 from a total of 17077 general dental practitioners with NHS contracts. The authors remarked, "The DPB database of GDPs held current details of GDPs submitting NHS payment forms. It was assumed therefore that the sample would comprise either full or part-time NHS dentists". This was not the case and replies were also received from private practitioners, orthodontic specialists, specialists in periodontology and those working in the prison service.

A carefully constructed questionnaire can identify ineligible members and exclude them from the study. Whilst it is still possible that all members of a population could have an equal chance of inclusion in the sample, the concern in these situations is one of wasted resources and reduction of the working sample size.

## 2.4 Sampling

Sampling error is defined by Dilmann et al [87] as "The result of collecting data from only a subset, rather than all of the sample frame, and exists as a part of all sample surveys.". Nevertheless, estimates can be made by taking a random sample and sample size calculation can deliver estimates of appropriate precision. Random sampling requires that every member of the sample frame has an equal chance of

being selected in the sample. A review of the literature reveals several approaches to sampling.

#### 2.4.1 Random sampling

Samples are very often the result of simple random sampling. For example, Tugnait et al [97] took a random sample of 800 from a sample frame of 17077 general dental practitioners. The randomisation is reported as being carried out “by the Dental Practice Board”. Other studies are more specific about the method of randomisation. In 2002 Iqbal and Glenny [98] carried out a survey entitled, “General dental practitioners’ knowledge of and attitudes towards evidence-based practice.” The authors explain that a list of general dental practitioners working in the North West of England was obtained and that names were then drawn at random from a container.

On other occasions a stratified random sample can be taken. An example is the study by Brian and Williamson [99] who surveyed dentists in the US state of Indiana to investigate the use of digital radiographic equipment. A 10% stratified sample was taken by randomly selecting 10% of the dentists in each county. In this way, dentists in each county of the state of Indiana were proportionally represented.

An example of a non-random sample is the 1998 study by Yang and Kiyak [100]. This study was carried out to investigate the timing of orthodontic treatment in the United States. The authors reported that there were four groups within the sample. The first was a random sample of members of the American Association of Orthodontists. A second group was a sample taken from the directory of the Midwest component of the Angle Society of Orthodontists. Thirdly questionnaires were distributed at an annual meeting of orthodontists. The final group consisted of orthodontists who were recommended by the collaborators on the study. The result was a sample which was not randomly selected. For example, one does not know how the orthodontists in the final group were selected by the collaborators. The orthodontists who were recommended by the collaborators may well have been of a different opinion from those who were not. Furthermore, only the Midwest section of the Angle Society was surveyed and members may have been of a different opinion from those in other areas of the United States. The result is that the authors introduced bias into the selection of the sample and therefore the study suffered from sampling error.

#### 2.4.2 Total population approach

Authors have often used the whole of a population as a sample. For example Taylor [70] investigated the prescription of bitewing radiographs for children by dentists in Greater Glasgow. A questionnaire was sent to all dentists in Greater Glasgow who had an NHS list number, a total of 384 dentists. Similarly, Pemberton et al [101] carried out an investigation into the management of trigeminal neuralgia by consultant oral and maxillofacial surgeons in the British Isles. The sample consisted of all of the population of 254 consultants.

This approach, at first glance, would seem to have the advantage that the whole population has the opportunity to respond and thus sources of sampling error are avoided. Nevertheless this approach has been criticised on several grounds.

##### Trading sampling error for non-response error [87]

Dillman et al [87] point out, "There is nothing to be gained by surveying all 1000 members of a population in a way that produces a 35% response rate". An example from the dental literature is Wenzel and Møystad's study which evaluated Norwegian General Dental Practitioners' decision criteria and characteristics for choosing digital radiographic equipment [102]. The authors report that a questionnaire was sent to all the dental practitioners in Norway, a total of 3940 dentists. The reported response rate was 56%. Whilst one could argue that there was minimal sampling error, the authors had the problem that 44% of their sample did not respond. In 2005 Montori et al [103] examined the assessment of non-response bias in surveys of North American clinicians. These authors commented, "The response rate below which validity is seriously compromised is arbitrary, however; substantial bias is possible from even a relatively small percentage of non-responders". Dillman et al [87] comment further, "Survey sponsors simply trade small amounts of sampling error for potentially large amounts of non-response error".

##### Better allocation of resources through the use of sampling [104]

Resources for research are always limited and researchers have an obligation to use them effectively. Reduction of non-response error can be costly. For example, several authors draw attention to the effectiveness of monetary incentives, the use of prepaid return envelopes, personalisation, pre-notification and follow up contacts [77], [78], [80] & [105]. Therefore attempts at contacting an entire population can be at the expense

of measures to reduce non-response. Wenzel & Møystad [102] surveyed 3,940 Norwegian dentists. Prepaid envelopes were used but there was no follow up contact and no other attempt to increase response. Even in much smaller populations, the issue of costs to reduce non-response can be an issue. In a UK study of endodontic practice in Birmingham in 2001, Stewardson [106] surveyed all 320 practicing dentists whose names were on the Birmingham Health Authority list. There was a single mailing of 320 questionnaires and the author reports that 188 useable replies were received. The author comments, “because of the cost of a second full mailing, no attempt was made to pursue non respondents”.

Cull et al [104] in 2005 examined response rates and response bias in 50 surveys of paediatricians. The authors draw attention to the, “better allocation of resources through the use of sampling”. Similarly, Dillman et al [87] comment, “resources might be better allocated to improving response rates among a smaller sample.

#### An appropriate sample size can provide precision [87]

The question is raised of whether the findings from a random sample of sufficient size are any less valid than those of a whole population.

In ‘Elementary Survey Sampling’ Scheaffer [107] observes, “Elementary statistics tells us that this estimate can be made as accurate as we wish simply by increasing the sample size.” Both Scheaffer [107] and Dilmann et al [87] present formulae to select an appropriate sample size. This is dependent on the size of the population, the estimated variability of the results, the desired margin of error and the desired confidence level. For example, for the population of 3,940 investigated by Wenzel and Møystad [102], the authors could have been 95% confident that findings will be within plus or minus 10% with a sample size of 94. This would be if the anticipated findings were split 50/50. If the anticipated findings were split 80/20 then a sample size of only 61 would be required. Therefore it could be argued that Wenzel and Møystad could have better employed their resources by choosing a much smaller sample and spending research funds on response enhancement strategies. Similarly in Stewardson’s study of 320 Birmingham dentists [106], the author could have been 95% confident that the results would be within a margin of error of 10% with a sample size of 74. This may have released funds to, “pursue non-respondents”, with a second mailing.

### Repeated large samples can lead to “questionnaire fatigue”

There is a danger that repeated questionnaire surveys of unnecessarily large samples can jeopardise future co-operation of health professionals. In an example from the medical literature, Kaner et al [108] in 1998 published an investigation into non-response of general medical practitioners to surveys entitled, “So much post, so busy with practice so no time!”. The authors comment, “Response rates by general practitioners to postal surveys have consistently fallen, compromising the validity of this type of research”. Their investigation found that 34% of general medical practitioners had lost their questionnaires in their paperwork, 21% were too busy for the extra work involved and that 16% “routinely binned” questionnaires. Similarly McAvoy and Kaner [68] published a commentary in the British Medical Journal entitled, “General practice postal surveys: a questionnaire too far?”. They report the case of one practitioner who returned an uncompleted questionnaire in its prepaid envelope, enclosing an invoice for £5 to cover his “administrative costs”. They comment further, “Researchers need to understand the pressures on general practitioners”. In 2002 Barclay et al [81] published, “Not another questionnaire! Maximizing the response rate, predicting non-response and assessing non-response bias in postal questionnaire studies of GPs”. The authors speculate on the reasons that GPs do not respond to questionnaires and report, “Many perceive a rising tide of questionnaires that they are too busy to complete”.

Whilst the above examples are all from the medical literature one would expect that the pressures on medical and dental practitioners would be similar. Comparable investigations of non-response to surveys are not found in the dental literature although as long ago as 1993 Horner et al [75] remarked on “questionnaire fatigue” by general dental practitioners.

These studies all relate to postal surveys which raises the question of whether modern electronic methods, using e-mail or web based surveys, have improved response rates. This does not seem to be the case. For example Akl et al in 2005 [109] conducted a randomised controlled trial in a university based internal medicine residency programme. These authors found that there were no differences in the quality of data or responses to their survey between postal and electronic methods. Similarly Raziano et al in 2001 [110] carried out a survey of heads of department of geriatric units in the USA and found a higher response to postal surveys than e-mail surveys.

### 2.4.3 Non-random “convenience” sampling

A convenience sample may be defined as one which is selected at the convenience of the researcher or where subjects are easy to recruit for a study. Bruce [111], in an editorial in 2002, defined a convenience sample as a “sample from the target population made up of those subjects available for study”. Bruce also warns, “findings, if generalised to the wider population, would have to be interpreted with caution.”

In 2000 Schleyer and Forrest [112] conducted an evaluation of a web based survey of dentists. The questionnaire investigated the use of the internet by dental practitioners. The authors report, “A random sample of dentists could not be selected because no comprehensive list of dentists with e-mail addresses was available.” The chosen sample was the 450 members of a dental discussion forum. The authors added, “The investigators believed that selection of this convenience sample, although not representative of all dentists with Internet access, was more appropriate than soliciting volunteers from general sites with unknown population”. Nevertheless, a criticism of this study is that contributors to a dental forum would be expected to be amongst the most enthusiastic users of the internet. The findings of the study cannot, therefore, be generalised to a wider population of dentists.

A more extreme example of convenience sampling is the study in 2005 by Gijbels et al [113] which was performed among Belgian dentists to evaluate the use of digital radiographic equipment. A questionnaire was included in a dental magazine which was freely distributed to Belgian dentists. One criticism of this approach is that it is unlikely that every Belgian dentist would read a free magazine. Furthermore, in a Cochrane review of methods to increase response rates to questionnaires, Edwards [77], found that a topic interesting to the recipient doubles the odds of response. Therefore it is more likely that dentists already using digital equipment would respond to the questionnaire. Also distribution of a questionnaire by this method does not allow for follow up contacts with non-responders. The number of responses to this survey was 350 but the circulation of the magazine is not reported by the authors. Nonetheless, in a 2008 document, European Union figures estimate the number of dentists in Belgium to be 8423 [114]. This equates to an approximate response rate for this study of 4%. The authors assert that 30% of Belgian dentists use digital equipment for intra oral exposures. This is an unsafe assumption based on this method of sample selection.

In an interesting variation on convenience sampling, Aps [65] in 2010 investigated Flemish Dental Practitioners' knowledge of dental radiology. In order to maintain a licence to practise, Flemish dentists are obliged to undertake postgraduate training in dental radiology and radiography. The author took the opportunity to distribute a questionnaire to all delegates immediately before the beginning of a radiology course. Completed questionnaires were collected before each course began. The collection of data ran for one year over several repeats of the course. The total sample amounted to some 10% of the population of Flemish dentists. Whilst this was a useful way of reducing non-response bias, a number of criticisms may still be made. The answers to the questionnaire were given in the course following the completion of the questionnaire. Therefore it is very possible that dentists were able to inform their colleagues who were attending future courses. Unfortunately the author did not publish the results in a form that could distinguish between the early and later results. Also it is likely that there will be some dentists who are reluctant participants at postgraduate courses despite their obligations to do so. These might be the dentists who would have revealed the most useful findings. Lastly we do not know what other courses may have been available that could have fulfilled the obligations of dentists. It may be that the population of dentists attending other courses was significantly different from those attending this one. This approach is therefore still prone to sampling error.

Other examples of convenience sampling include the use of the lists of professional associations. For example Hellen-Halme et al in 2005 [73] conducted an investigation into quality aspects of dental digital radiography. The stated aim was to, "evaluate the experiences of Swedish Dental Practitioners". The chosen sample was the list of the private dental association of the Skåne region of Sweden. Even if all private dentists were members of the association it would be unsafe to generalise findings to all Swedish dentists. Other authors have used the data from manufacturers. For example, Berkhout et al [115] in 2002 compared digital and film radiography in Dutch dental practices by questionnaire. The authors' sample included names and addresses supplied by equipment manufacturers.

Whilst the above studies demonstrate sampling error, an acceptable use of convenience sampling might be for pilot studies. An example is the study carried out by Davies et al [74]. These authors investigated the radiation practices of general dental practices in the North East of England. They report, "The questionnaire was piloted using a convenience sample of five practices in North Wales and Southern

England, which were representative of the demographic mix of the selected research population”.

#### 2.4.4 Sample size

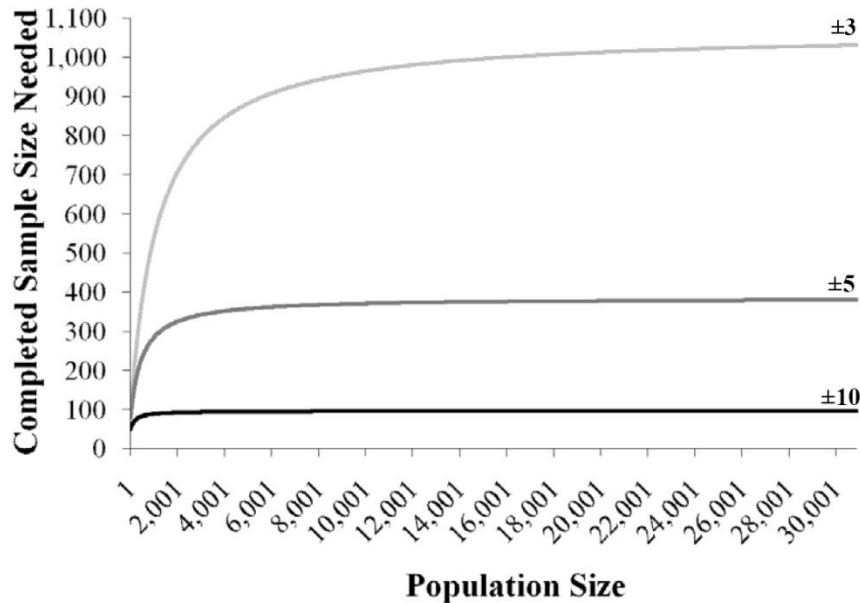
Sample size calculations are rarely referred to in reports of questionnaire surveys to dentists. 68 questionnaire surveys involving dental radiography from 1983 to 2010 were reviewed. Of these, only four stated that a sample size calculation had been carried out. [93] [97] [116] [117]. For example, a 1995 study by Kogon, “A survey of the radiographic practices of general dentists for edentulous patients”, [93] refers to the formula given by Scheaffer in, “Elementary Survey Sampling” [107]. Parashos in 2005 [118] reported on response rate and non-response bias in a questionnaire study about the use of endodontic instruments. In this investigation the sample size was calculated using an equation presented by Dilmann et al [87].

In the equations presented by both Scheaffer and Dilmann et al, the sample size is dependent on the size of the population, the margin of error, the confidence level and the proportion of the population expected to choose one of two response categories. For example, a population of 1000 dentists might be expected to split 50/50 on a question of interest. According to Dilmann et al one can be 95% confident that the results will be within a margin of error of 5% with a sample size of 278. Alternatively, if the population is expected to split 80/20 and a margin of error of 10% is acceptable, a sample size of only 58 would suffice.

In 2005 Sutton et al [119] evaluated the self-perceived educational needs of a randomly selected group of general dental practitioners in Merseyside. This included the subject of dental radiography. 87 practitioners were selected from a population of 850 in the region. There were 75 responses and the authors found that 40% would like to undertake training in dental implants. The authors comment, “Further research, involving a larger sample of GDPs, is necessary to confirm this finding.” Nonetheless, if a sample size calculation had been performed, the authors would have been able to quantify their uncertainty. Calculation with the equation of Dillman et al [87] indicates that the authors could have been 95% certain that, with a completed sample of 75, the result was within a margin of error of plus or minus 10.59%. In other words, there was 95% confidence that the percentage of the population of Merseyside practitioners who were interested in training in dental implants was between 29.41% and 50.59%.



Interestingly, according to the formula of Dillman et al [87], there is virtually no difference in the sample size needed for a given level of precision in large populations. This is demonstrated in Figure 1 page 25.



**Figure 1 - Completed sample size needed by population size and desired margin of error (95% confidence level with 50/50 split) [87]**

Therefore, even for very large populations with a desired margin of error of 3%, there is no greater precision above sample sizes of 1067. If a margin of error of 10% is acceptable, the required sample size is never greater than 96.

## 2.5 Non-response

The response of individuals to surveys is often regarded as a key indicator of survey quality. Nevertheless, attention given exclusively to response rates has been questioned. Johnson and Owens [120] conducted an investigation into survey response reporting in the professional literature in 2003. They commented, "Response rates are one key indicator of quality, right or wrong". In a similar investigation in 2001 Cummings et al [121] concluded, "Reported response rates are often used by researchers as a quick proxy for survey quality".

In 1997 Rugg-Gunn [122], as editor of the British Dental Journal, set out guidelines for acceptable response rates. These are still used by researchers. A rate of 80% or over was regarded as good and over 70% as acceptable. In response Martin [123] criticised this approach and commented, "Crude response rates are not a valid way of judging manuscripts". Burke and Palenik [124] added to the discussion and remarked, "To achieve the magic 70% return, researchers will be encouraged to make surveys overly simple and offer them to non-random audiences." In the same year Asch [83] writes, "'Investigators, journal editors and readers should devote more attention to assessments of bias, and less to specific response rate thresholds.'" In a further complication of this issue, Johnson and Owens [120] also draw attention to, "little consistency in response rate estimation methods".

In summary, widespread concern has been expressed that response rates in themselves are unreliable indicators of survey quality. A high reported response rate may mask other deficiencies in a study. Conversely, a low response rate does not necessarily lead to bias. This section of this literature review will discuss issues of non-response and the methods used to reduce it.

### 2.5.1 Definitions of response rate

At first glance this seems as simple as dividing the number of responses by the number of surveys distributed. Nevertheless, authors have accounted for the following in their calculations: the number of ineligible responses, the number of ineligible individuals in the sample as a whole, the number of individuals of unknown status, the number of incomplete or partially incomplete surveys and the number of refusals to participate in a survey. These refinements of response rate calculations have led to inconsistency in response rate reporting. Johnson and Owens [120] comment, "when a response rate is given with no definition, it can mean anything".

As early as 1977 Kviz [125] addressed this problem in his article, "Toward a Standard Definition of Response Rate". Kviz gives two distinct definitions which he terms response rate and completion rate. Nevertheless, in the British Dental Journal guidelines in 1997, Rugg-Gunn [122] appears to use the terms response rate and completion rate interchangeably. Twenty eight years after Kviz, Parashos [118] writes, "Confusion between completion rate and response rate will continue until a standard definition is adopted".

Table 1 below shows the definitions of response rate and completion rate according to Kviz. [125]:

<b>Response rate</b>	$\frac{\text{Number of completed interviews/questionnaires}}{\text{Number of eligible sample members}}$
<b>Completion rate</b>	$\frac{\text{Number of completed interviews/questionnaires}}{\text{Sample size}}$

**Table 1 - Response rate definitions according to Kviz [125]**

The difference between the response rate and the completion rate is represented, in the denominator of the formula, by the number of sample members who are ineligible. The problem with this calculation is that the number of eligible sample members will be made up from the total sample size minus the ineligible responders and ineligible non responders. It is unlikely that the number of ineligible non responders will be known since they have, by definition, failed to respond. Only the ineligible responders can be accounted for.

Shosteck [126] introduced new terms in 1979. These were, “Gross response rate”, “Gross completion rate”, and “Final completion rate”. These are defined in Appendix A on page 291. This author deals with the problem of the ineligible non responders by redefining the initial sample to exclude ineligibles. This is then termed the “effective sample”. Nevertheless the total number of ineligibles cannot be known if they are amongst the non-responders and so it is difficult to see how this can be comprehensively calculated.

In Asch et al’s study in 1997 [83], the authors compared the response rates of 219 surveys published in the United States’ medical literature. Response rates were extracted from the articles using raw figures wherever possible. The response rate for the purpose of this study was simply defined as the ratio of the number of surveys returned to the number of surveys distributed. This formula is different from Kviz’s completion rate [125] and so introduces a further definition. Ineligible responders are included in the numerator and all ineligibles are included in the denominator. It also includes incomplete or partially complete surveys in the numerator. This is an uncomplicated definition by which to compare studies as it does not include any

unknown figures. Nevertheless, it could be argued that it is unsuitable for reporting the response to an individual study since it artificially inflates the true response.

In 1989 Groves introduced yet another definition of response rate [86]. In this definition, ineligible responders are excluded. The problem of the ineligible non-responders is dealt with by assuming that all non-responders are eligible. Nevertheless, where this is not true, the response rate would be underestimated. Locker in 2000 [127] gave similar definitions to Kviz for response rate and completion rate. In addition Locker introduces a third measure, "Cooperation rate". Here the denominator includes only completed cases and refusals.

Johnson and Owens' [120] undertook a survey of editors of eighteen journals which included nine health science journals such as the journal of the American Medical Association. The editors were asked about their policies regarding standards for survey response rate calculation. One editor observed that calculating responses was very straightforward and was unwilling to accept the possibility that they could be estimated in different ways. Nevertheless most editors recognised the different opportunities for response rate calculation and some had adopted the definitions set out by the American Association for Public Opinion Research (AAPOR). These were first published in 1989 in an attempt to tackle the problem of inconsistency in reporting. The latest revision is the 2009 document [128].

As an illustration of the challenge of response rate calculation, the AAPOR document includes 6 definitions of response rate, 4 definitions of cooperation rate, 3 definitions of refusal rate and 3 definitions of contact rate. Some of the definitions of response rate do account for the ineligible non responders by including estimations. A list of the definitions of all of the response rates above is included in Appendix A on page 291.

#### An example of response rate reporting from the dental literature

In 1995 Kogon et al [93] carried out a questionnaire study of the radiographic practice of graduates from two Ontario Dental Schools. The sample frame was reported as 2887 and the sample 963. The authors state, "The adjusted response rate was 80%". 748 dentists returned questionnaires of which 31 were ineligible. There were therefore 717 completed cases. According to Kviz [125] the response rate and completion rate would be as follows:

**Response rate**  $\frac{\text{Number of completed interviews/questionnaires}}{\text{Number of eligible sample members}}$

$$\frac{717}{963-31} = 76.9\%$$

To find the number of eligible sample members, the only known ineligible (ineligible responders) are deducted from the sample size.

**Completion rate**  $\frac{\text{Number of completed interviews/questionnaires}}{\text{Sample size}}$

$$\frac{717}{963} = 74.5\%$$

According to Asch [83] the response rate would be:

**Response rate**  $\frac{\text{Number of surveys returned}}{\text{Number of surveys distributed}}$

$$\frac{748}{963} = 77.7\%$$

In order to reach an adjusted response rate of 80%, as reported by the authors, one would have to ignore the ineligible responses in the numerator but deduct them from the denominator. This would give 80% as follows:

**Kogon et al's adjusted response rate**  $\frac{\text{Number of surveys returned including ineligible}}{\text{Sample size minus ineligible}}$

$$\frac{748}{963-31} = 80.3\%$$

Whilst these authors might argue that even ineligible questionnaires were "completed", this example illustrates the potential to adjust response rates by selecting a suitable definition or applying adjustments to the figures. In 2003 Johnson and Owens [120] audited published articles from the professional literature and commented, "We have

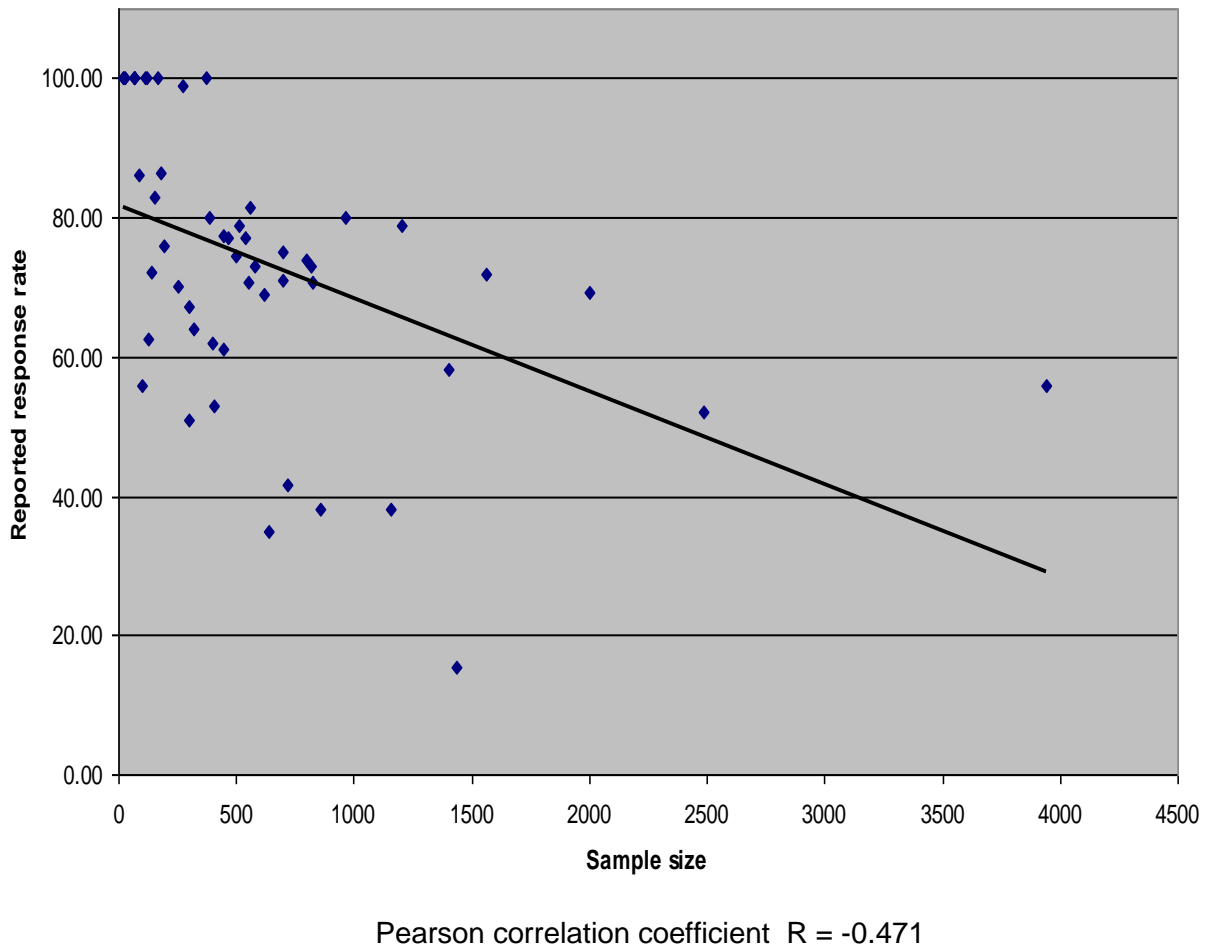
yet to encounter any case in which a response rate has been underestimated. There are powerful incentives to presenting one's work in the most favourable light possible".

### 2.5.2 Response rates found in the medical and dental literature

In analyses of surveys of physicians, there is conflicting evidence that response rates have declined over time. There is little discussion of this, however, in the dental literature. In 2007, in an assessment of different modes of survey on response rates, Beebe et al [129] commented, "There is evidence that response rates to physician surveys may be declining". Similarly, Cull et al [104] investigated response rates in surveys of paediatricians. They concluded, "Response rates to the 50 surveys examined declined significantly across survey years (1994–2002)". Conversely, Cummings et al in 2001 [121] examined trends in reported response rates to mailed physician questionnaires. They report, "We found that physician response rates have not been declining over time and, in fact, have remained somewhat constant."

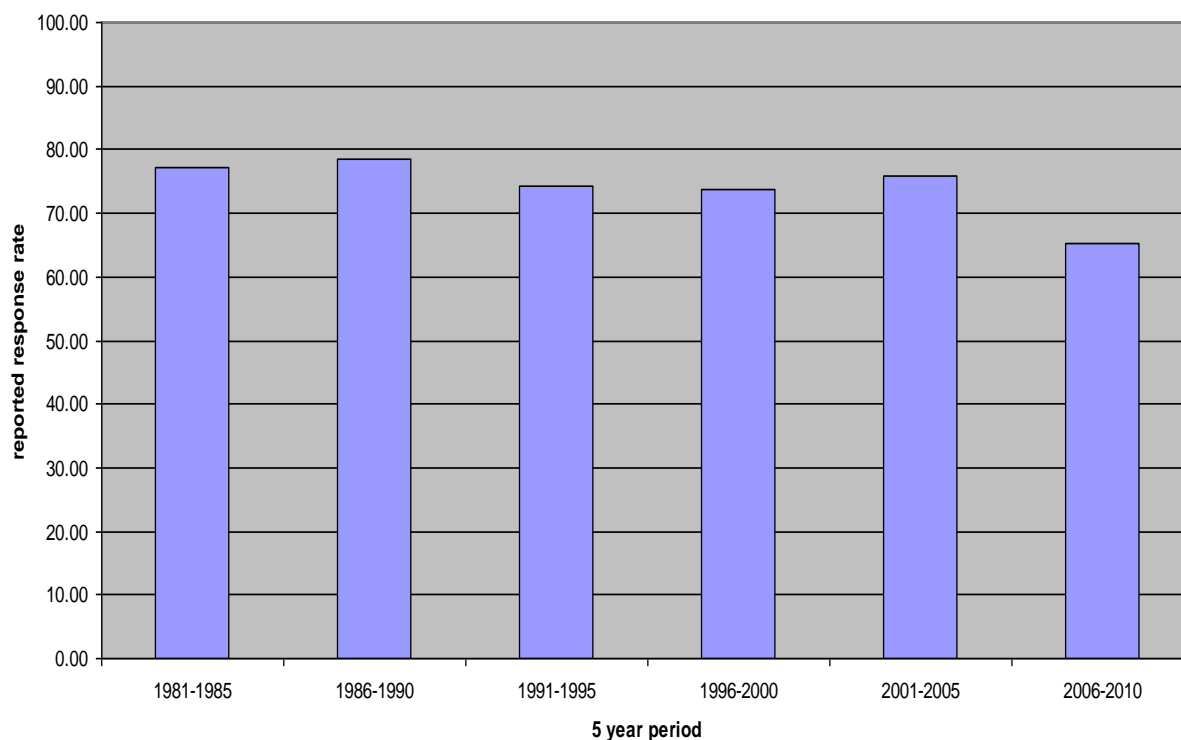
Fifty three questionnaire studies were identified in the dental literature which concerned dental radiography and for which a response rate was reported [65, 66, 70-75, 88, 90, 92, 93, 95, 96, 99, 101, 102, 106, 117, 119, 130-162]. These were published between 1983 and 2010. An analysis shows a mean reported response of 73.7%. This is a simple mean of the reported response rates. Interestingly, if the pooled data for all the studies is analysed using the completion rate of Kviz [125], the overall response is 61.9%. The explanation for the discrepancy between the mean of the reported response rates and the pooled mean is that the smaller sample sizes generally have the higher response rates.

For the fifty three questionnaire studies, the sample size was plotted against the reported response rate. A linear regression line is shown. Whilst this is far from a close fit, the graph does show a trend for decreasing response at higher sample sizes and a cluster of the highest response rates for the smaller sample sizes. The graph is presented in Figure 2 on page 31.



**Figure 2 - response rates against sample size, questionnaire surveys in dental radiography**

The mean reported response rate in each five year period from 1980 to 2010 was also calculated. The figures are presented in Figure 3 on page 32.



**Figure 3 - Reported response rates by 5 year period, questionnaire surveys in dental radiography**

The 2006-2010 figure is affected by an outlier, a Brazilian study which had an unusually low response rate of 15.4% [162]. Notwithstanding, for questionnaire studies of dentists which concern dental radiography, it cannot be concluded from these figures that rates of response are in significant decline. This finding is consistent with that of Cummings et al in their study of response rates by physicians in 2001 [121].

Interestingly, some authors have surveyed the surveyors. Both Johnson and Owens [120] and Asch et al [83] carried out investigations of response rates in the medical literature. For this, they contacted authors of relevant articles who had carried out questionnaire surveys. The response from those who carried out surveys themselves was reported as 62.9% and 56% respectively.



### National differences

Authors have suggested that there are national differences in response rates. For example, in the British Medical Journal in 1996 Springer and Marwijk [163] comment on Dutch questionnaire studies of general medical practitioners and claim, "We are far ahead in integrating research in general practice into postgraduate education and training". The authors refer to "100% response in a survey of employment among all Dutch general practitioners". This commentary concerned general medical practice. Nonetheless, five studies have been identified in which dental radiography was surveyed amongst Dutch General Dental Practitioners [132] [95] [164] [115] [153]. The mean response rate was 69.1%, a little below the mean response rate of 73.7% for similar studies. Tan and Burke [80] reviewed 77 publications where questionnaires were mailed to dentists and analysed methods used to maximise response rates. Higher response rates were found in the studies from Australia and Canada and very much lower in a study from Japan. Nevertheless out of 77 studies only two were Australian, one was Canadian and one was Japanese. Therefore it cannot be concluded that these data demonstrate a national difference.

A review of questionnaire studies which investigate dental radiography does not reveal any national pattern in response rates. Rather it appears to be a question of how the study was conducted. Those studies with the highest response rate are most commonly those where questionnaires were handed directly to, and collected directly from, the subject at a meeting or at a visit to the subject's place of work. For example in the study by Aps [65] to investigate Flemish general dental practitioners knowledge of dental radiography, the subjects were given questionnaires at a postgraduate course which were collected during the day. Similarly, in the study by Stavrianou [158], on site surveys of dental practices were carried out to investigate compliance with a quality assurance program in dental radiography in Greece. Unsurprisingly, both of these studies had a 100% response rate. 100% response rates from mail surveys are rare but typically involve smaller sample sizes where response enhancement strategies can be effectively used. For example Ekestubbe [144] surveyed all 23 oral radiology clinics in Sweden with a 100% success rate after two mailings. In a study of the 65 oral radiology departments in the United States and Canada, Geist and Katz [148] received a 100% response after two mailings and a telephone call to verbally complete outstanding questionnaires. Interestingly, when the same lead author surveyed 1157 dental practitioners by mail in Michigan, Geist et al [133] reported a 38% response rate.

### 2.5.3 Unit non-response and item non-response

Non-response as defined by Locker [127] is the failure to collect data from some of the individuals comprising the sample. Locker describes two forms of non-response. In unit non-response no information is obtained from a member of a sample. In item non-response, answers to specific questions are missing. This means that even where a headline response rate is very high, it is possible that significant item non-response bias can still exist. An example is the study by Tugnait et al [97] in 2004 which investigated the use of radiographs in the assessment of periodontal diseases in general practice. The authors report that 580 useable responses were received from random sample of 788 eligible general dental practitioners. The response rate according to Kviz [125], and reported correctly by the authors, was therefore 74%. Nonetheless, the authors also report, "within the returned questionnaires not all questions were answered fully", and, "more complex questions that required greater effort were more likely to be left unanswered". The headline response rate is based on unit response and could be interpreted as "acceptable" [122]. Based on item response, however, the response rate could be interpreted differently. The numbers and details of this are not reported and therefore an assessment of bias owing to item non-response cannot be made.

### 2.5.4 Non-response and non-response bias

Although response rates themselves receive the most attention in the medical and dental literature, non-response and non-response bias are different. Cull et al [104], in an investigation of response rates for surveys of paediatricians in 2005 remarked, "more attention should be devoted by investigators to assessments of response bias rather than relying on response rates as a proxy of response bias". Similarly, in an investigation of non-response bias in a survey of dentists' infection control, McCarthy [82] commented, "A low response rate does not necessarily entail non-response error. Conversely, it cannot be assumed that surveys with comparatively high response rates do not have non-response bias". Further, Montori et al [103] investigated methods of assessment of non-response bias and explained, "Similarity in a limited number of characteristics between responders and non-responders does not guarantee similarity in their responses, because characteristics available for comparison between responders and non-responders may be weakly related or totally unrelated to the outcome variables in the survey". One example from the dental literature is the study by Salti and Whaites [92] in which radiographic practices of dentists in Damascus,

Syria were surveyed. Thirty three percent of the sample failed to respond. The authors state, "The known information on the non-responders showed a very similar distribution in terms of age, sex, years in practice and place of qualification, to that provided by the responders". Nonetheless, it cannot be concluded from this that the non-responders would have had similar radiographic practices to the responders. Conversely, Wenzel and Møystad's study of digital radiography in Norway [102] received a 56% response. The authors remark, "There were no significant differences between the respondents and non-respondents for gender or age. However the difference with respect to type of employment was significant". Even though a difference in characteristics between responders and non-responders was noted, it cannot be concluded from the figures presented that this suggested a difference with regard to the variables of interest.

Stocks and Gunnell in 2000 [165] carried out a study of serial non responders in surveys of general medical practitioners in the UK and observed that, "Serial non-responders" tend to be older, less likely to possess a postgraduate medical qualification or belong to a practice that is involved with postgraduate or undergraduate training". Nonetheless, the authors also remark, "Non-response bias in postal questionnaires will only occur if there are differences between responders and non-responders in their knowledge, attitudes and beliefs that then lead to systematic differences in measured outcomes". Parashos [118], in a study of non-response bias in a questionnaire survey of dentists commented further, "Assessment of non-response bias based on demographic data alone would seem to be insufficient. Consequently, relying on assessment of non-response bias to justify a low response rate may be inherently flawed."

#### 2.5.5 How can authors assess non-response bias?

The comments by Parashos [118] raise the question of how the magnitude of non-response bias can be effectively assessed by authors. If the non-responders have, by definition, not responded then limited information is available. Locker outlined three possible solutions [127].

##### Survey a sample of non-responders.

In this method, a random sample of non-responders is surveyed using a shortened version of the original questionnaire which includes only the main variables of interest.

Telephone interviews can be used encourage participation. The intention is that the non-responders are more likely to respond to a convenient, shortened version. From this information, the results are adjusted and these are compared to the results of the responders alone.

An example is the analysis of an email study of North American clinicians carried out by Montori [103] et al in 2005. The questionnaire presented clinical scenarios for which the clinicians would plan treatment. After 3 waves of emails, a random sample of non-responders was selected. These were contacted by telephone and a shortened survey was sent by fax.

#### Identification of “non-response variables”.

Where no direct information on the main outcome variables is available, assumptions based on demographic variables may be used. No examples of this technique in surveys of health professionals were identified. Locker, however, in his 1993 investigation of public oral health in Ontario, Canada [166], used demographic information gained from a recent census in this way. Firstly the author looked for differences in the demographic variables between responders and non-responders. These were then termed, “non-response variables”. Secondly the clinical data from the responders was analysed for associations between the non-response variables and the outcome variables of interest. Where significant associations were observed the results were adjusted to account for these in the non-responders.

#### Analyse the trends in successive waves of a survey

Where multiple waves of a questionnaire have been issued, the trends in responses can be extrapolated. For example, McCarthy and MacDonald in 1997 [82] carried out a questionnaire study of Canadian dentists’ attitudes to HIV and infection control. A first wave of questionnaires received 3046 responses from a sample of 6444. A second wave of questionnaires was sent to non-responders after four weeks and this elicited a further 741 responses. A third wave of questionnaires after seven weeks received another 320 responses. Trends were seen in key variables for these early, middle and late responders. For example, responders were asked to say whether they agreed with the statement, “I would refuse to treat any patient with HIV”. Of the early responders 14.2% agreed. Of the middle responders 14.9% agreed and of the late responders 15.2% agreed. The authors obtained an estimate of the percentage

response for a 100% response rate by extrapolation. Their adjusted estimate was 17.1%. The magnitude of non-response bias was then judged by comparing the adjusted estimate with the response obtained from the respondents.

There are criticisms to be made of these methods of estimating the magnitude of non-response bias. Firstly they assume that the information they gain from selected non-responders is the same for all non-responders and that the non-responders are a homogenous group. This seems unlikely. Secondly they assume that subjects with similar demographic characteristics will also be similar on the variables of interest. Further, where extrapolations are made, an independent linear relationship is assumed.

Where non-response bias is judged to be severe then corrections can be made to the data. Locker [127] described the available methods as, "imputation", where data is assigned to a non-responder, or, "weighting", where existing data are adjusted to make them more representative of the target population. A criticism is, despite methods to quantify the degree of bias, that the severity of the bias remains a matter of judgment. The decision to carry out imputation or weighting is based on this judgement. Locker comments, "There is no quantitative rule to determine how large the difference between crude and adjusted estimates has to be before bias is considered to be important" [127]. It is also possible that these methods could be carried out on the false assumptions above and so increase rather than decrease the degree of non-response bias. As Parashos remarks, "Avoiding the complexities of non-response bias is best managed by incorporating measures and strategies to achieve a high response rate." [118]

It is perhaps unsurprising that authors often avoid analysis of response rate and non-response bias. In a 2001 study of response rates to mailed physician questionnaires, Cummings et al [121] observed that only 44% of articles reported a discussion of response bias and that only 18 % performed any type of comparison between responders and non-responders. Similarly Tan and Burke [80] reviewed 77 publications in 1997. These were all mailed questionnaire surveys to dentists. They report that no information on non-responders was available in any of the 77 papers which they assessed.

### 2.5.6 Response enhancement strategies

There have been several attempts to identify individual strategies which enhance the response rate to postal and electronic questionnaires. Edwards et al [77] in 2009 published the second update of a Cochrane Collaboration, systematic review of methods to increase response to postal and electronic questionnaires. The authors analysed 481 trials of postal questionnaires using 110 different response enhancement strategies. They also analysed 32 trials of electronic questionnaires using 27 different response enhancement strategies. One criticism of this study is that it included trials of all types including health related questionnaires, non-health related questionnaires, surveys of health professionals and of the general public. Inclusion of surveys of all kinds in this review means that it may be inappropriate to apply findings to a particular group. For example it is difficult to know which of these strategies would be most effective for surveys of dentists or, more specifically, surveys of dentists on the subject of dental radiography. Another criticism concerns the finding that the most effective response enhancement strategy for mail was "Monetary incentive". This was defined by the authors as, "Any incentive that could be used by participants as money". Other researchers have demonstrated that there is a crucial difference between incentives freely given with the request to complete a questionnaire and promises to pay participants after completion of the survey. For example, Church [167] carried out an investigation into the effect of incentives on mail survey response rates. He reported, "It appears that people respond more favourably to incentives that are included with the questionnaire rather than those that are offered as contingent on the completed return". Similarly James and Bolstein [168] investigated monetary incentives. They found that incentives as small as \$1 significantly increased response rates. The level of payment was also significant. Conversely, the promise of \$50 after completion and return of the questionnaire had no effect on response. Therefore, in the review by Edwards et al, the broad category of "Monetary incentive" concealed at least two separate strategies; payment at the time of the request and the promise of payment on completion.

Of 413 publications reviewed by Edwards et al [77], six concerned surveys of dentists [79, 80, 84, 169-171]. One of these, published by Tan and Burke [80] was itself a review of 77 publications which reported response rates of questionnaires mailed to dentists. Reviews of questionnaire surveys of physicians have also been published by VanGeest in 2007 [78] and Kellerman in 2001 [105]. Asch in 1997 [83] also published an analysis of response rates of health professionals including dentists. The review by Edwards et al includes a comprehensive consideration of 137 response enhancement strategies. Other analyses consider far fewer strategies and therefore comparisons are

difficult to make. Nevertheless there is agreement amongst most studies that monetary incentive and shorter questionnaires can significantly increase response rates.

Edwards et al also found that the odds of a response were significantly better when there was a teaser\*\* on the envelope of postal questionnaires and when the topic of the survey was more interesting. Nonetheless, it may not be appropriate to generalise the findings of Edwards et al to specific survey groups such as dentists.

There is also disagreement about some strategies. For example, in a review of published articles, Asch [83] found no association between response rate and monetary incentive. Edwards et al [77] considered the use of non-monetary incentives such as key rings, pens, pencils or the offer of study results. The authors found that the odds of a response were raised. Nonetheless, in similar analyses, Kellerman and Herold [105] found no difference in response when non-monetary incentives were used whilst VanGeest et al [78] calculated that the odds of response were reduced. In another example, VanGeest et al found that personalised mail out packages raised the odds of a response whilst Kellerman and Herold found no difference.

These disagreements raise the question of why authors have found different results from the same response enhancement measure. It could be argued that this is because individual measures are not independent. In other words, it may be that to concentrate attention on one strategy in isolation is to miss the effectiveness of a package of measures working together. For example, in Tan and Burke's analysis [80], four studies are considered in which duplicate questionnaires are sent. In one of these studies reminder cards are also used. In another, telephone contact and monetary incentive were used. The heterogeneity of these studies makes it difficult to assess the effect of a duplicate questionnaire in isolation. Furthermore, we do not know anything about the visual design of the questionnaires, the intrusiveness of the questions, the reputation of the person or organisation conducting the study or many other factors which will have influenced the decision to respond. There are also likely to be other factors and interactions which are unknown. Therefore, whilst some measures have been demonstrated to be more effective than others, it is likely to be a mistake to rely, for example, on monetary incentive alone to maximise response. The conclusion could be drawn that high response rate will result from attention to all aspects of the survey design and that analyses of individual measures to enhance response rates are only partially helpful.

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\*\* Teaser on the envelope – defined by Edwards et al. as a comment suggesting to participants that they may benefit if they open it.

This conclusion would be consistent with the approach of Dillman et al [87] which the authors term the “Tailored design method”. This was previously known as the “Total design method”. These authors stress the importance of survey procedures that work together and address the multiple sources of survey error. They advise that participation is encouraged by creating trust in the researcher and by emphasising the benefits of participation. No single survey design or procedure can create this and the authors propose that surveys should be customised or “tailored” for each situation.

It seems logical that an approach which pays attention to all aspects of a survey design will be the most effective in enhancing response rate. Even though an incentive such as a monetary gift may be used, it seems safe to assume that this will not be fully effective in the absence of attention to other aspects of survey design. For example, Waltemyer et al [172] found, under the conditions of their particular investigation, that a mailed questionnaire on coloured paper secured a higher response rate than one on white paper. Nevertheless, one would not assume that the brilliance of Pablo Picasso’s paintings during his blue period was simply because they were blue. Furthermore, other studies have found that paper colour makes no difference to response [77] and, in any event, it would seem a common sense position to assume that the enhancement of response rate is multifactorial.

Although high response rate is widely acknowledged as a crucial factor in establishing validity in questionnaire studies, authors have warned about some dangers of response enhancement measures. In a study of response rates amongst general medical practitioners, Barclay et al [81] express the opinion, “Response rates of 100% will rarely be achieved without tactics that may influence the quality of data obtained and affect the potential for future collaboration”. Whilst no evidence is presented to support this, it does seem intuitive that high pressure measures are likely to be counterproductive. Locker [127] also warns of the possibility that some response enhancement measures can actually increase non-response bias. He points out that response enhancement measures may be more effective on some groups of non-responders than others. Locker explains that if these groups differ on the variable of interest then, whilst non-response is decreased, non-response bias will be increased. Therefore, although research is available which suggests strategies to enhance response rates, this should be interpreted and applied with appropriate caution.



## 2.6 Measurement

Measurement error occurs when a respondent's answer is inaccurate or imprecise. This raises the question of whether respondents always tell the truth on questionnaires and whether the wording, design or mode of the questionnaire leads respondents to answer in a certain way.

### 2.6.1 Do respondents always tell the truth?

Stewardson in 2001 [106] conducted a questionnaire study to investigate the endodontic practices of general dental practitioners in Birmingham UK. The author commented that respondents may report the use of materials and techniques which they know to be recommended although, in reality, they do not use them. Nevertheless, in respect of his own study, the author concludes that the responses were honest. This is because a high number of respondents admitted to not using rubber dam although it is taught as mandatory. He therefore reasons that these were honest responses and therefore all other responses must have been honest. This conclusion may be questioned by comparing the reported use of rubber dam with the reported use of sodium hypochlorite irrigation in the study. For example 72% of private practitioners reported that they always used sodium hypochlorite to irrigate. Only 36% of the same group report that they use rubber dam isolation "always" or "more often than not". The use of sodium hypochlorite irrigation without rubber dam is difficult if not impossible. These two findings therefore seem at odds and question the veracity of the responses.

### 2.6.2 The wording of questions

In 2010 Aps [65] carried out a questionnaire study of Flemish general dental practitioners' knowledge of dental radiology. The questionnaire included the following question, "For intra oral radiography I usually use the parallel technique". The respondent was then prompted to answer yes, no or no idea. There was no choice given between the parallel technique and the bisecting angle technique. This probably led the respondents to answer yes, especially if they were unsure of the difference between the two techniques. The confusion over the parallel technique question is revealed in the results which suggested that 81% of the respondents used short cone x-ray machines and 81% used the parallel technique. Since the two are mutually exclusive, this demonstrates a case of measurement error arising from the wording of

the questionnaire. The wording did not take account of the possible low level of knowledge of the respondents with regard to dental radiography.

### 2.6.3 Questionnaire design

In 2008 Ghasemi et al [91] investigated Iranian dentists' treatment decisions based on bitewing radiographs. Instead of real radiographs, the subjects were presented with schematic drawings of carious lesions as in Figure 4 on page 42.



**Figure 4 - Drawings of carious lesions from Ghasemi et al [91]**

Whilst this was a convenient way to present the questionnaire, dentists do not make decisions from drawings of radiographs in practice. Decisions are made from real radiographs. Measurement error was therefore introduced.

### 2.6.4 Different survey modes

Another possible source of measurement error arises from the mode of the survey. For example Salti and Whaites [92] conducted a survey of radiographic practice amongst general dental practitioners in Damascus, Syria. Only one mailing was sent. Non responders were then contacted directly and questionnaires were completed either by telephone or by personal interview. Whilst this was undoubtedly an effective way of reducing non-response, one cannot be sure that the respondents did not answer differently according to whether they were interviewed, telephoned or completed a written questionnaire. In particular, the presence of an interviewer may provoke a different response from those written on an anonymous questionnaire. Dillman et al [87] comment, "A significant limitation to using multiple modes of data collection is that survey modes introduce measurement error because people may provide different answers to the same question depending on the mode being used to ask the question".

## 2.7 Questionnaire studies which investigate the custom and practice of dentists in preoperative imaging of implant sites

The availability of dental cone beam computed tomography (CBCT) represented a fundamental change in the options available for a preoperative imaging strategy for dental implants. Therefore, only the most recent studies, undertaken when CBCT was available, have been reviewed. The earliest evaluations of CBCT appeared in the dental literature around 2003 to 2004 [173, 174]. The 2004 edition of the guideline document, "Selection Criteria for Dental Radiography" [37] published by the Faculty of General Dental Practice (UK), does not consider the use of CBCT. Therefore, studies which predate these publications were not considered. A search of the dental literature identified three studies published more recently which, in full or in part, investigated the custom and practice of dentists when imaging potential implant sites [71, 155, 162].

### 2.7.1 de Morais et al, 2007 [155]

This Brazilian study investigated the use of the following imaging techniques prior to dental implant placement: panoramic radiography, computed tomography, conventional tomography and periapical radiography. It is not clear from the text whether the term CT was used as a generic one which would include CBCT. Nonetheless, further investigation revealed that this study represented a re-evaluation of data collected by the same four authors for a paper published in 2003 [90]. This predated the widespread availability of CBCT. Therefore this paper was not considered any further.

### 2.7.2 Ribeiro-Rotta et al, 2010 [162]

In this study, a mailed questionnaire was sent to all 1435 dental implant specialists registered with the Brazilian Federal Council of Dentistry. Reminders were posted 20 and 40 days after the initial mailing. The use of preoperative radiography for dental implant planning was considered by these authors. Nevertheless, the purpose of the questionnaire was to investigate assessment of bone quality only. The prescription of radiographs to plan implant placement as a whole was not considered. Therefore this paper was not reviewed further. Notwithstanding, it was noted that this study had a response of 221, a rate of 15.4%. Non-response of 84.6% raises questions about non-response bias and the reliability of the authors' findings.

### 2.7.3 McCrea 2008, [71]

McCrea carried out a postal questionnaire study which was sent to all active members of the British Society of Periodontology. In the introduction to this article, the author states, "This is the first study that systematically confronts the issue of radiographic compliance in dental implant planning". No subsequent studies have been identified. Compliance was tested against the following guidelines: "Selection Criteria in Dental Radiography", published in 2004 by the Faculty of General Dental Practice (UK) [37], and, "Selection criteria for dental implant site imaging: a position paper of the American Academy of Oral and Maxillofacial radiology." [39] published in 2000.

Unfortunately, whilst the publication date is June 2008, it is reported that the data were collected in July 2005. It is around this time that the first few CBCT machines were becoming available in the UK. There is some discussion of CBCT in the text and, after a reported "further analysis" by the author, seven out of a working sample of 280 dentists reported using it. Nevertheless, as an illustration of the relative unimportance of CBCT at the time, the author does not include it in his table of effective doses of available imaging modalities. Furthermore, the guideline documents used in the study do not refer to it. CBCT has become very widely available since this survey was conducted and one would expect that the results would be very different if it were conducted in 2011.

#### Coverage

The population of interest is stated as the active membership of the British Society of Periodontology. The author suggests that he had access to the membership list of this society which comprised 630 members. A group of 70 were identified as no longer professionally active and therefore the sample frame was comprised of the remaining 560 members. It can be said that every member of the survey population appeared on the sample frame. Nevertheless the sample frame contained a large number of ineligible individuals. Amongst the respondents, for example, 179 were ineligible as they did not place or restore dental implants. This represented 32% of the sample.

#### Sampling

Sampling was not carried out and questionnaires were sent out to the whole of the sample frame of 560 members. The disadvantages of this "total population approach" are discussed in paragraph 2.4.2 on page 19. In short, it could be argued that the

author traded sampling error for non-response error and that sampling would have allowed better allocation of resources to improve response. There is also the danger of creating “questionnaire fatigue” if potential respondents are subjected to repeated surveys.

No sample size calculation was carried out which could have quantified the precision of the estimates. If a sample size calculation had been carried out according to Dillman’s formula [87], the author could have been 95% confident that his working sample size of 280 gave estimates within 3% of the population value. If an estimate within 10% was considered acceptable, then a sample size of 77 would have sufficed. The author states in his conclusion, “Further studies should be carried out with a larger sample size...to verify the results/conclusions drawn in this study”. Nevertheless, since no sample size calculation was made, it is difficult to see how this conclusion was reached.

#### Response rate and non-response

The figures for response were as follows:

Questionnaires mailed	560
Responses received	459
Non responders	101 (560-459)
Ineligible responders	179
Working sample size	280 (459-179)

There were 459 responses to 560 questionnaires and the response rate is reported as 81.5%. Nevertheless, this calculation included a large number of ineligible respondents which inflated the reported response rate. There were 179 respondents who did not carry out any implant work leaving a working sample size of 280. According to Kviz [125] the ineligible responders should not have been included in the response rate calculation and this reduces the response rate to 73.5%. Further, the completion rate is calculated from the sample size of 560 and the final working sample of 280. The completion rate is therefore 50%. (See Appendix A, page 291)

This study was published in the British Dental Journal. Rugg-Gunn, the editor of the British Dental Journal in 1997, wrote the “Guidelines for acceptable response rates in

epidemiological surveys” [122]. These have not been superseded by newer guidelines. They stated,

*“the following guidelines for judging the adequacy of completion rates are proposed:*

*80% or over, good;*

*70-79%, acceptable;*

*55-69%, suspect;*

*below 55% rejection.”*

Therefore, based on the definition of Kviz [125], the British Dental Journal’s own guidelines suggest rejection of this paper on the basis of the completion rate of 50%. In these guidelines, Rugg-Gunn also writes as follows [122]:

*“When deciding whether to accept or reject a certain response or completion rate, the following may be relevant:*

*Attempts to raise the response rate,*

*Attempts to elicit reasons for non-response,*

*Attempts to determine the relevant characteristics of non-responders*

*..The first three should be part of any well conducted study”.*

Response enhancement measures in this study are reported as being a covering letter, which explained the background to the survey, and a reply paid envelope. One reminder letter was sent some two months after the initial mailing. Despite the author’s claim of, “The excellent response rate of 81.5%”, there were, nonetheless, 101 non responders compared to a working sample size of 280. There is neither discussion of the reasons for non-response nor any report of attempts to determine the characteristics of the non-responders. Therefore there could not have been any assessment of non-response bias nor corrections made to the data.

### Measurement

The questionnaire was piloted on a group of 70 members of an implantology study group. Amendments and refinements were made to the questionnaire as a result. This is considered good practice in reducing measurement error by eliminating confusing or

misleading questions [87]. Pilot studies can also be helpful in sample size calculation as they can indicate the possible variance in data [175]. Sampling and sample size calculation, however, were not reported in this case.

A source of error is the use of solely text based questions. Clinical photographs or artefacts do not form part of the survey. In reality, a clinician will base imaging decisions on what is seen or examined. Furthermore, the questions about imaging for implant planning are very general. The section on single implant assessment is reproduced in Figure 5 on page 47. In practice, it is likely that a practitioner will use a range of different imaging techniques for different single implant cases according to their clinical features. Therefore it is possible that a respondent may either answer these questions according to a single implant case that is in mind at the time or respond so generally that answers do not bear relation to individual clinical cases. Measurement error is therefore introduced.

6. When assessing for a SINGLE implant, do you:	
Take an OPG?	Yes / No
Take a periapical of the site?	Yes / No
Use ball-bearing analysis or other radio-opaque measurement method for the occluso-apical assessment?	Yes / No
Apply ridge mapping for the alveolar width?	Yes / No
ALWAYS prescribe cross-sectional imagery?	Yes / No

**Figure 5 - Part of questionnaire used by McCrea [71]**

If, for example, the respondent had in mind a missing upper second premolar, the initial radiographic examination might be a periapical radiograph. The results may lead the clinician to plan implant placement based on this and clinical examination alone. Alternatively, the periapical radiograph might suggest a pneumatized maxillary sinus which restricts the bone volume available. Under these circumstances further radiographic examinations may be carried out. This single response, closed question, tick box format cannot capture an imaging strategy. Further, the appropriate imaging may well take into account other clinical factors such as dental disease at other sites. Therefore, when the first question of this section asks, "Do you take an OPG?" the

appropriate answer for a respondent might be “sometimes”. This option, however, is not available

The author remarks, “The active membership of the British Society of Periodontology overwhelmingly did not follow the published UK or USA selection criteria”. Nevertheless, it is difficult to see how compliance with guidelines has been assessed. For example the FGDP(UK)<sup>††</sup> guidelines are summarised by McCrea and shown in Figure 6 on page 48. Nonetheless, the FGDP(UK) guidelines are different from these and are shown in Figure 7 on page 49. The summary of McCrea requires a periapical view for single site assessment and a panoramic view for multiple implant sites. Cross sectional imaging is then dependant on the individual case. The FGDP(UK) selection criteria themselves are much more fluid and allow for combinations of techniques according to clinical circumstances. It is therefore unclear how compliance has been judged. Whilst the respondents may not have followed the author’s own summary of the FGDP(UK) guidelines, it seems unlikely that non-compliance with the guidelines as published by the FGDP(UK) had been demonstrated.

**Table 2 Summary of FGDP(UK) radiographic selection criteria for dental implant planning<sup>7</sup>**

- |  |
|--|
| 1. Clinical and visual examination including palpation and study model assessment.   |
| 2. An initial intra-oral two-dimensional periapical radiograph for single site assessment.   |
| 3. A panoramic radiograph for multiple implant sites – this being dependent on dose implications and the wish to investigate anatomical factors.                             |
| 4. The use of cross-sectional imaging will be dependent on the individual case and on the availability of the resource, the preferred choice being computed tomography (CT). |

**Figure 6 - Summary of FGDP(UK) selection criteria by McCrea [71]**

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<sup>††</sup> FGDP(UK) – The Faculty of General Dental Practice of the Royal College of Surgeons of England



<i>Table 8.2: Selection criteria for radiology in implantology</i>	
<b>TREATMENT PLANNING</b>	
<b>Single implant</b>	
Anterior maxilla	Combinations of periapical, lateral cephalometric and panoramic radiography. Alternatively, use cross-sectional tomogram.
Anterior mandible	Combination of periapical, lateral cephalometric and panoramic radiographs. Alternatively, use cross-sectional tomogram.
Premolar maxilla	Combination of periapical and panoramic radiographs. Alternatively, use cross-sectional tomogram.
Molar maxilla	Combination of periapical, occlusal and panoramic radiographs. Cross-sectional tomograms may be particularly useful to image the morphology of the antral floor.
Molar mandible	Combination of periapical, occlusal and panoramic radiographs. Cross-sectional tomograms may be particularly useful to image the position of the interior dental canal and to show the concavity of the submandibular fossa.

**Figure 7 - Section from the FGDP(UK) selection criteria [37]**

A further criticism of this study is that the author carried out a postal questionnaire study which was sent to all active members of the British Society of Periodontology. This raises the question of whether the members of the British Society of Periodontology are similar to wider groups of dentists who practise implantology. For example, the findings may not be applicable to UK implant practitioners as a whole.

Notwithstanding the criticisms of this study, the author does correctly point out that both the FGDP(UK) and US guidelines have a very low level of evidence to support their use. He completes his paper by drawing attention to the need for research based selection criteria.

## 2.8 Concluding comments

A review of the literature revealed only one, relatively recent study in which the custom and practice of dentists in preoperative imaging of implant sites is surveyed by questionnaire (McCrea 2008 [71]). Unfortunately, the data for this study were gathered in 2005, before the widespread availability of Cone Beam Computed Tomography (CBCT). This technology has introduced the option of true cross sectional images, free from superimposition, at a relatively low radiation dose compared with medical CT. CBCT now appears to be very widely used. There is therefore a need to re-evaluate

the custom and practice of dentists, with regard to dental implantology, in the light of the imaging options currently available.

Response levels are often used incorrectly as the key indicator of survey quality and many authors have investigated methods of raising response. Nevertheless, non-response is only one of four broad areas of error to which questionnaire surveys are subject. These are: coverage, sampling, non-response and measurement.

### 2.8.1 Coverage considerations

Once a population of interest has been defined, a list of the members of the population is compiled. This is termed the sample frame and the working sample is drawn from it. Inaccuracies in the sample frame are potential sources of coverage error. Researchers will often wish to investigate as broad a population as possible so that findings are widely applicable. The trade-off is that the larger the population, the more difficult it is to correctly identify every member and their contact details so that they can be included in the sample frame. The difficulties of identifying the members of a population without omissions, duplications or other errors have been discussed. These difficulties sometimes lead researchers to choose sub-groups to represent a population. An example is the study by Sakakura [90] in which the delegates at a Brazilian dental conference were chosen to represent Brazilian dentists as a whole. Nevertheless, the results can only be said to relate to dentists who attended that particular conference.

### 2.8.2 Sampling considerations

In order to avoid sampling error, every member of the sample frame should have an equal chance of being selected in the sample. Random sampling fulfils this requirement and the precision of estimates increases with the sample size. Nevertheless, resources for research are always limited. Therefore, the balance in this case is between the size of the sample and the costs of contacting the sample members effectively. Attempts to contact large samples, or even whole populations, restrict the resources available to implement response enhancement measures. Under these circumstances, researchers trade sampling error for non-response error. An example is the study by Wenzel and Møystad [102] in which all 3940 dental practitioners in Norway were surveyed with only a 56% response rate.

Non-random, or convenience sampling, is common. An example is the study by Aps [65] in which the sample was comprised of the participants at a dental radiology course. There was a 100% response rate. Nonetheless, error is introduced because those who attended the course may have different attitudes or knowledge from those who did not attend.

Sample size calculations are rarely given in reports of surveys of dentists. Nevertheless authors often conclude that research should be repeated with larger sample sizes to confirm their findings. An example is the survey by Sutton [119] which investigated educational needs of general dental practitioners. Nonetheless, where no sample size calculation has been made, there can be no basis for this conclusion.

### 2.8.3 Response rates and non-response

The issue of response rates is complicated by the inconsistency in calculation and the capacity for overestimation of the true response. Further, non-response represents only the potential for non-response bias. Bias will occur only if there are differences between the responders and the non-responders on the measures of interest. Equally, similarity in demographic characteristics of responders and non-responders does not necessarily mean that they are similar in their attitudes or beliefs with regard to the matter under investigation. Therefore, post survey analyses of this kind cannot give confidence that non-response bias does not exist. Although statistical methods are available to assess the degree of non-response bias and apply corrections to the data, these too have their limitations and even have the potential to increase bias [127].

Parashos [118] correctly remarks, "Avoiding the complexities of non-response bias is best managed by incorporating measures and strategies to achieve a high response rate." Whilst authors have attempted to quantify the effectiveness of response enhancement strategies, analysis presents difficulties. There are many features of a survey to consider, including the subject matter, the length of the questionnaire, the design, the phrasing of questions as well as individual response enhancement measures such as monetary incentive. It seems logical that all of these will have effects on response rate both alone and in combination. The effects of single measures are therefore difficult to interpret and studies which compare individual response enhancement strategies are only partially helpful.

The question of what is an acceptable response rate remains a question of judgement. Johnson [120] comments that most scientific journals rely on the expertise of their peer reviewers on this matter. By contrast, Rugg-Gunn [122] wrote specific guidelines for the British Dental Journal. Nevertheless, the situation is probably best encapsulated by Montori [103] who commented, "The response rate below which validity is seriously compromised is arbitrary".

#### 2.8.4 Measurement considerations

There is measurement error when a respondent's answers are inaccurate or imprecise. This may arise from the wording of questions, the design of the questionnaire or the mode of the survey. For example, measurement error commonly arises when single answer, tick box questions do not present all the possible answers. This occurred in the study by Aps [65]. The over simplification of clinical information is also a source of measurement error. An example is the study by Ghasemi [91] in which drawings of radiographs, rather than real radiographs, were presented to dentists for assessment. The mode of a survey may also be the source of measurement error if some respondents are asked questions by interview whilst others answer the same questions by anonymous written response. An example is the survey by Salti and Whaites [92]. Pilot studies, such as that carried out by Davies et al [74] are essential in identifying aspects of survey design which are confusing or misleading.

### 2.9 Implications for the next stage of the research

There are numerous potential survey errors that may be encountered in questionnaire studies. There is a need to perform questionnaire studies which are, as far as possible, robust and free of error. In the next part of this research, the principles learned from the narrative literature review were applied in planning a questionnaire study to investigate custom and practice of imaging methods for the anterior region of the mandible prior to dental implant placement

- 3 Part 2 - A questionnaire study to investigate custom and practice of imaging methods for the anterior region of the edentulous mandible prior to dental implant placement**



### 3.1 Introduction

A preliminary review of the literature revealed no questionnaire studies which investigate custom and practice when planning imaging methods prior to implant placement in the symphyseal region of the edentulous mandible.

Following the results of the literature review, a questionnaire study was carried out to investigate the custom and practice of private dental implant practitioners in the North West of England when planning imaging methods prior to implant placement in the symphyseal region of the edentulous mandible.

#### 3.1.1 Aim and objectives of this study

##### Aim

To investigate the custom and practice of independent dental implant practitioners in the North West of England when planning imaging methods prior to implant placement in the symphyseal region of the edentulous mandible and to gain an understanding of decision making when prescribing imaging methods.

##### Objectives

1. To develop a web based questionnaire which presents two realistic clinical scenarios, of different clinical difficulty, for the prescription of images.
2. To incorporate survey design features and implementation procedures which enhance response.
3. To reduce measurement error by conducting a pilot study which addresses any confusing or misleading questions.
4. To define a population so that there is a realistic chance of approaching full coverage in the sample frame.
5. To select a random sample of a size that conveys appropriate precision whilst enabling the application of response enhancement strategies.
6. To conduct a mixed-mode survey which combines postal pre-notification and post survey reminders with the web based questionnaire.
7. To incorporate survey design features which allow analysis of non-responders and non-response bias.
8. To present survey results to determine the range and variety of imaging strategies used by dentists.

9. Carry out statistical analyses to gain an understanding of:
  - a. Whether case difficulty influences imaging strategies and the factors affecting this.
  - b. The prescription of 3D imaging<sup>‡‡</sup> techniques or conventional radiography and the factors influencing this decision.
  - c. The use of conventional radiography prior to the decision to prescribe 3D imaging techniques and the factors influencing this.
  - d. The use of radiographic guides and the factors influencing this.

Demographic variables to be included in the analyses were:

1. Gender
2. Age
3. Place of qualification
4. Year of qualification
5. Number of dental implants placed per year
6. Type of training in dental implantology
7. Postgraduate qualifications
8. Imaging machines available in the place of work

### 3.1.2 Null hypotheses

3.1.2.1 There is no significant difference in the imaging strategy of dentists in relation to case difficulty

3.1.2.2 There are no significant differences in the use of 3D imaging and conventional radiography<sup>§§</sup> in relation to the demographic variables

3.1.2.3 There is no significant difference in the use of initial conventional radiography prior to 3D imaging in relation to the demographic variables

3.1.2.4 There is no significant difference in the use of radiographic guides in relation to the demographic variables

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<sup>‡‡</sup> 3D imaging – Computed tomography techniques

<sup>§§</sup> Conventional radiography – Radiography other than computed tomography techniques



## 3.2 Materials and methods

- ▶ Development of the questionnaire
- ▶ Population and sample frame
- ▶ Sample size and calculation
- ▶ Survey implementation
- ▶ Survey of non-responders
- ▶ Ethical considerations - anonymity
- ▶ Statistical Methods

### 3.2.1 Development of the questionnaire

A web-based questionnaire was developed to present two realistic clinical scenarios to respondents. Both clinical scenarios were of edentulous patients for whom implant retained lower complete dentures were planned. Implants were to be placed in both lower canine regions. One case had a well-formed lower edentulous alveolar ridge. The other had an atrophic lower edentulous alveolar ridge.

Two fictional clinical scenarios were prepared. For each scenario there was a clinical description (Figure 8 page 58), a clinical photograph and a choice of eleven radiographic images. (Figure 9 page 59) Two mandibles were acquired from private historical collections. One had a well-formed ridge and the other an atrophic ridge. These were used in x-ray phantoms to allow repeated exposures for the eleven different views. The patients for the clinical photographs were chosen so that their photographs represented a realistic match to the two mandibles. Written consent was obtained from the two patients and is presented in Appendix C on page 295.

The x-ray phantoms consisted of containers in the stylised form of the lower third of the head and neck and contained water as a soft tissue equivalent. They allowed a human cervical spine (from the third to the seventh vertebrae) and mandible to be positioned within them using small amounts of impression compound. They were supported by a tripod system allowing the phantoms to be posed at convenient heights for all x-ray machines used in the study. Details of the x-ray phantom have been previously published by the author of this thesis. [176] A diagram of the phantom is presented in Figure 10 page 61.

**Case 1 of 2**

The patient is a 70 year old female. She is retired and has never smoked. She complains that she cannot eat with her lower complete denture. You have discussed options and agreed that you will provide an implant retained complete lower overdenture. The plan is to place two implants in the lower canine regions. On examination she has a very atrophic ridge and poor support potential.

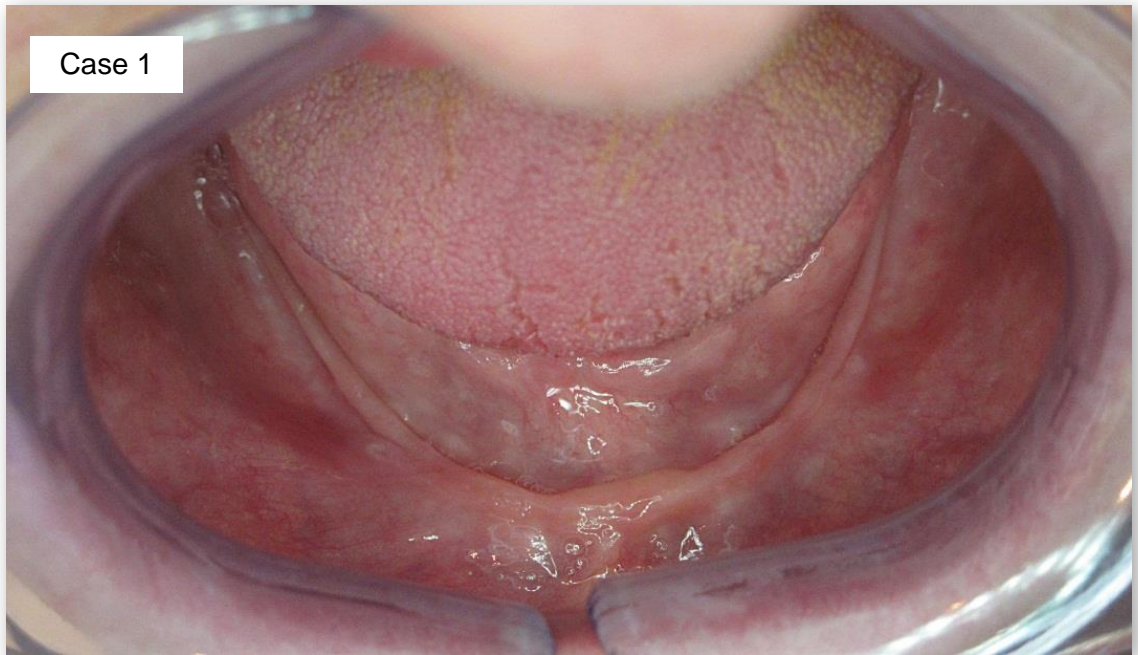
Assume that there are no unexpected limitations to the choice of radiograph.

**Case 2 of 2**

This patient is a 63 year old male. He is retired and is a former smoker. He has difficulty in controlling his lower complete denture. You have discussed options and agreed to provide an implant retained complete lower overdenture. The plan is to place two implants in the lower canine regions. On examination he has good bone height at the anterior mandible but a knife edge ridge with some flabby tissue on the crest.

Assume that there are no unexpected limitations to the choice of radiograph.

**Figure 8 - Case descriptions**



**Figure 9 - Clinical photographs for the questionnaire**

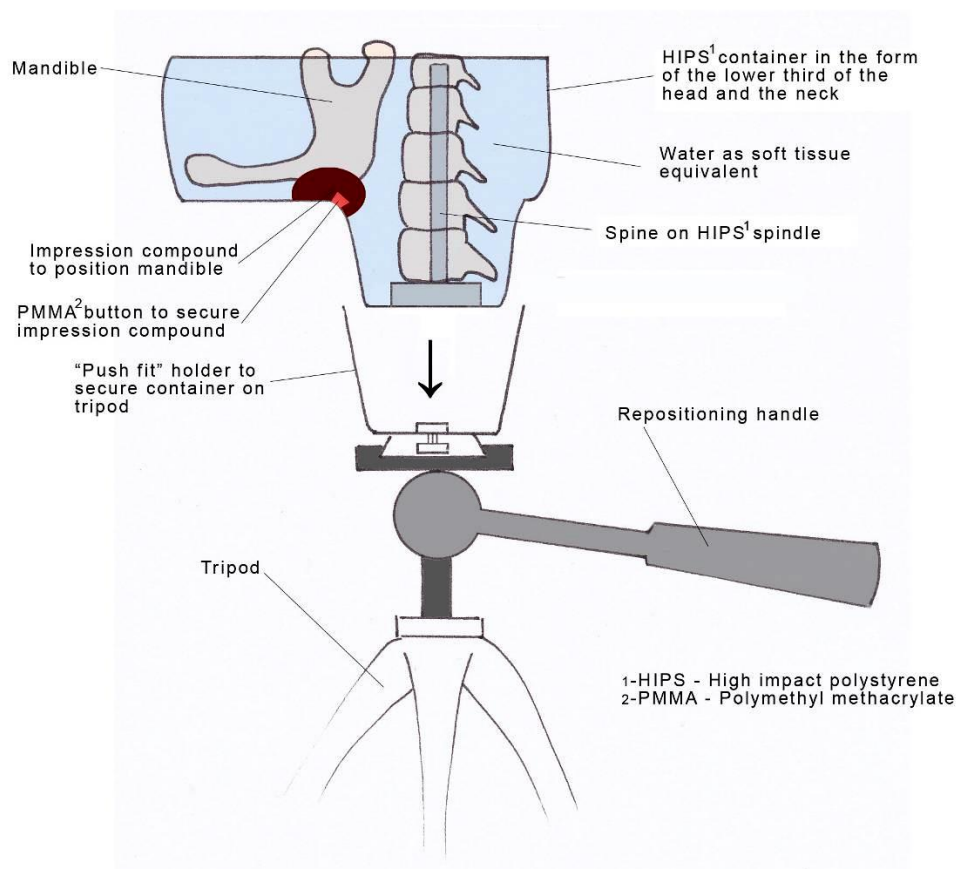
1	Panoramic radiograph
2	Panoramic radiograph with a radiographic guide using 5mm ball bearings at the proposed implant sites
3	Lateral cephalometric view
4	Transsymphyseal view
5	Scanora tomogram at the proposed implant sites
6	Conventional periapical views of the proposed implant sites
7	Conventional periapical views with a radiographic guide using 5mm ball bearings at the proposed implant sites
8	CBCT examination
9	CBCT examination with a radiographic guide using radiopaque markers at the proposed implant sites
10	Medical CT examination
11	Medical CT examination with a radiographic guide using radiopaque markers at the proposed implant sites

**Table 2 - List of radiographic images presented for each case in the questionnaire**

The images listed in Table 2 page 60 were acquired using the x-ray phantoms. (See Figure 11 page 62) The acquisition of medical CT images required a modification to the x-ray phantom because medical CT images are taken in the supine position. Cling film was used to contain the water in the phantoms and foam was used outside the phantom to hold it horizontally. A second, radiolucent container around the phantom was used in case of water spillage. (Figure 12 page 63).

Where radiographic markers had been used, and their use was intended to be optional, image manipulation software was used to modify a duplicate of the final image<sup>\*\*\*</sup>. The radiographic markers were removed so that the images with and without the radiographic markers were identical in every other respect.

The complete set of images are presented in Figure 13 beginning on page 64 and Figure 14 beginning on page 67. Exposure factors for all images are presented in Appendix L on page 313. If respondents wished to prescribe unusual views, which were not available as an option, they could describe their prescription in a free text box.

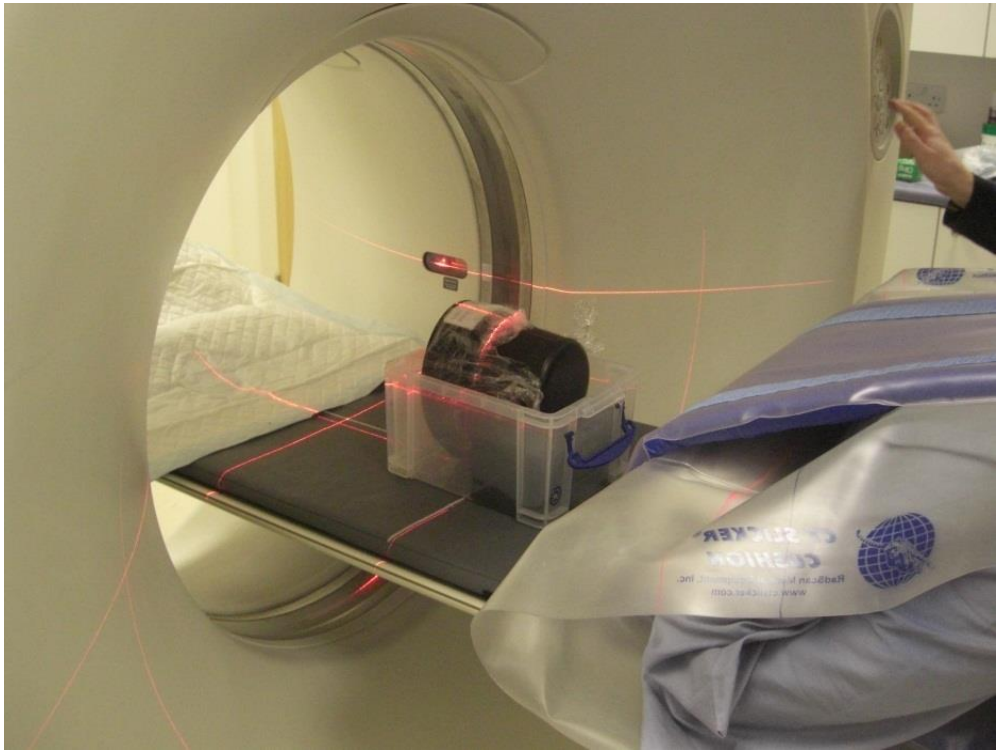


**Figure 10 - Diagram of the x-ray phantom**

<sup>\*\*\*</sup> Adobe Photoshop. Adobe, San José, California, USA



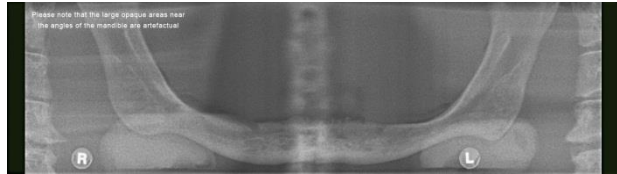
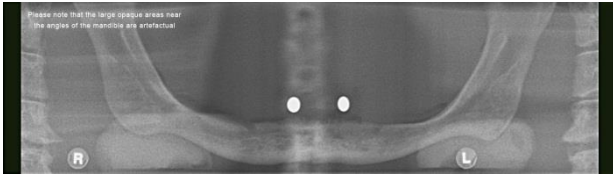
**Figure 11 - Acquisition of the images**



**Figure 12 - Acquisition of the medical CT images**

Figure 13 - Images case number 1 atrophic mandible

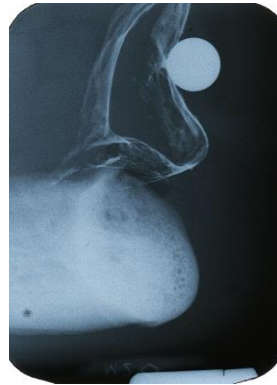
Panoramic radiograph with and without radiographic guide



Lateral cephalometric view



Transsymphyseal view

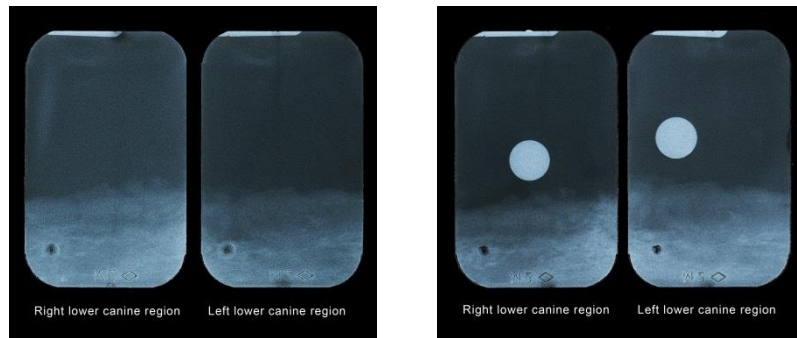


Scanora





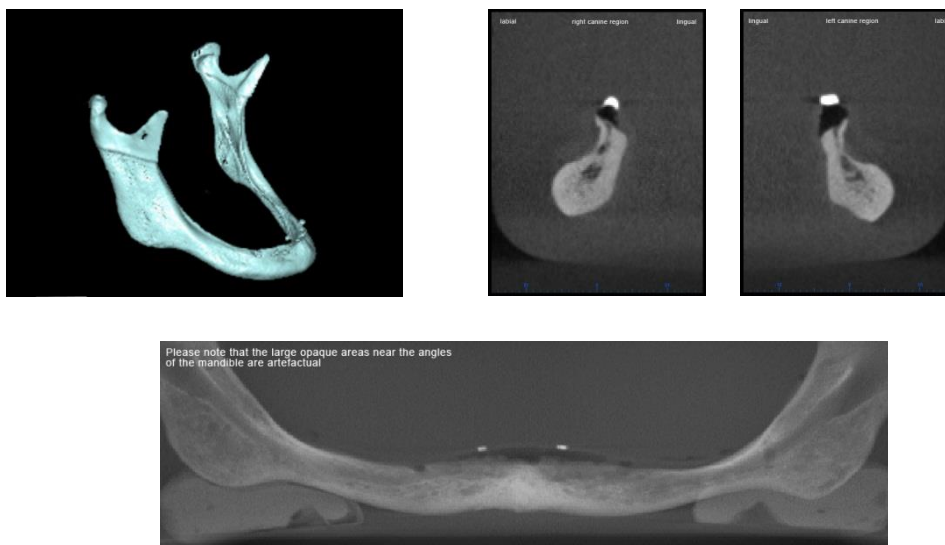
## Conventional periapical views



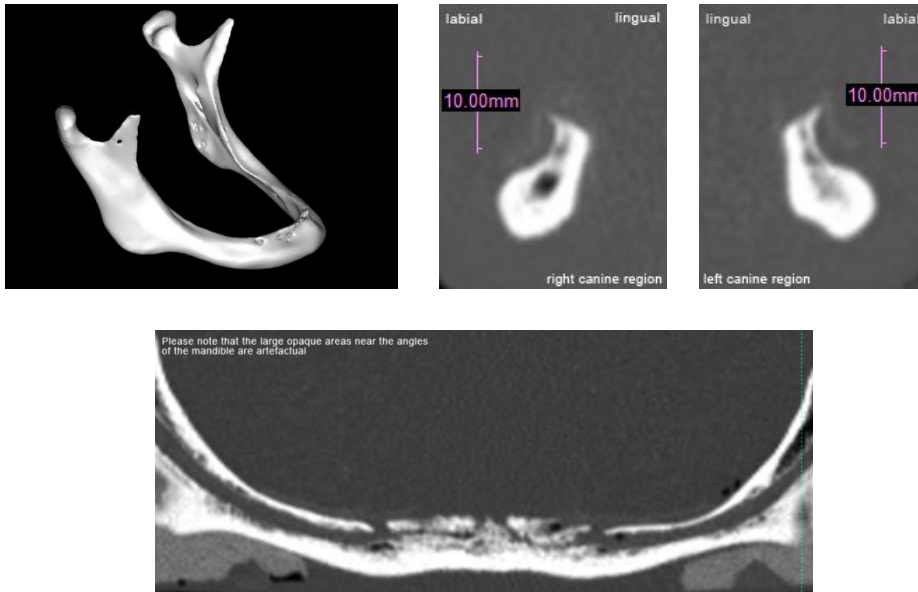
## CBCT examination (4 views presented)



## CBCT examination with a radiographic guide using radiopaque markers at the proposed implant sites (4 views presented)



## Medical CT examination (4 views presented)



## Medical CT examination with a radiographic guide using radiopaque markers at the proposed implant sites (4 views presented)

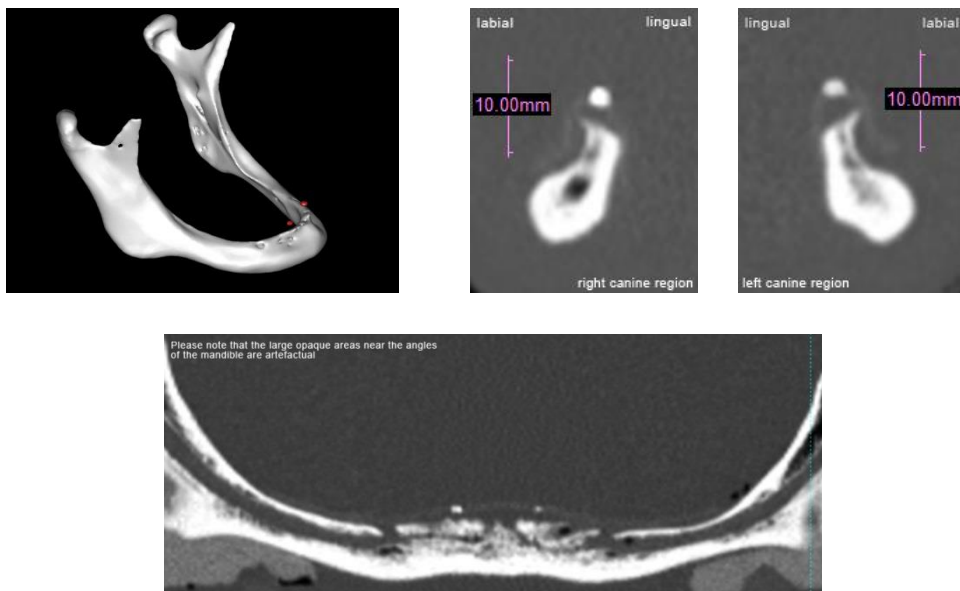
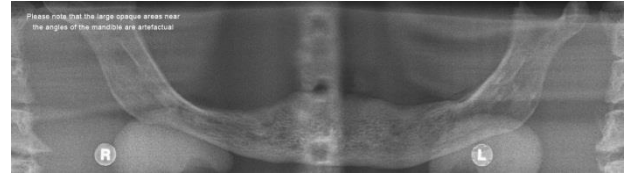
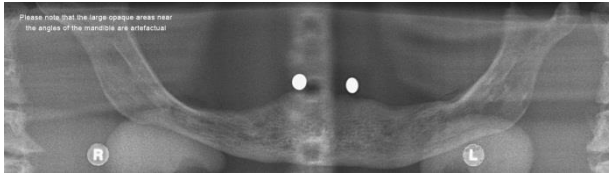


Figure 14 - Images case number 2 well-formed mandible

Panoramic radiograph with and without radiographic guide



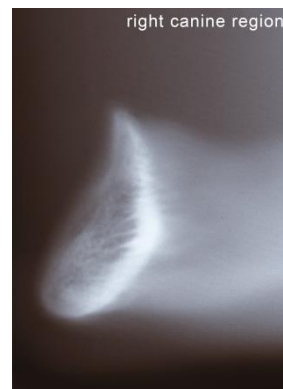
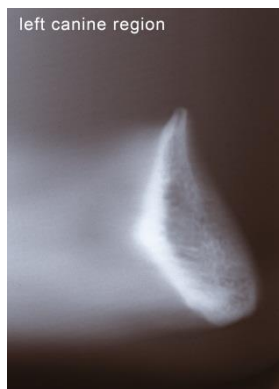
Lateral cephalometric view



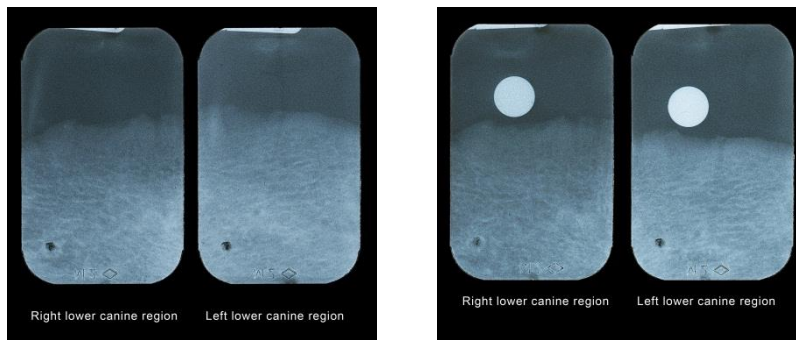
Transsymphyseal view



Scanora



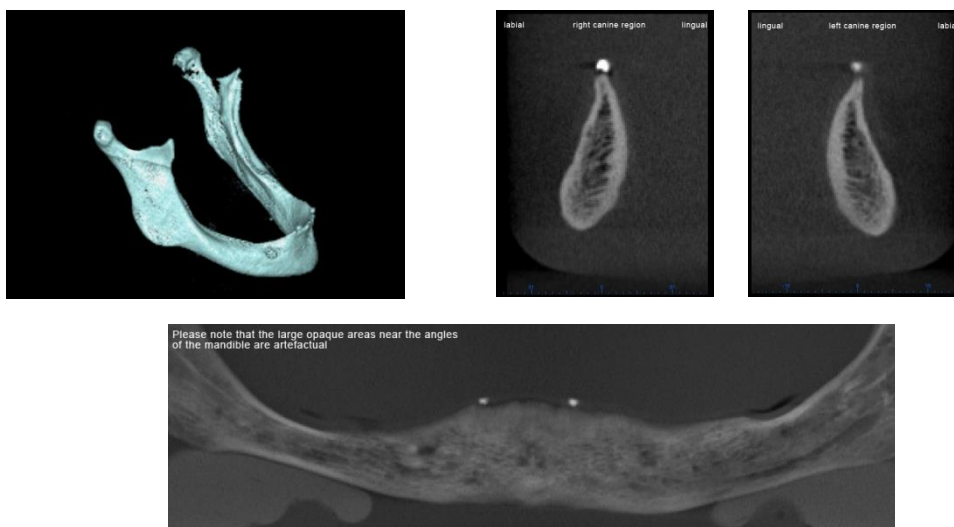
Conventional periapical views



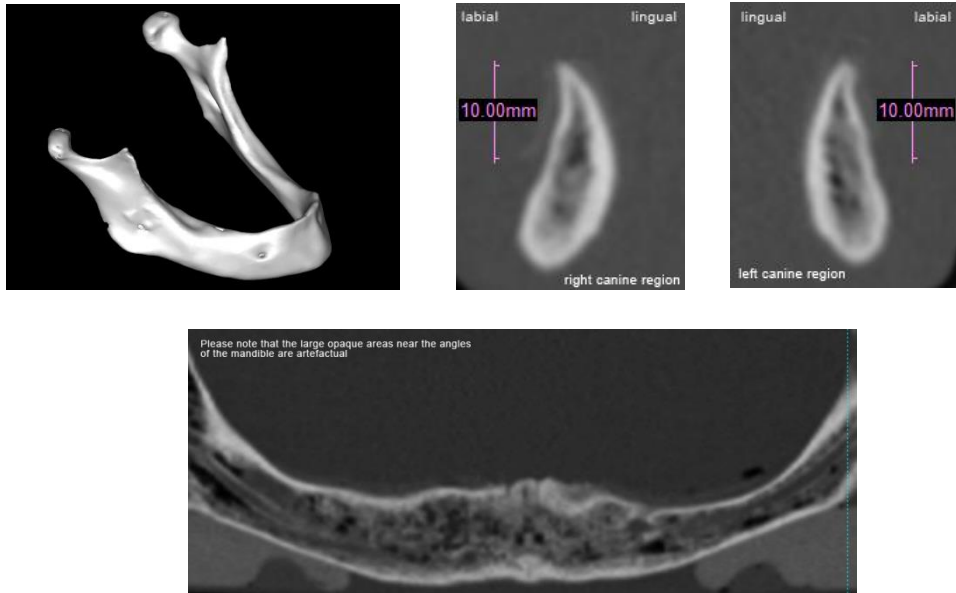
CBCT examination (4 views presented)



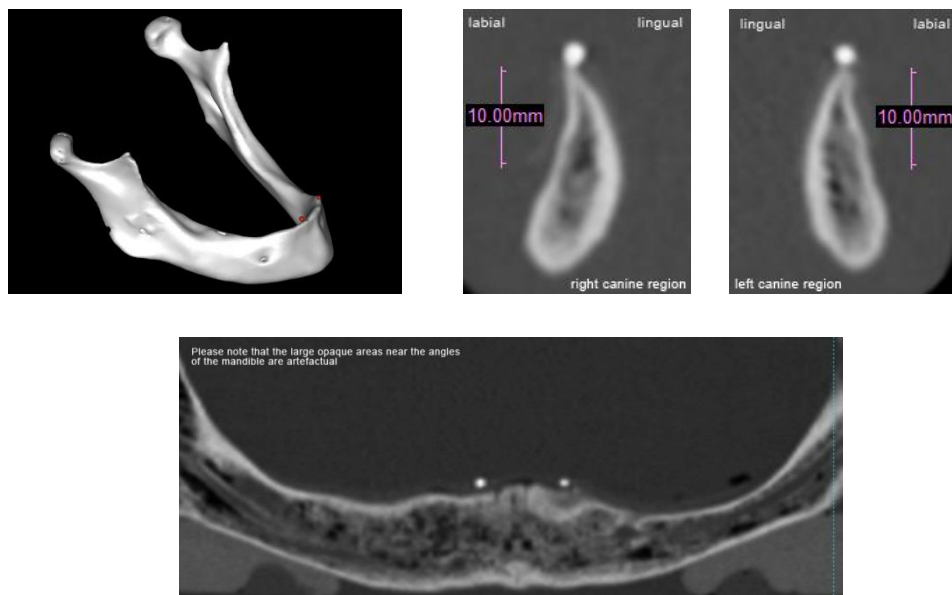
CBCT examination with a radiographic guide using radiopaque markers at the proposed implant sites (4 views presented)



## Medical CT examination (4 views presented)



## Medical CT examination with a radiographic guide using radiopaque markers at the proposed implant sites (4 views presented)



Web developers were engaged to develop a web based questionnaire. The questionnaire included presentation of the two clinical cases and requests for additional information as follows:

- ▶ Male/female
- ▶ Your age in years
- ▶ Where did you qualify?
- ▶ What year did you qualify?
- ▶ Approximately how many implants do you place each year?
- ▶ What was your main training in dental implantology?
- ▶ Do you have postgraduate qualifications?
- ▶ What x-ray equipment do you have at your usual place of work ?

A flow diagram was developed in order to instruct the web developers. This is presented in

Figure 15 page 71. The flow diagram was supplemented with draft layouts for the webpages.

Initial designs were presented by the developers to establish the visual style of the website. After minor amendments, the developers proceeded to develop the final website. Sample pages from the final web-based questionnaire are presented in Figure 16 page 72.

A data file was compiled on the remote server as responses were received. The responses were recorded anonymously, using only access codes which had been allocated to the respondents. The date of each response was recorded. The data file was checked periodically for responses and finally downloaded onto a personal computer for analysis.

At the time of submission of this thesis, the web-based questionnaire is available at [www.implantresearch.co.uk](http://www.implantresearch.co.uk) and can be accessed by using the access code 9999.

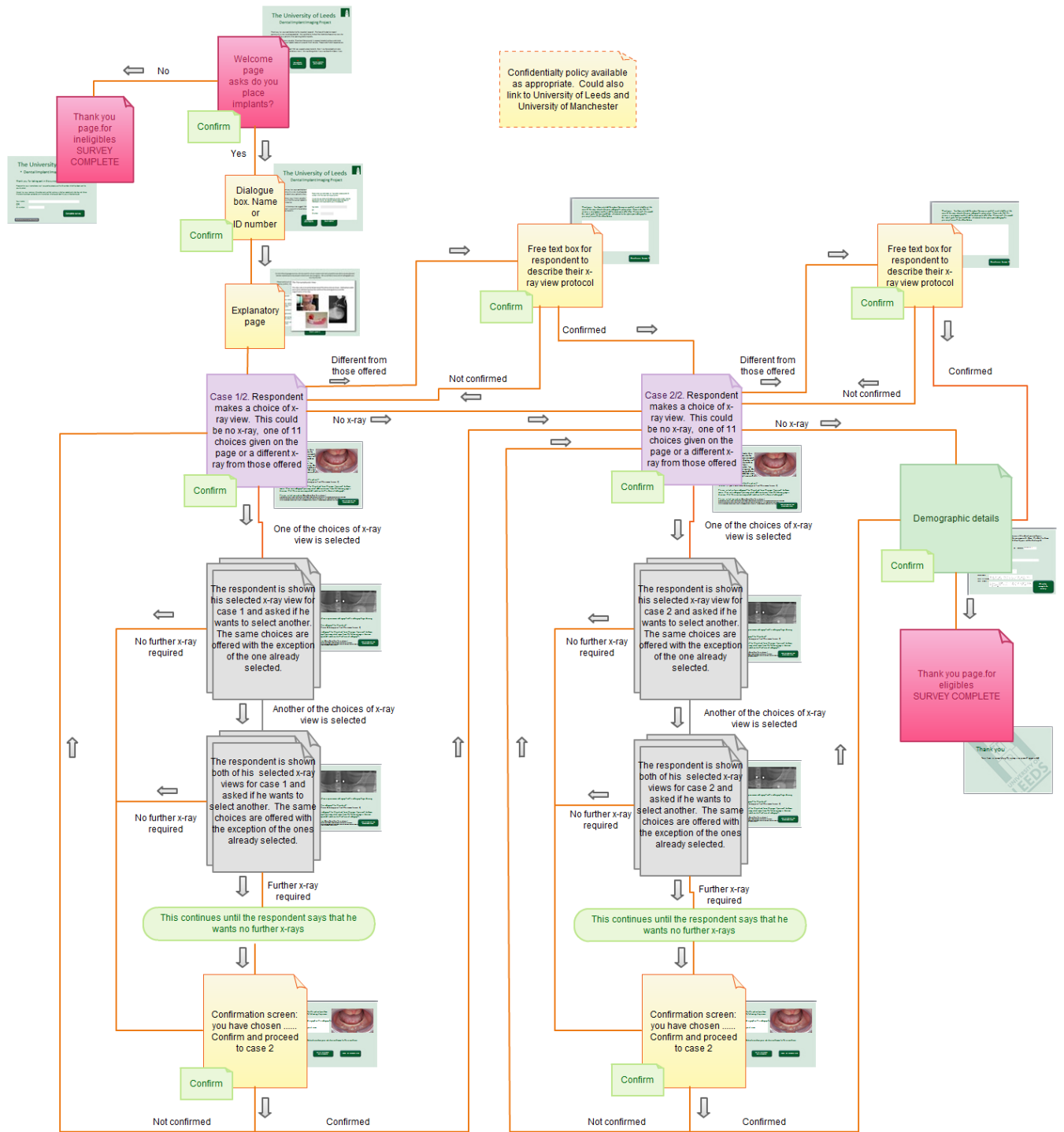


Figure 15 - Flow diagram to instruct web developers

## Leeds Dental Implant Survey

Thank you for your contribution to this important research. The help of the dental implant community is very much appreciated. We would like to find out how dentists choose x-ray views for their edentulous patients when planning dental implants.

We know your time is valuable. Therefore, there are only two cases to look at and our pilot study shows that this survey typically takes only around 5 minutes (if you are interrupted, the system will timeout after 40 minutes of inactivity and you will need to start again). Please note that all responses are confidential.

Our initial enquiries suggest that you surgically place implants. Even if you have placed only one implant we are still interested in your views. We would be grateful if you would confirm below if you place implants.

YES

I do surgically place implants

NO

I do not surgically place implants


Lead Researcher **Andrew Shelley BDS MSc**

## Leeds Dental Implant Survey

**Case 1 of 2**

The patient is a 70 year old female. She is retired and has never smoked. She complains that she cannot eat with her lower complete denture. You have discussed options and agreed that you will provide an implant retained complete lower overdenture. The plan is to place two implants in the lower canine regions. On examination she has a very atrophic ridge and poor support potential.

Assume that there are no unexpected limitations to the choice of radiograph.



**Would you prescribe a radiograph for this patient?**

If YES, please choose one from the list. If NO, please [click here to go to case 2](#)

Please select one from the list (you can select additional views later)...

Please select one from the list (you can select additional views later)...

- Panoramic radiograph
- Panoramic radiograph with a radiographic guide using 5mm ball bearings at the proposed implant sites
- Lateral cephalometric view
- Transsymphyseal view
- Let Tomogram at the proposed implant sites (Scanora)
- Conventional periapical views of the proposed implant sites
- Conventional periapical views with a radiographic guide using 5mm ball bearings at the proposed implant sites
- Cone beam CT examination
- Cone beam CT examination with a radiographic guide using radiopaque markers at the proposed implant sites
- Conventional medical CT examination
- Conventional medical CT examination with a radiographic guide using radiopaque markers at the proposed implant sites
- Another form of radiograph

## Leeds Dental Implant Survey

**Case 1 of 2**

You have chosen **Cone beam CT examination with a radiographic guide using radiopaque markers at the proposed implant sites**

[ENLARGE IMAGE \(opens in new window\)](#)



**Would you take a further radiograph for this patient?**

If YES, please choose one from the list below. If NO, [click here to go to case 2](#)

Cone beam CT examination

confirm selection

Lead Researcher **Andrew Shelley BDS MSc**

## Leeds Dental Implant Survey

To complete the survey we need to know a little about you and your experience. All our information will be anonymised. Once the data has been collected, all information which could identify you will be destroyed.

Gender  Male  Female

Your age in years

At which dental school did you gain your primary qualification as a dentist?  and in what year?

Approximately how many implants do you place each year?  Please select ...

What was your main training in dental implantology?  Please select...

Do you have a postgraduate dental qualification?  yes  no

What x-ray equipment do you have at your usual place of work?  Please select one or more...  
Intra-oral x-ray set  
Panoramic x-ray set  
Panoramic x-ray set with cross sectional imaging  
Hold down the 'ctrl' key ('cmd' key for Mac users) to make multiple choices

[confirm and continue](#)

Lead Researcher **Andrew Shelley BDS MSc**

**Figure 16 - Pages from the web-based questionnaire**



### 3.2.2 Population and sample frame

The population was defined as practice based dental implant practitioners in the North West of England. Hospital and University based dental surgeons were included only if they also carried out implant surgery in independent practice.

A strategy was devised to compile a sample frame which is as close as reasonably possible to the real population of dental implant practitioners who surgically place dental implants in the North West of England. This involved a number of overlapping searches from different sources. The starting point was the membership list of the Association of Dental Implantology (ADI). This list is openly published on the internet and has a convenient search facility by region. Not all ADI members place implants. Others are technicians or dentists who only restore implants. This was checked for each member by examining their websites, which are linked from the ADI site, by telephone calls or sometimes by local knowledge. The next search was an internet search, then a yellow pages directory search. Similar searches were then made of other business directories, advertisements in newspapers and periodicals, internet search engines, implant company websites and published lists of specialist societies. Finally, personal contacts were used to finalise the search. Similar checks were carried out at each stage to ensure that the practitioners surgically placed implants. Naturally, many duplicates were found and so, at each stage, only the newly found dental implant practitioners were added. This process was repeated until no further additional implant practitioners were found and it was felt that the list was as complete as it could reasonably be.

This search was carried out by a research assistant. The brief to the research assistant for compiling the sample frame is included in Appendix G on page 302. A sample frame of 208 was compiled.

### 3.2.3 Sample size and calculation

The sample size was calculated using the equation of Dillman et al [87]. Figure 17 page 74. The margin of error was selected as  $\pm 5\%$  and the confidence level as 95%. This yielded a sample size of 135. This target sample size was adjusted to allow for an 80% response rate giving a final sample size of 169.

The sample of 169 was selected randomly from the sample frame of 208 in the following manner. An alphabetical list of the members of the sample frame was numbered sequentially. A random number generator was then used to randomise the numbers 1 to 208. The first 169 of these randomly arranged numbers were then used to select the sample from the numbered sample frame. A record of the randomisation is presented in Appendix H on page 305.

$$N_s = \frac{(N_p)(p)(1 - p)}{(N_p - 1)(B/C)^2 + (p)(1 - p)}$$

Where  $N_s$  = the *completed* sample size needed for the desired level of precision

$N_p$  = the size of the population

$p$  = the proportion of the population expected to choose one of the two response categories

$B$  = margin of error (ie. half of the desired confidence interval width: .03=±3%)

$C$  = Z score associated with the confidence level (1.96 corresponds to the 95% level)

**Figure 17 - The sample size calculation of Dillman et al**

#### 3.2.4 Survey implementation

The survey was conducted using a mixed mode methodology. The initial contact by mail allowed the delivery of the £5 token of appreciation. Follow up contacts by email allowed for easier access to the survey since a direct link to the survey was embedded into the email message.

The implementation protocol was as follows:

- ▶ First letter
- ▶ 1st email reminder after 1 week

- ▶ 2nd email reminder after a further four days
- ▶ Telephone call after a further four days (See Appendix I on page 306 for script)

Where an email address was not available, a second letter was sent in place of the emails. These letters were found to have a better response than the emails.

Therefore, after the second email reminders, a second letter was also sent out to all non-responders in an attempt to maximise the response.

The dates of the implementation of the survey were as follows:

Initial letter containing the £5 incentive	10/11/11
1 <sup>st</sup> email	20/11/11
2 <sup>nd</sup> email	27/11/11
2 <sup>nd</sup> letter	30/11/11
Telephone call	6/12/11

After a further one week, the survey was considered closed. The letters and emails which were sent at each stage are presented in Appendix D on page 296.

### 3.2.5 Survey of non-responders

A post survey telephone questionnaire of non-responders was carried out to assess the direction and magnitude of any non-response bias using a protocol described by Locker [127].

The protocol was as follows:

- ▶ A telephone interview of non-responders was conducted which asked a question from the main survey
- ▶ The proportion of subjects completing the telephone interview was applied to the whole population of non-responders.
- ▶ This data was added to that found in the responders.
- ▶ The proportions of the adjusted sample were calculated
- ▶ The adjusted proportions were compared to those found amongst the responders.

An attempt was made to contact all of the non-responders. Where it was possible to talk to the non-responders, they were asked, "Please consider an edentulous patient with good ridges. You are planning an implant supported lower complete denture with a dental implant in each of the lower canine regions. Which x-ray views would you prescribe?" This was the same question which was asked for case 2 of the full survey. A comparison of the responses to this question by the "response" group and the "non-response" group then allowed an assessment of the direction and magnitude of non-response bias. The script for this telephone call is included in Appendix J on page 307

### 3.2.6 Ethical considerations - anonymity

Ethical approval for this study was granted by the University of Leeds Dental Research Ethics Committee. Application number 160511/AS/29. (Appendix B page 294)

Each participant was assigned a unique four figure identification number or access code. This served the dual purpose of preserving anonymity and preventing those who might have stumbled across the survey from accessing it. The access code was a four figure number. One hundred and sixty nine such codes were assigned at random intervals. In this way it was less likely that a respondent could accidentally enter another respondent's access code.

There was a "link file" which was separate from the data file. The "link file" linked the name of the respondent with their access code. Therefore, during the period of research, it was possible to use the link file to see who had replied and who had not. The file could then be deleted when the research was complete thus permanently anonymising the data. The respondents were reassured both by letter and on the website that the only purpose of the access code was to determine who had replied and who had not. (Appendix D page 296)

### 3.2.7 Statistical Methods

Data were inputted into PASW <sup>†††</sup> statistics 18.0 <sup>†††</sup> (formerly SPSS). Descriptive statistics were prepared (Section 3.3.2 from page 86 and section 3.3.4 from page 91) followed by statistical analysis (Section 3.4 from page 94).

Null hypotheses were tested as follows:

There is no significant difference in the imaging strategy of dentists in relation to case difficulty.

The use or non-use of 3D imaging at any stage of the prescription was analysed for cases 1 and 2. Following the recommendations of Gardner and Altman [177], this analysis was carried out by presentation of 95% confidence intervals.

A second analysis identified individuals who had made the same prescription for both cases. The use or non-use of the same prescription was tested against the demographic variables using Pearson's chi-square test. From the results of this analysis, logistic regression was used to identify the strongest predictor.

There are no significant differences in the use of 3D imaging and conventional radiography in relation to the demographic variables.

The demographic variables were tested against the use or non-use of 3D imaging using Pearson's chi-square test. Separate analyses were carried out for each case. From the results of these analyses, logistic regression was used to identify the strongest predictor.

There is no significant difference in the use of initial conventional radiography prior to 3D imaging in relation to the demographic variables.

Individuals who had prescribed conventional views prior to prescription of 3D imaging were identified. The demographic variables were tested against the use or non-use of this "conventional before 3D protocol" using Pearson's chi-square test. Separate

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<sup>†††</sup> PASW - Predictive Analytics Software

<sup>†††</sup> SPSS Inc. Chicago, Illinois, USA.

analyses were carried out for each case. From the results of these analyses, logistic regression was used to identify the strongest predictor.

There is no significant difference in the use of radiographic guides in relation to the demographic variables.

The demographic variables were tested against the use or non-use of radiographic guides, at any stage of the prescription, using Pearson's chi-square test. Separate analyses were carried out for each case. From the results of these analyses, logistic regression was used to identify the strongest predictor.

### 3.2.8 The demographic variables

Not all answers to survey questions were included as demographic variables in the statistical analysis. This would have had the effect of increasing the number of separate analyses and further contributing to the problem of multiple comparisons. Therefore, only those variables were included which were most relevant to testing the hypotheses or were suggested by a pre-analysis exploration of the data.

In order to reduce the number of analyses, some answers were reduced or omitted. For example, answers to the question, "At which dental school did you gain your primary qualification as a dentist?", were reduced to those who were UK graduates or non-UK graduates. Also, the analyses did not include the variable, "age". This was because the variable, "date of qualification", was a proxy for age and was a more useful measure of a dentist's experience. The problem of multiple comparisons is discussed in section 3.4.5 page 101.

Demographic variables which were selected for inclusion in the analysis were:

#### Descriptive

- ▶ Male or female
- ▶ UK or non UK qualified

#### Experience

- ▶ Qualified from 0 to 10 years or not
- ▶ Placed more than 100 implants per year or not

#### Training

- ▶ Independently run course or not
- ▶ University course or not
- ▶ FGDP(UK) course or not
- ▶ Manufacturer's course or not

#### Equipment available

- ▶ Intra oral set or not
- ▶ Panoramic machine or not
- ▶ CBCT machine or not
- ▶ Medical CT machine or not
- ▶ Lateral cephalogram or not

#### Qualifications

- ▶ Has postgraduate qualifications or not

In each of these analyses, Pearson's chi-square test was used to test for relationships between categorical data. Contingency tables were produced. Where individual cells had a count of less than five, however, Fisher's exact test was used. Statistical significance was set at  $P < 0.05$ .

### 3.2.9 Pilot study

#### 3.2.9.1 Aims and Objectives of the Pilot Study

The aims of this pilot study were to evaluate the online questionnaire and the associated questionnaire procedures.

The aims can be broken down into several objectives.

To evaluate:

- ▶ Methods of contact
- ▶ The wording of: Initial mailing, email 1, email 2
- ▶ Ease of access and completion of the questionnaire.
- ▶ The monetary incentive
- ▶ The use and functionality of the website
- ▶ Confidentiality procedures
- ▶ Intrusiveness of the questions
- ▶ Time to complete the questionnaire.

#### 3.2.9.2 Method

A panel of 12 dental practitioners was selected through personal contacts and recommendation. This convenience sample was chosen on the basis that panel members surgically place dental implants, would agree to take part in advance and be trusted to give their honest opinion. The geographical area for the main study was the North West of England. Therefore, the panel members were drawn from other parts of England in order to avoid possible future bias in the main study.

The participants were advised in advance that they would be sent two email reminders after 3 to 4 days whether they had replied or not. This was done so that all the participants would have the opportunity to see and evaluate the email reminders even if they had already replied. The 12 participants were then each assigned an access code in the same way as they would be for the main study. They were each sent a letter to invite them to participate in the study. This letter contained the £5 incentive. The initial letter and e-mail reminders are reproduced in Appendix D on page 296.



A second online questionnaire was set up to record the panel's evaluation of the study. This was pretested by a group of three experienced researchers. A bespoke web-based questionnaire was not necessary for this evaluation since the responses were all text based. Therefore a proprietary online survey tool was used.<sup>§§§</sup>

In this evaluation survey there were 21 multiple choice questions under the following headings:

- ▶ The initial letter
- ▶ The £5 gift
- ▶ The follow up emails:
- ▶ The web-based questionnaire: Layout and Navigation
- ▶ The web-based questionnaire: Case studies
- ▶ The web-based questionnaire: Confidentiality and security
- ▶ The web-based questionnaire: Functionality
- ▶ Software bugs

For each of these sections there was also a free text box for further comments or clarifications. There was also the opportunity to comment on the survey as a whole in a final free text box.

Following the evaluation survey, the following changes were made:

### **Demographic questions**

In answer to the question, "Where did you qualify?", one dentist answered "UK". This question was intended to find the dental school at which the respondent qualified. It was therefore changed to, "At which dental school did you qualify as a dentist?"

One of the respondents in the pilot study considered their main training in implantology to be the course offered by the Faculty of General Dental Practice (UK). This option had not been included in the demographic questions. Therefore a new option was included, "FGDP(UK) course".

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<sup>§§§</sup> [www.surveymonkey.com](http://www.surveymonkey.com)

**Initial letter**

In the initial letter, an estimate of 10 minutes to complete the survey was made. The respondents in the pilot study were asked how long it took them to complete the main survey. The result was a median time of 6 minutes and mean time of 6.83 minutes (SD=3.43). Therefore, the initial letter was amended to say that survey would take, "around 6 minutes".

**Software bugs**

It was reported that the website crashed if it was left open, partially completed for a lengthy period of time. This issue was discussed with the web developers. This problem was unavoidable but it was possible to change the time available to complete the survey from twenty minutes to forty minutes. The text of the opening page of the survey was amended to advise respondents accordingly.

### 3.3 Results and Statistical Analysis

#### 3.3.1 Response

There were 138 responses from a total of 169 in the sample. There were, however, three ineligible responses. Three members of the sample had been incorrectly identified as surgically placing dental implants. Response rate calculations are presented in Table 3 page 83.

Sample frame	208
Sample size calculation according to Dillman et al [87]	135
Invitations to participate sent out to account for an 80% response rate	169
Responses received	138
Number of ineligible responses	3
<b>Response rate according to Kviz [125]</b>	<b>81.33%</b>
$\frac{\text{Number of completed questionnaires}}{\text{Number of eligible sample members}}$	$\frac{138-3}{169-3}$
<b>Completion rate according to Kviz [125]</b>	<b>79.88%</b>
$\frac{\text{Number of completed questionnaires}}{\text{Sample size}}$	$\frac{138-3}{169}$
<b>Response rate according to Asch [83]</b>	<b>81.66%</b>
$\frac{\text{Number of surveys returned}}{\text{Number of surveys distributed}}$	$\frac{138}{169}$

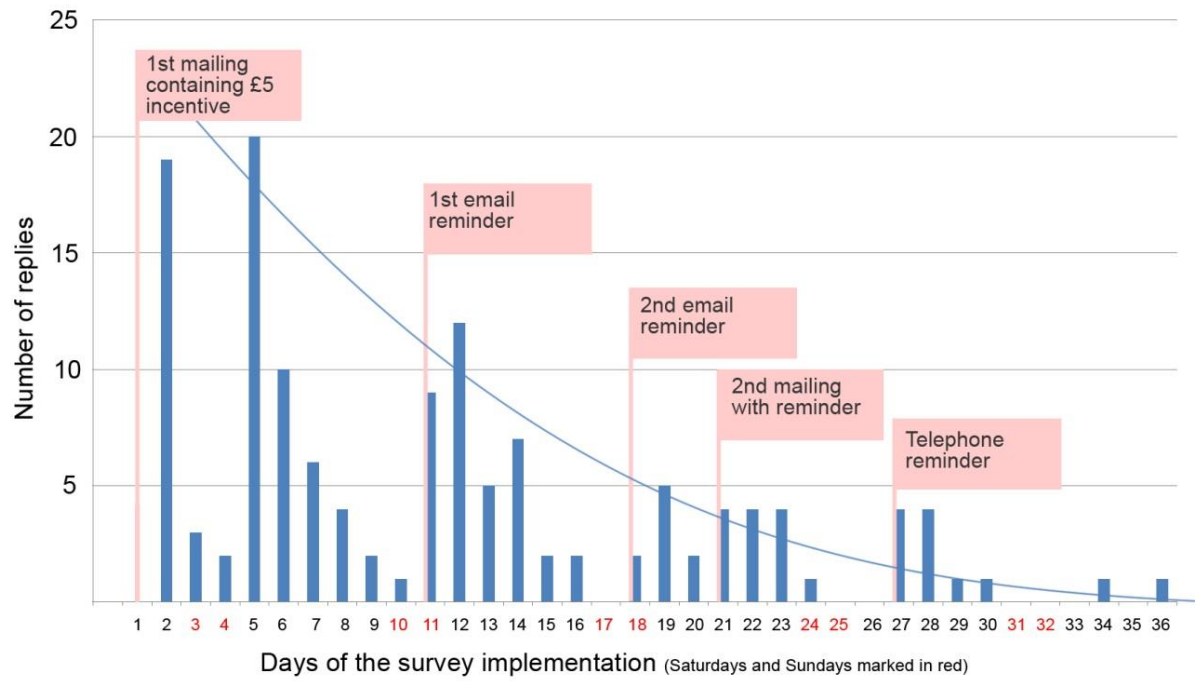
**Table 3 - Response and response rate calculation**

Method and date of contact	Number of responses and cumulative response rate (according to Asch [83])
Invitation letter containing £5 incentive Sent 10/11/11	67 39.64%
First email reminder 20/11/11	37 61.54%
Second email reminder 27/11/11	12 68.64%
Postal reminder 30/11/11	10 74.56%
Telephone reminder 6/12/11	12 81.66%

**Table 4 - Dates of contacts and cumulative response rates**

There were no instances of “item non-response”[127] because the website would not allow the survey to be completed unless all questions were answered.

The dates of each contact and the cumulative response are shown in Table 4 page 84. A graph of response over each of the 36 days of implementation of the survey is presented in Figure 18 page 85. It can be seen how each new contact was timed to coincide with declining response. A line is drawn on the graph to suggest the trend in responses over time.



**Figure 18 - Graph to show daily response for the period of the survey**

### 3.3.2 Demographic data

#### Gender

Male	89.63%	n=121
Female	10.37%	n=14

#### Age

Mean age	46.11 years (SD 9.17)
Range	26 to 66 years

#### Number of years qualified

Mean	22.19 years (SD 9.66)
Range	3 to 44 years

#### Years qualified groups

0-10 years	14.81%	n=20
11-20 years	28.15%	n=38
21-30 years	36.30%	n=49
31-40 years	18.52%	n=25
41-50 years	2.22%	n=3

#### Dental School of first qualification as a dentist

Manchester	30.37%	n=41
Liverpool	22.96%	n=31
Sheffield	6.67%	n=9
Leeds	5.93%	n=8
Birmingham	5.93%	n=8
Newcastle	4.44%	n=6
London	4.44%	n=6
Dundee	4.44%	n=6
Glasgow	2.22%	n=3
Cardiff	1.48%	n=2
Belfast	1.48%	n=2
Edinburgh	0.74%	n=1
Bristol	0.74%	n=1
Non UK	8.15%	n=11

**Number of implants placed per year**

1-20	34.81%	n=47
20 -50	25.19%	n=34
50-100	17.78%	n=24
More than 100	22.22%	n=30

**Main training in dental implantology**

Independently run course	46.67%	n=63
University course	33.33%	n=45
FGDP(UK)	8.89%	n=12
Manufacturer's course	5.19%	n=7
Mentoring by a colleague	2.96%	n=4
Other	2.96%	n=4

**Radiographic equipment available**

Intra oral set	79.26%	n=107
Panoramic machine	67.41%	n=91
CBCT machine	10.37%	n=14
Panoramic machine with cross sectional imaging	7.41%	n=10
Lateral cephalostat	6.67%	n=9
Medical CT machine	1.48%	n=2

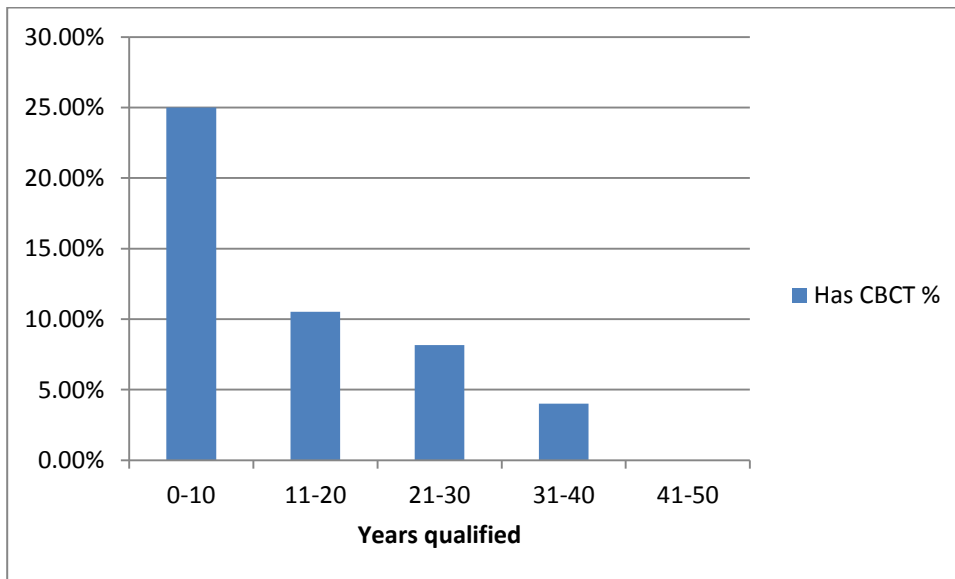
**Has postgraduate qualifications**

Yes	62.96%	n=85
No	37.04%	n=50

3.3.3 Secondary analysis of the “years qualified” groups

Years qualified group	0-10	11-20	21-30	31-40	41-50	Total
Number of respondents	20	38	49	25	3	135
No. respondents with CBCT	5	4	4	1	0	14
% respondents with CBCT	25.00%	10.53%	8.16%	4.00%	0.00%	

**Table 5 - Number and percentage of respondents who have CBCT available by "years qualified" group**

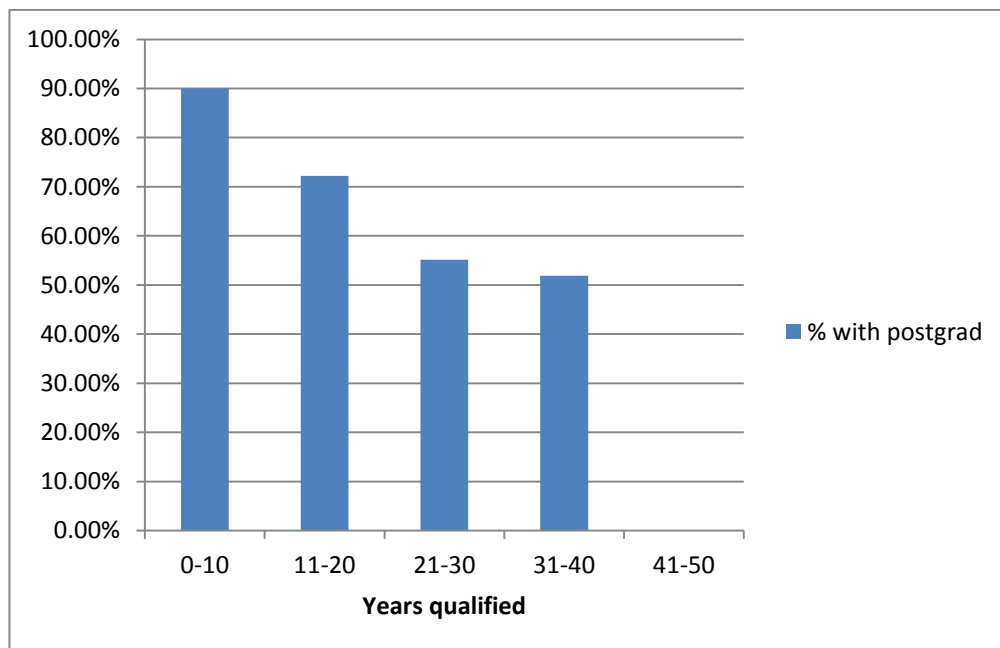


**Figure 19 - Percentage of each 'years qualified' group who have CBCT available**



Years qualified group	0-10	11-20	21-30	31-40	41-50	Total
Number of respondents	20	38	49	25	3	135
No. respondents with/without postgrad qual <sup>n</sup>	18/2	26/10	27/22	14/13	0/3	85/50
% respondents with postgrad qual <sup>n</sup>	90.00%	72.22%	55.10%	51.85%	0.00%	

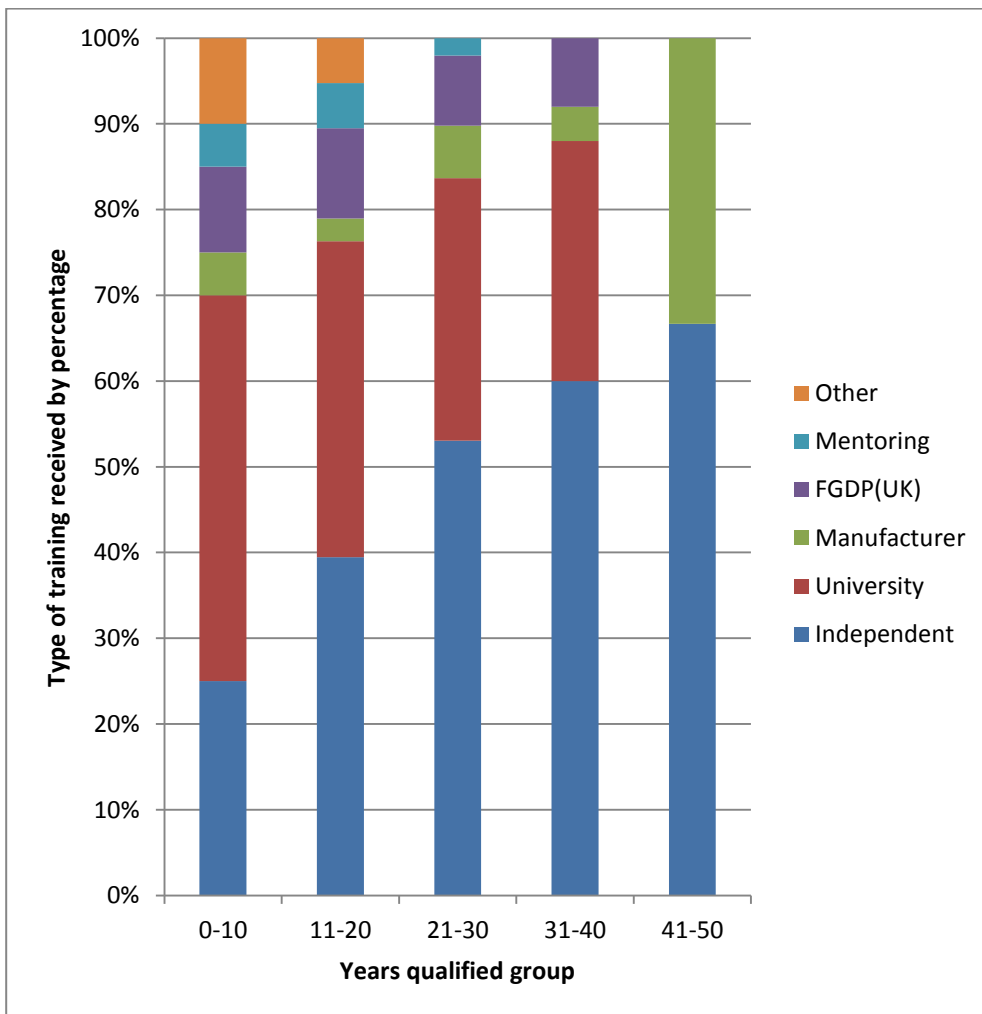
**Table 6 - Number and percentage of respondents who hold postgraduate qualifications by "years qualified" group**



**Figure 20 - Percentage of each 'years qualified' group who hold postgraduate qualifications**

Years qualified group v Main training	0-10	11-20	21-30	31-40	41-50	Total
Independent	5 25%	15 39.47%	26 53.06%	15 60.00%	2 66.67%	63
University	9 45.00%	14 36.84%	15 30.61%	7 28.00%	0 0.00%	45
Manufacturer	1 5.00%	1 2.63%	3 6.12%	1 4.00%	1 33.33%	7
FGDP(UK)	2 10.00%	4 10.53%	4 8.16%	2 8.00%	0 0.00%	12
Mentoring	1 5.00%	2 5.26%	1 2.04%	0 0.00%	0 0.00%	4
Other	2 10.00%	2 5.26%	0 0.00%	0 0.00%	0 0.00%	4

**Table 7 - Main type of training undertaken for dental implantology by "years qualified" group. Number and percentages within each group are shown**



**Figure 21 - Main type of training received for each 'years qualified' group**

### 3.3.4 Radiographic prescriptions

The radiographic prescriptions for the whole sample and for each individual are presented in Figure 23 page 92 and Figure 24 page 93. The prescription for each respondent is represented by one horizontal division in the figure. Where more than one choice has been made, these are shown in separate columns. The first choice is shown in the first column, the second choice in the second column and so on. Each image type has a different colour. The abbreviated names of the views are also shown. A key to the colour code and abbreviated names for the image types is shown in Figure 22 page 91. A radiographic guide is referred to simply as “guide” and the abbreviation + is used.

If the figure was reproduced on one page in its true proportion, the text would be too small to read. Therefore, in order to make the text large enough to read on one page, the longer columns have been truncated. A smaller figure in its true proportion is inset for each case.

Panoramic (PAN)	Panoramic with guide (PAN+)
Cone beam CT (CBCT)	Cone beam CT with guide (CBCT+)
Periapical (PA)	Periapical with guide (PA+)
Medical CT (MCT)	Medical CT with guide (MCT+)
Transsymphyseal view (TS)	
Lateral cephalogram (LCeph)	
Occlusal (OCC)	
Scanora (SCAN)	
No Radiograph (NoRad)	

**Figure 22 - Key to colour code and abbreviations for image types**



Figure 23 - Radiographic prescriptions for case 1 (See full description section 3.3.4 page 91)

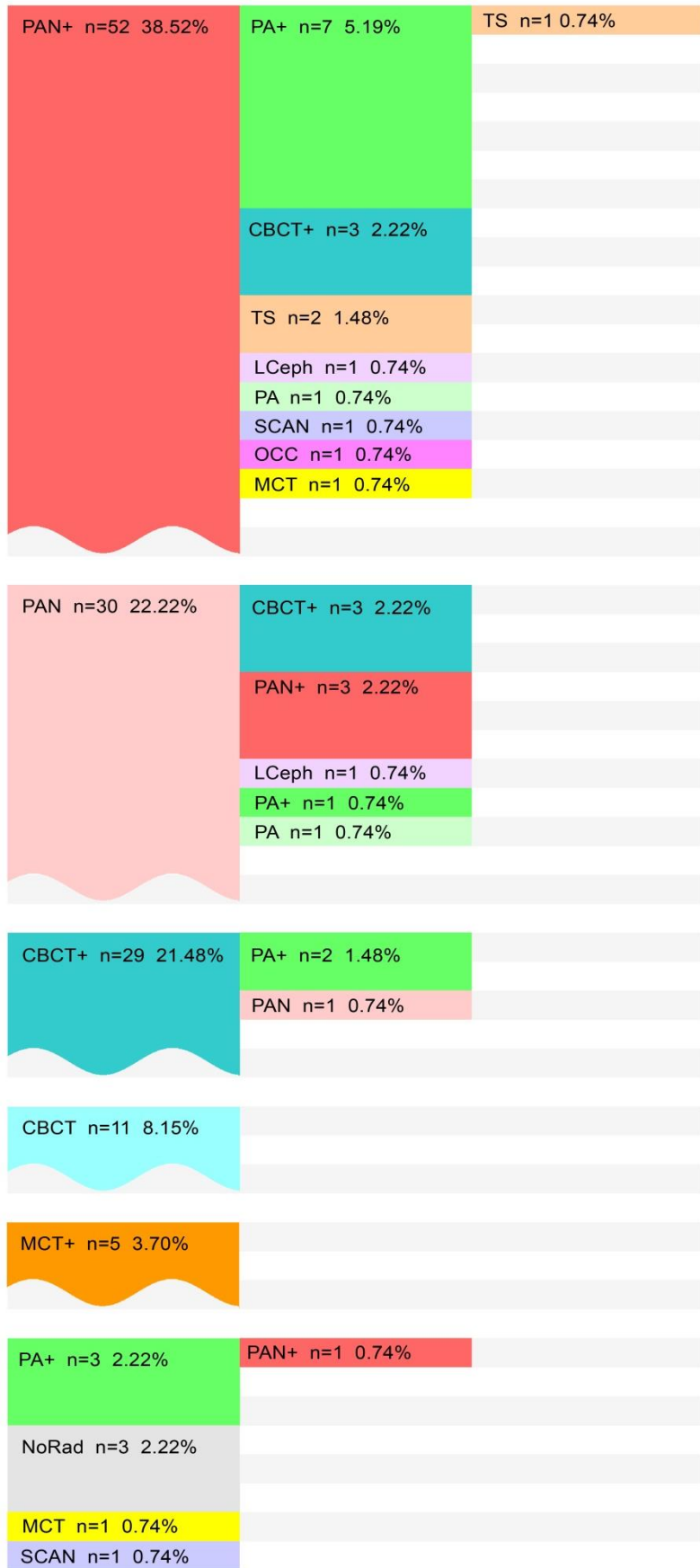


Figure 24 - Radiographic prescriptions for case 2 (See full description section 3.3.4 page 91)

### 3.4 Statistical analyses

Each of the following analyses relate to the null hypotheses stated in section 6.1.2 page 210.

#### 3.4.1 The imaging strategy of dentists in relation to case difficulty.

An analysis was carried out to compare the use of 3D imaging for case one, the very resorbed edentulous ridge, and case two, the well-formed ridge. The use of 3D imaging was defined as the use of either CBCT or medical CT at any stage of the prescription. The number and proportion of respondents who prescribed 3D imaging for each case are presented in Table 8 below.

Case	Number who prescribed 3D imaging	Proportion of whole sample (n=135)	95% confidence interval (lower)	95% confidence interval (upper)
1 ( Very resorbed )	75	0.5556	0.4714	0.6367
2 (Well-formed )	53	0.3926	0.3143	0.4768

**Table 8 - Proportion who prescribed 3D imaging for case 1 and case 2 with 95% confidence intervals**

The difference in proportions and the 95% confidence intervals of the difference in proportions are presented in Table 9 below [178].

Difference in proportions	95% confidence interval (lower)	95% confidence interval (upper)
0.1630	0.0438	0.2757

**Table 9 - Differences in proportion of those prescribing 3D imaging for case 1 and case 2 with 95% confidence intervals**

The difference in proportion of dentist who prescribed 3D imaging for each case was significant at the level of the 95% confidence intervals. These results therefore favour rejection of the null hypothesis that there is no significant difference in the imaging strategy of dentists in relation to case difficulty.

### 3.4.1.1 Secondary analysis

Seventy four respondents prescribed the same views or combination of views in the same sequence for both cases (54.81%). Further analysis is presented in Table 10 page 95.

SINGLE VIEWS PRESCRIBED	Number of respondents	Percentage of whole sample (n=135)
CBCT with guide	19	14.07%
Panoramic with guide	16	11.85%
Panoramic	12	8.89%
CBCT	10	7.41%
Medical CT with guide	3	2.22%

COMBINATION VIEWS PRESCRIBED	Number of respondents	Percentage of whole sample (n=135)
CBCT with guide followed by periapicals with guide	2	1.48%
Panoramic with guide followed by periapicals with guide	3	2.22%
Panoramic with guide followed by CBCT with guide	2	1.48%
Panoramic with guide followed by lateral cephalogram	1	0.74%
Panoramic with guide followed by transsymphyseal	1	0.74%
Panoramic followed by CBCT with guide	2	1.48%
Panoramic followed by panoramic with guide	2	1.48%
Periapicals with guide followed by panoramic with guide	1	0.74%

**Table 10 - Analysis of responses when the same view for both cases was prescribed**

Further investigation was of interest. A chi square analysis was carried out to identify the demographic variables which were associated with the prescription of the same view for both cases.

Significant positive associations were found between prescription of the same view for both cases and the following demographic variables:

Placed more than 100 implants per year	$\chi^2(1) = 9.878, p=0.002$
CBCT machine available	$\chi^2(1) = 6.021, p=0.014$
Training – FGDP(UK) course	$\chi^2(1) = 4.325, p=0.038$

A full table of these results, including non-significant findings, is presented in Appendix K on page 309.

A logistic regression was carried out to identify the strongest predictor from these demographic variables. The results are presented in Table 11 page 96 and suggest that placing more than 100 implants per year is the only significant predictor for making the same prescription for both cases.

	significance	Odds ratio	95% CI	
			Lower	Upper
More than 100/year	0.016	3.436	1.256	9.400
CBCT available	0.064	4.477	0.914	21.930
Training FGDP(UK)	0.120	3.619	0.715	18.324

Hosmer and Lemeshow  $\chi^2(2) = 4.402, p=0.111$  Nagelkerke R square 0.163

**Table 11 - Logistic regression, predictors for use of same view for both cases**

3.4.2 The use of 3D imaging and conventional radiography in relation to the demographic variables.

A chi square analysis was carried out to test for associations between the demographic variables and the use or non-use of 3D imaging.



**Case 1 – resorbed edentulous ridge**

Significant positive associations were found between prescription of 3D imaging and the following demographic variables:

0 to 10 years since dental qualification	$\chi^2(1) = 8.244, p=0.004$
CBCT machine available	$\chi^2(1) = 5.754, p=0.016$
Has a postgraduate qualification	$\chi^2(1) = 5.910, p=0.015$

A significant negative association was found between prescription of 3D imaging and the following demographic variable:

Training – Independently run course	$\chi^2(1) = 9.763, p=0.002$
-------------------------------------	------------------------------

A full table of these results, including non-significant findings, is presented in Appendix K page 310.

## Case 2 – well-formed edentulous ridge

Significant positive associations were found between prescription of 3D imaging and the following demographic variables:

0 to 10 years since dental qualification	$\chi^2(1) = 6.524, p=0.011$
CBCT machine available	$\chi^2(1) = 10.123, p=0.001$
Has a postgraduate qualification	$\chi^2(1) = 4.222, p=0.040$

A significant negative association was found between prescription of 3D imaging and the following demographic variable:

Training – Independently run course	$\chi^2(1) = 9.519, p=0.002$
-------------------------------------	------------------------------

In addition, a significant positive association was found between the use of 3D imaging for case 2 and training by the FGFP(UK) course. Fisher's exact test was used because the cross tabulation contained one cell with a count less than five.[179]

Training – FGDP(UK) course	Fisher's exact test, $p=0.012$
----------------------------	--------------------------------

A full table of these results, including non-significant findings, is presented in Appendix K on page 310.

These results favour rejection of the null hypothesis that there are no significant differences in the use of 3D and conventional radiography in relation to the demographic variables

## Secondary analysis

A logistic regression was carried out to identify the strongest predictor from these demographic variables.

### Case 1 – resorbed edentulous ridge

The results are presented in Table 12 page 99 and showed that being qualified for 0 to 10 years is the only significant predictor for prescribing 3D imaging for case 1.

	significance	Odds ratio	95% CI	
			Lower	Upper
<b>0-10 yrs qualified</b>	0.043	3.976	1.047	15.093
<b>Independent course</b>	0.088	0.483	0.209	1.115
<b>CBCT available</b>	0.110	3.746	0.740	18.961
<b>Has postgrad qual<sup>n</sup></b>	0.437	1.406	0.595	3.321

Hosmer and Lemeshow  $\chi^2(4) = 1.598$ ,  $p=0.809$  Nagelkerke R square 0.184

**Table 12 - Logistic regression, predictors for use of 3D imaging case 1**

### Case 2 – well-formed edentulous ridge

The results are presented in Table 13 page 99 and show that having a CBCT machine available is the only significant predictor for prescribing 3D imaging for case 2.

	significance	Odds ratio	95% CI	
			Lower	Upper
<b>0-10 yrs qualified</b>	0.084	2.627	0.878	7.857
<b>Independent course</b>	0.230	0.572	0.229	1.424
<b>CBCT available</b>	0.024	5.131	1.246	21.136
<b>Has postgrad qual<sup>n</sup></b>	0.691	1.210	0.474	3.086
<b>FGDP(UK) course</b>	0.060	4.048	0.942	17.392

Hosmer and Lemeshow  $\chi^2(5) = 2.019$ ,  $p=0.846$  Nagelkerke R square 0.217

**Table 13 - Logistic regression, predictors for use of 3D imaging case 2**

### 3.4.3 The use of initial conventional radiography prior to 3D imaging in relation to the demographic variables

Those respondents who had prescribed conventional radiographs prior to prescription of 3D imaging were selected. Twenty one dentists (15.55%) followed this protocol for case one and seven (5.19%) for case two. Chi square analyses were carried out to identify if demographic variables were associated with the prescription of conventional radiography before 3D imaging. No associations were found. These results favour acceptance of the null hypothesis that there is no significant difference in the use of initial conventional radiography prior to 3D imaging in relation to the demographic variables. Full tables of these results, including non-significant findings, are presented in Appendix K on page 311.

### 3.4.4 The use or non-use of radiographic guides in relation to the demographic variables

Chi square analyses were carried out to test for associations between the demographic variables and the use or non-use of radiographic guides.

#### **Case 1 – resorbed edentulous ridge**

A significant negative association was found between prescription of radiographic guides and the following demographic variable:

Places more than 100 implants per year	$\chi^2(1) = 9.446, p=0.002$
--	------------------------------

In other words, those who place more than 100 dental implants per year were less likely to use radiographic guides. A full table of these results, including non-significant findings, is presented in Appendix K on page 312.

#### **Case 2 – well-formed edentulous ridge**

A significant negative association was found between prescription of radiographic guides and the following demographic variable:

Places more than 100 implants per year	$\chi^2(1) = 5.934, p=0.015$
--	------------------------------

A full table of these results, including non-significant findings, is presented in Appendix K on page 312.

These results favour rejection of the null hypothesis that there is no significant difference in the use of radiographic guides in relation to the demographic variables.

#### 3.4.5 The problem of multiple comparisons

Fourteen demographic variables were included in the analysis. These are listed in section 3.2.8 on page 79. These were tested against each of the four null hypotheses stated in section 6.1.2 on page 210. It could be argued that these analyses encounter the problem of multiple comparisons. That is to say, one might expect that some of the findings may be significant simply by chance because of the large number of comparisons which were made. Notwithstanding, one cannot know which explanatory variables may be important in advance of exploring the data. One solution to this problem is to use the Bonferroni correction. This sets significance at a more demanding level by dividing it by the number of explanatory variables. [179] With fourteen explanatory variables this leads to a new significance level of  $0.05/14 = 0.004$ . If this correction were applied, it would lead to fewer significant findings as shown below. For each hypothesis, the remaining significant findings are shown in blue. Findings which have become non-significant are shown in grey.

#### **The imaging strategy of dentists in relation to case difficulty.**

Placed more than 100 implants per year	$\chi^2(1) = 9.878, p=0.002$
CBCT machine available	$\chi^2(1) = 6.021, p=0.014$
Training – FGDP(UK) course	$\chi^2(1) = 4.325, p=0.038$

Only, “placed more than 100 implants per year”, remains as a significant relationship. After correcting for multiple comparisons, this analysis favours rejection of the null hypothesis that there is no significant difference in the imaging strategy of dentists in relation to case difficulty.

**The use of 3D imaging and conventional radiography in relation to the demographic variables.**

Case 1

CBCT machine available	$\chi^2(1) = 5.754, p=0.016$
0 to 10 years since dental qualification	$\chi^2(1) = 8.244, p=0.004$
Has a postgraduate qualification	$\chi^2(1) = 5.910, p=0.015$

Training – Independently run course	$\chi^2(1) = 9.763, p=0.002$
-------------------------------------	------------------------------

The positive relationship, “0 to 10 years since dental qualification”, and the negative relationship, “Training – Independently run course” remain as significant relationships.

Case 2

CBCT machine available	$\chi^2(1) = 10.123, p=0.001$
0 to 10 years since dental qualification	$\chi^2(1) = 6.524, p=0.011$
Has a postgraduate qualification	$\chi^2(1) = 4.222, p=0.040$

Training – Independently run course	$\chi^2(1) = 9.519, p=0.002$
-------------------------------------	------------------------------

Training – FGDP(UK) course	Fisher’s exact test, $p=0.012$
----------------------------	--------------------------------

The positive relationship, “CBCT machine available”, and the negative relationship, “Training – Independently run course” remain as significant relationships.

These results, after correcting for multiple comparisons, favour rejection of the null hypothesis that there are no significant differences in the use of 3D imaging and conventional radiography in relation to the demographic variables

**The use of initial conventional radiography prior to 3D imaging in relation to the demographic variables.**

No significant relationships had been found in the initial analysis and, therefore, none are found after accounting for multiple comparisons.

**The use of radiographic guides in relation to the demographic variables.**

Case 1

Places more than 100 implants per year	$\chi^2(1) = 9.446, p=0.002$
--	------------------------------

The negative relationship “Places more than 100 implants per year” remains significant. After correcting for multiple comparisons this analysis favours rejection of the null hypothesis that there is no significant difference in the use of radiographic guides in relation to the demographic variables.

Case 2

Places more than 100 implants per year	$\chi^2(1) = 5.934, p=0.015$
--	------------------------------

There are no longer significant relationships after correcting for multiple comparisons.

### 3.5 Survey of non-responders - results and analysis

There were thirty one non responders. They were asked the same question as presented in case two of the main survey. Twelve responded to the post survey questionnaire, a response of 38.71%. Ten “responding non-responders” prescribed panoramic radiographs, three prescribed CBCT, four prescribed periapical views and one an occlusal view. Similarly to the main survey, some respondents prescribed more than one view. The results were adjusted pro rata so that they represented all thirty one of the non-responders. The result and calculations are presented in Table 14 page 104.

Prescription	Number of respondents (n=12)	Figures adjusted to represent all 31 non responders (x31/12)
Panoramic view	10	25.83
CBCT	3	7.75
Periapical view	4	10.33
Occlusal view	1	2.58

**Table 14 - Results of the post survey telephone questionnaire**

A table of results was prepared from the responders for case two. The adjusted data, representing all the non-responders, were added to the data from the responders to create a nominal data set for the whole of the eligible sample. New percentage totals for each view were then calculated and compared to those for the responders alone. The figures are presented in Table 15 page 105. This analysis did not take into account the use of radiographic guides. This, and other limitations of the survey of non-responders, is further discussed in section 3.6.4 on page 128.



Prescription	Totals from main survey (n=135)	Adjusted totals from post survey questionnaire (n=31)	Totals for nominal data set (columns 1+2) (n=166)
	1	2	3
Panoramic	84	25.83	109.83
CBCT	46	7.75	53.75
Periapical	15	10.33	25.33
Medical CT	7		7
Lateral Cephalogram	2		2
Transsymphyseal	3		3
Scanora	2		2
Occlusal	1	2.58	3.58
No radiograph	3		3

Prescription	% from main survey (n=135)	% for nominal data set (n=166)	Difference between columns 4 & 5
	4	5	6
Panoramic	62.22%	66.16%	3.94%
CBCT	34.07%	32.38%	-1.69%
Periapical	11.11%	15.26%	4.15%
Medical CT	5.19%	4.22%	-0.97%
Lateral Cephalogram	1.48%	1.20%	-0.28%
Transsymphyseal	2.22%	1.81%	-0.41%
Scanora	1.48%	1.20%	-0.28%
Occlusal	0.74%	2.16%	1.42%
No radiograph	2.22%	1.81%	-0.41%

**Table 15 - Calculation for non-response bias, primary analysis**

The greatest difference between the actual and the adjusted figures was for periapical radiographs (4.15%). The sample size was calculated for a precision of  $\pm 5\%$ .

Because the difference between the actual and adjusted percentages was within the intended precision of the survey, it was concluded that non response bias was not significant and that post survey adjustment of data was not required.

## Secondary analysis

The statistical analysis of the main survey results suggested that being qualified between 0 and 10 years was a significant predictor of radiographic prescription (Table 12 page 99). The date of qualification is held on the UK's General Dental Council register\*\*\*\*. This enabled an analysis of non-response based on the percentages of those qualified between 0-10 years and those qualified longer than 10 years. The data from the non-responders were added to those of the responders to form a new, nominal, data set representing the whole of the eligible sample. This was compared with the responders alone. The results are presented below:

	Non responders 1	Responders 2	Responders + non responders 3
Total number	31	135	166
Qualified >10 years	25	115	140
Qualified 0-10 years	6	20	26

	Responders % 4	Responders + non responders % 5	Difference between columns 4&5 6
Total number	100.00%	100.00%	
Qualified >10 years	85.19%	84.34%	+0.85%
Qualified 0-10 years	14.81%	15.66%	-0.85%

**Table 16 - Calculation for non-response bias, secondary analysis**

The difference between the actual and the adjusted figures was 0.85%. This difference was within the intended precision of the survey. On this basis, it was concluded that non response bias was not significant.

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\*\*\*\* <http://www.gdc-uk.org>

As additional verification, a null hypothesis was tested that responders were no more or less likely to be in the 0-10 years qualified group than the non-responders.

Pearson's chi-square test was carried out to investigate if there was a relationship between being a responder or non-responder and being in the 0-10 years qualified group or the above 10 years qualified group. The contingency table is shown. (Table 17 page 107)

		Non responders	Responders	Total
Qualified >10 years	Observed	25	115	140
	Expected	26.1	113.9	140
Qualified 0-10 years	Observed	6	20	26
	Expected	4.9	21.1	26
Total	Observed	31	135	166
	Expected	31	35	166

**Table 17 - Contingency table for post survey analysis using Pearson's chi-square test**

No relationship was demonstrated. ( $\chi^2(1) = .393, p=0.531$ ). This result favours acceptance of the null hypothesis and adds weight to the argument that there is no significant non-response bias.

## 3.6 Discussion

### 3.6.1 Materials and methods

#### 3.6.1.1 The population and the sample frame

The overwhelming majority of research into dental implantology is carried out in the university or hospital environment. The intention of this study was to investigate the practices of dentists in the practice environment where the majority of dental implants are placed.[51] The population was defined as dental implant practitioners in the North West of England who surgically place dental implants. Hospital and University based surgeons were included if they also carried out implant surgery in practice. The intention was to compile a sample frame that was as close as possible to the real population of surgical implant practitioners in the North West of England. It cannot be known how many of these practitioners were not identified. Nevertheless, there is some evidence that the strategy of overlapping layers of different resources was close to the real population, since only three responders replied that they had been wrongly identified as not surgically placing implants. In any event, one would expect that this population is not fixed. New dentists will begin to place implants and others may stop, for example, because of retirement. It was therefore assumed that the sample frame was acceptably close to the real population.

The lead researcher is based in dental practice in the North West of England and restriction of the survey to this geographical area was felt to have a number of advantages

- ▶ Smaller sample sizes generally have the higher response rates
- ▶ A smaller sample size releases resources to employ response enhancement strategies which can be costly. For example, a monetary incentive could be used.
- ▶ Local resources, knowledge and contacts could be used to identify members of the population.
- ▶ Current email addresses could be found by telephoning practices. This is resource intensive and would not have been possible for a large survey.
- ▶ A smaller survey allows personalisation techniques such as hand written signatures, reminders through social networking web sites and use of personal contacts.

- ▶ Many of the population will know of the lead researcher and therefore be more likely to reply. In some cases a direct approach was used to produce a response.
- ▶ The study was carried out under the auspices of the Universities of Leeds and Manchester. These are local Universities and this might be expected to enhance response. Many in the sample frame were expected to have qualified at one of these dental schools. The results bore this out, 36% of the sample having qualified at one of these Universities.

### 3.6.1.2 Sampling

The equation of Dillman et al requires the proportion of the population expected to choose one of two response categories [87] (Figure 17 page 74). In this study there were more than two response categories. This raised the question of the proportion which should be entered into the equation under such circumstances or, whether a different sample size calculation would be more appropriate. This was discussed by personal communication with one of the authors of "Internet, Mail and Mixed Mode Surveys, the Tailored Design Method" by Dillman et al in which the equation is published [180] [87]. The conclusion of this discussion was that the equation of Dillman et al should be used and that the most conservative assumption, that of a 50/50 split in the response categories, should be entered.

The rationale for this was that, if the proportion of the population expected to choose one of two response categories is 0.5, this gives the largest sample size. If there are multiple response categories, then there are many potential permutations. In order to allow for a proportion of 0.5 somewhere in the results, it is prudent to choose this most conservative option. The implication of this was also that a pilot study to estimate the variance of the results was unnecessary.

The literature review in preparation for this survey showed that, for questionnaire surveys in dental radiology, a sample size of 135 is likely to elicit a response of some 80% (Figure 2 page 31). The sample size of 135 was therefore adjusted to allow for an 80% response rate giving a final sample size of 169.

The aim of the study was to gain an understanding of decision making when prescribing imaging methods. In order to achieve these aims, it was felt that a precision of  $\pm 5\%$  with a confidence level of 95% was the most appropriate. Higher

precision would have meant a larger sample size, higher costs and, potentially, increased difficulty in achieving an acceptable response. This level of precision is commonly used in similar surveys. On balance, therefore, a precision of  $\pm 5\%$  with a confidence level of 95% was selected.

#### 3.6.1.3 Reduction of measurement error

The intention was to attempt to reproduce realistic clinical decision making as far as possible. A web-based questionnaire was chosen so that plausible clinical scenarios could easily be presented to respondents. The photographs were of real patients and the available images were of real mandibles in realistic radiographic phantoms. By being web based, the questionnaire could be interactive. Respondents were shown each image that they had chosen. In this way they would be able to make a realistic decision on whether further images were necessary based on the results of the first and subsequent selections. This also enabled the sequence of prescribed images to be recorded. Analysis of the sequence was therefore possible. For example, those respondents who prescribed conventional radiography, before making a decision to prescribe 3D imaging, could be identified.

The pilot study was helpful in identifying misleading questions, missing options, and other issues of presentation and implementation. The results of the pilot study are presented in section 3.2.9 beginning on page 80.

#### 3.6.1.4 Survey implementation

The effectiveness of multiple contacts can clearly be seen in the graph presented (Figure 18 page 85). Whilst the continued effect of a contact after each subsequent contact cannot be known, a change in response from a trough to a new peak can be seen following each new mailing, email or telephone call.

Every contact was different. For example, the letters and emails each had different wording and took a different approach (Appendix D page 296). The effectiveness of this strategy is in keeping with the findings of Dillmann et al [87] who advocate a multiple contact strategy, each with a different look and appeal. Figure 18 on page 85 suggests that the final contact, by telephone, had a better response than might have been expected from the trend set by previous contacts. This finding is consistent with that of other authors who have found that the perceived final contact is particularly effective in improving overall response rates to surveys [181] [182]. Given the

effectiveness of the final telephone contact, the question is raised of whether telephone calls could have been used to boost response at an earlier stage. Nevertheless, the effectiveness of the telephone call may have simply been because it was distinguished from previous contacts and perceived as “final”. It may therefore have been effective only in the context of the previous contacts. Furthermore, the surveyor might reasonably consider the telephone call to be the “last tool in the drawer”. If the response is inadequate after an early telephone contact, then all that is left is to contact the respondents by telephone again. This might be interpreted as intrusive and so possibly counterproductive.

#### 3.6.1.5 Response enhancement measures

These aspects of the survey were designed using principles described by Dillman et al. [87] These authors view the decision to respond to a survey as a “social exchange”. According to Dillman et al, enhancement of response results from attention to the principles of social exchange in four broad areas: personalisation, increasing the benefits of participation, decreasing the costs of participation and establishing trust.

##### Personalisation

All contacts with the individuals within the sample were addressed by name (See Appendix D page 296). Commercially available mail merge software was used to produce letters and emails<sup>†††</sup>. This enabled editing of the final communications so that familiar first names could be used where the respondent was personally known to the lead researcher. There was some use of social networking websites, where appropriate, as an additional reminder to respond.<sup>†††</sup> Personal signatures written in blue ink were used on all written communications.

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<sup>†††</sup> Microsoft Office 2010, Microsoft, Redmond, Washington, USA

<sup>†††</sup> [www.facebook.com](http://www.facebook.com)

### Increasing the benefits of participation

It has been shown that a questionnaire which is more interesting to the respondent has much better odds of a response [77]. The use of the internet allows a very visual approach. The intention was that a visually based questionnaire which presented realistic cases of dental implants would be an interesting one to the population of implant practitioners.

The approach of asking for help was also felt to be valuable. People do feel a sense of reward in helping others and this approach was taken in the contacts with respondents. (See Appendix D page 296)

### Decreasing the costs of participation

A web based questionnaire was chosen as the most convenient method of response. The questionnaire was designed to be easy to complete with simple navigation and clear instructions. Question and answer sections were clearly identifiable. The website was designed to be visually simple, uncluttered and consistent. The audio-visual capabilities of the internet were used minimally and only if they led to simpler operation. (Figure 16 page 72). The web address, [www.implantresearch.co.uk](http://www.implantresearch.co.uk), was chosen to be short, direct and relevant to the survey.

The survey was kept as short as reasonably practical and was restricted to two cases. It was felt that a well-formed ridge case and an atrophic case would be sufficient variation in order to investigate implant practitioners' normal radiographic prescribing patterns for lower edentulous cases.

The instructions to the web developers are included in Appendix F on page 301.



### Establish trust

It was made clear that this research project was carried out under the auspices of the University of Leeds and the names of supervisors were clearly shown. A further way of establishing trust was to give the respondents confidence in their anonymity.

Participants were reassured by being assigned randomly generated individual access codes. They did not log into the survey with their names. The term "Access code" was used rather than "Identification number". The implication of the term "Identification number" was thought to be that the respondent could be identified. A link to the confidentiality policy was clearly shown on the first page of the survey. (See Appendix E on page 299). Anonymity is further discussed in section 3.2.6 page 76.

The initial approach to participants was by letter. This allowed a monetary incentive of £5 to be sent in advance of completion of the questionnaire. Inclusion of the monetary incentive with the initial approach was felt to be very important. It has been demonstrated that promises to pay respondents on condition that they respond has little or no effect. [167] [168] Further, the level of the incentive is not as important as the gesture of trust itself. Therefore, an incentive of £5 was chosen as the smallest value paper bank note that could easily be sent by post. Kindly, having already responded to the survey, one responder did send back the monetary incentive so that it could be used to further fund the research. All of the non-responders kept the £5 incentive with one exception. This dentist returned the incentive with a letter expressing annoyance that the practice had been identified. Nevertheless, the name of the practitioner and their dental implant service was publically available on the internet.

#### 3.6.1.6 Reasons for non-response

An attempt was made to elicit the reasons for non-response. Contacts with non-responders or their staff were made by telephone call when they received their reminders. Some also contacted the lead researcher or the research assistant with enquiries.

Two members of the sample contacted the lead researcher to report that the website did not, “come up”, when they looked for it on the internet. Further questioning revealed that they had tried to type the web address into a search engine rather than typing the address into the address bar of a web browser. These respondents were advised accordingly but others may have abandoned the survey in the mistaken belief that it did not function correctly. When the research assistant contacted non-responders to deliver the telephone reminder, further information about the reasons for non-response was collected. Responses were most often from receptionists at practices and were typically: “The dentist has recently moved away”, “The dentist is on leave”, “He hasn’t had time to do it” and, “The dentist is too busy”. The receptionist at the practice of one non-responder also reported that the dentist had “dismissed” the request. Similar responses were collected at the stage of the post survey telephone questionnaire.

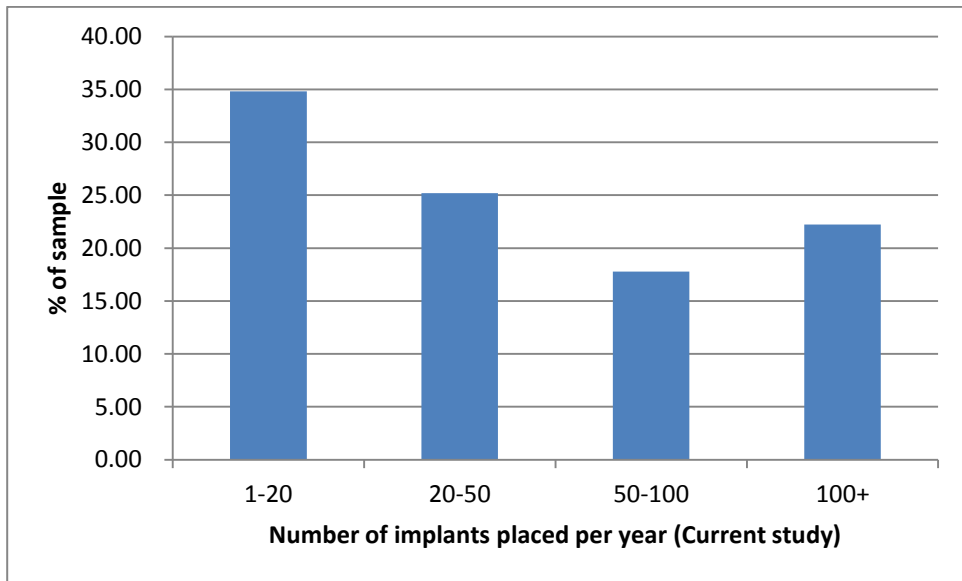
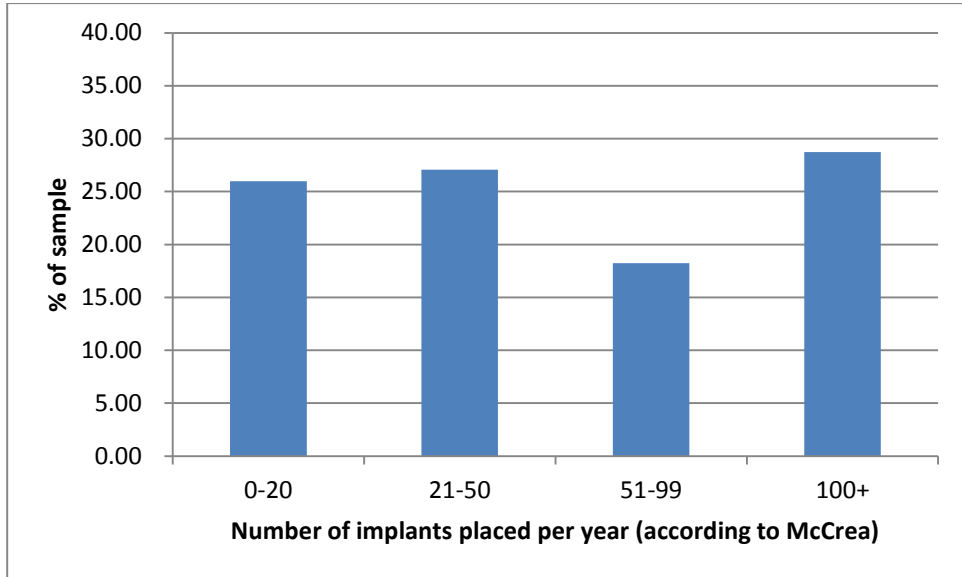
Despite thorough testing, there were some minor technical problems with the web site. Intermittently, the site would take a long time to load, sometimes as long as 3 or 4 minutes. Following discussions with the web developers, the fault was traced to the internet service providers themselves. After a period of a few days they made changes to their servers. Nevertheless, this may have been enough to discourage some sample members from responding in the belief that the site was irretrievably faulty.

### 3.6.2 Discussion of results

#### 3.6.2.1 Demographic data

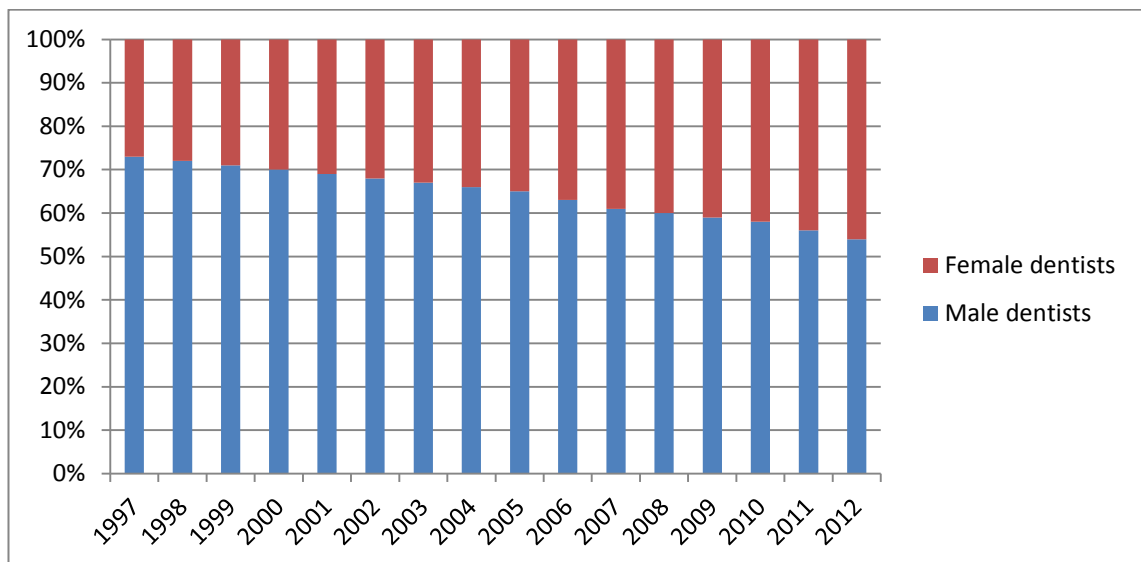
The practitioner who surgically places dental implants in the North West of England is typically male, has a postgraduate qualification and is in the second half of his career. He qualified at the University of Manchester and trained for dental implantology by taking an independently run course. He has a panoramic machine at his practice where he places fewer than 50 implants per year. This profile represents a snapshot in time and would be expected to change in the future. By observing trends in the data for each group by “years qualified”, the profile of the future dental implant practitioner in say, ten years’ time, may be surmised. This practitioner is more likely to be female (Figure 26 page 117), although most will still be male. This is discussed more fully on page 117. This dentist is almost certain to hold a postgraduate qualification (Figure 20 page 89). Training for dental implantology will probably be University based (Figure 21 page 90) and it is likely that there will be a CBCT machine available at the place of work (Figure 19 page 88).

Only one recent published study was identified which presented any comparable demographic data for those who surgically place implants in dental practice. In his 2008 study of compliance with selection criteria, McCrea [71] presented data for the number of implants placed per year. The data presented were for members of the British Society of Periodontology, in all practicing circumstances, who both placed and restored dental implants. Those who restrict themselves to only placing implants were excluded. Notwithstanding, the distribution of the number of implants placed per year shows similarities between the two studies with the smallest number in the 50-100 group. The explanation for this may be that those who surgically place dental implants in the UK tend either to place small numbers of dental implants per year, in conjunction with their general practice work, or restrict themselves only to dental implant work and so place large numbers of dental implants per year. Graphs of the results are presented in Figure 25 page 116.



**Figure 25 - Numbers of implants placed per year by percentage of sample.  
Comparison of current study with that of McCrea[71]**

This study found that, of those who surgically place dental implants in the North West of England, 89.63% are male. This is at odds with findings in the population of all dentists in England in which the percentage of male dentists is some 56.50% [183] §§§§. This raises the question of why so few female dentists surgically place implants. This is partly explained by the fact that the older dentists are the ones more likely to place dental implants and that these dentists are more likely to be male. This study has shown that the mean age of practitioners who surgically place implants in the North West of England is 46.11 years (SD 9.17). Therefore, at least in part, the larger percentage of males in the sample reflects the gender mix of dentists who qualified in the late 1980's and early 1990's. According to Eaton [184], 77% of UK registered dentists in this period were male. Available figures from the NHS Information centre are shown in Figure 26 page 117.



**Figure 26 - Graph to show gender mix of NHS practitioners in England from 1997 to 2012**

This does not fully explain the small number of women in the sample and other factors are relevant. In a 2002 study, Murray draws attention to the fact that UK female dentists are less likely to be practice owners and that 50% of women work for no more than two days per week [185]. The main reason for choosing to work part time was given as, "caring for children". Further, time commitment is cited by Rostami et al and

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§§§§ The NHS Information Centre published this figure in 2011. It refers to dentists in practice who hold an NHS contract (n=22,799). The number of dental practitioners who work outside of the NHS is not known. Nevertheless, it is expected that this report represents the vast majority of English dental practitioners.

Colletti et al as a deterrent to women in surgical disciplines in general [186] [187]. Training and equipment to provide dental implants is a postgraduate endeavour and a substantial time and financial commitment. Therefore it may be speculated that this is a significant discouragement to female dentists who work part time, care for children and do not own their own practices. Murray also reports that “loss of confidence” was repeatedly mentioned as a major obstacle by UK female dentists when considering a return to work after a career break [185]. This may also be reflected in the small number of women who surgically place dental implants.

### 3.6.2.2 Radiographic prescriptions

These results show no agreement on radiographic prescription prior to implant placement in the edentulous anterior mandible. Most respondents based their prescription around either panoramic radiography or CBCT. Supplementary views were then sometimes prescribed. In some instances, both panoramic and CBCT views are used. Two other studies have been identified in which radiographic prescription prior to implant placement was investigated. In the studies of both Sakakura [90] and McCrea [71] the data were collected before the widespread availability of CBCT and therefore meaningful comparisons cannot be made. Therefore the current study presents new information in the context of changing practices following the widespread availability of CBCT technology.

These largely inconsistent results may represent the idiosyncratic nature of independent dental practice. Dental practitioners work in relative isolation. They most often prescribe and interpret their own radiographs. This is compared, for example, to the university hospital situation where advice and guidance is readily available from a consultant in dental radiology who may also enforce appropriate selection criteria. This might lead to more consistency in prescription.

It might also be speculated that training for dental implantology, whilst dealing with the availability and interpretation of imaging techniques, may not give sufficient weight to selection criteria. In 2008, the FGDP(UK) published “Training Standards in Implant Dentistry” [188]. These standards are supported by the UK’s General Dental Council who expect educational providers to refer to these as the authoritative source of training standards for implant dentistry in the UK. Radiology and radiography are mentioned only as follows, “the dentist should have detailed knowledge and understanding of radiology and radiography of the mandible and the maxilla, and how

to interpret the findings from radiological examinations". There is no specific mention of selection criteria.

Guideline documents on selection criteria for radiography prior to implant placement have been issued by several authorities.[36-39, 189] Evidence has been presented in two studies that practitioners are either unaware of guidelines or fail to follow them. In a Brazilian study, Sakakura [90] concluded that dentists, "are not following the American Academy of Oral and Maxillofacial Radiology recommendations regarding cross-sectional imaging". Nevertheless, this study only represented the prescription of dentists who attended a single conference in Sao Paulo, Brazil. Further, the authors asked about prescription of imaging prior to dental implant placement in general. Clinical situations which might lead to specific prescriptions do not appear to have been presented to the respondents. McCrae [71] compared the practice of members of the British Society of Periodontology with guidelines issued by the FGDP(UK) [37] and the American Academy of Oral and Maxillofacial Radiology [39]. The author concluded, "over 80% of the respondents to this survey are not following the published UK and USA selection criteria recommendations for pre-implant radiographic imaging assessment". Nevertheless, this study presented only two written scenarios for prescription of images. These were, "When assessing for a single implant", and, "When assessing for multiple implants". No additional clinical information was given such as whether the sites had a pronounced buccal concavity or if there was extensive bone resorption. McCrea himself quotes the FGDP(UK) guidelines as follows, "The use of cross sectional imaging will be dependent on the individual case". Therefore these guidelines would lead to different prescriptions in different clinical circumstances. Consequently, it is difficult to say whether the respondents followed guidelines in this study or how this was assessed.

Notwithstanding, guidelines on selection of images for dental implantology are often non-specific, stated in vague terms and open to wide interpretation. For example, available guidelines state, "The use of CBCT is not recommended as a routine imaging technique for all implant cases" [190], "Cross-sectional imaging is often beneficial" [36] "selection criteria....must be used in the light of each patient's individual needs" [37], "Clinical judgment as to need for and type of radiographic images for evaluation" [38], "additional imaging may be beneficial" [189] and "the information provided by cross-sectional imaging may be of more importance to some practitioners than to others" [39]. Therefore the available guidelines could be interpreted to support a wide range of prescriptions. Further, the older of these guidelines also refer to techniques such as

spiral tomography which might be regarded as obsolete following the widespread availability of CBCT technology.

In conclusion, the overall pattern of prescription of imaging prior to dental implant placement in the edentulous anterior mandible is chaotic with no agreement on the most appropriate prescription. Available guidelines are probably not known or followed. If they are followed, they are stated in such vague terms that they could be interpreted to support many different prescriptions. Further, training in dental implantology may well leave dentists to make their own judgements about selection criteria.

### 3.6.3 Statistical analysis

#### 3.6.3.1 The imaging strategy of dentists in relation to case difficulty.

The use of 3D imaging was defined as either CBCT or medical CT at any stage of the prescription. There was a statistically significant difference in the prescription of 3D imaging between case 1 and case 2 with more respondents choosing 3D imaging for the more surgically difficult case 1. (See results section 3.4.1 page 94). The explanation for this difference is likely to be that respondents were making a judgment about the difficulty of the case and prescribing preoperative imaging accordingly. The increased difficulties of placing dental implants in restricted bone volume and the risks of perforation of the lingual cortex do seem to have been taken into consideration in prescribing imaging.

Notwithstanding, 54.81% of the respondents prescribed the same view for both cases. Pearson's chi-square test revealed that prescription of the same view for both cases was associated with those who place over 100 implants per year, those whose training was stated to be the FGDP(UK) course and the availability of a CBCT machine. Logistic regression analysis revealed the only significant predictor to be 'placing more than 100 implants per year'. (See results section 3.4.1.1 page 95). It may be conjectured that those who place more than 100 implants per year have a well-established routine which they use for all lower edentulous cases.

Many of those who have CBCT machines available will have purchased them or leased them themselves. These are very expensive machines, typically costing from some £60,000 to £200,000. It is therefore understandable that these dentists would wish to



make as much use of them as reasonably possible. Further, the fact that they have chosen to make such an investment demonstrates their belief in their usefulness.

For the third variable, training on the FGDP(UK) course, it would be easy to conclude that these dentists were trained to prescribe a standard imaging strategy. This does not seem to be the case. The prescriptions themselves varied. There were 12 individuals who stated their main training to be “FGDP(UK) course”. Ten prescribed the same view for both cases but there was a spread of prescriptions which was not dissimilar to the sample as a whole. For example, for case 1, five individuals prescribed a panoramic view as first choice, five a CBCT view and two prescribed other views. Rather, it seems as if this training, in some way, encouraged consistency between the cases. It may be speculated that this course promotes a culture in which consistency is perceived to be desirable. The FGDP(UK) course concludes with an examination of implant cases including a defence of their planning and execution. It may be that the candidates perceive consistency as an advantage in this defence and that this leads to their later behaviour in prescribing images.

### 3.6.3.2 The use of 3D imaging and conventional radiography in relation to the demographic variables.

For both cases, it was found that respondents were more likely to prescribe a CBCT or medical CT examination if they were in the 0-10 years qualified group, if they had a CBCT machine available or if they had a postgraduate qualification. It was found that those who described their training as “Independent course” were less likely to prescribe 3D imaging.

Table 5 page 88 and Figure 19 page 88 show the number and percentage of each ‘years qualified’ group who have CBCT available at their main place of work. In percentage terms, the 0-10 years qualified group form, by far, the biggest group. Similarly, Table 6 page 89 and Figure 20 page 89 shows that some 90% of the 0-10 years qualified group have postgraduate qualifications compared with smaller percentages in the other groups. An analysis of the main type of training received by “years qualified” group is shown in Table 7 page 90 and Figure 21 page 90. In terms of percentage, a steady decline in training by independent course is seen from some 65% in the longest qualified group to around 25% in the ‘0-10 years qualified’ group. As independent training has decreased in percentage terms, university training has increased. Therefore, the 0-10 years qualified respondents seem to form a separate

group. They are more likely to have a postgraduate qualification, more likely to have a CBCT machine available and less likely to have described their training as "Independent course". All of these variables are linked to the prescription of 3D imaging.

Logistic regression revealed that a single, significant predictor was different for each case. For case 1 this was being in the 0-10 years qualified group. For case 2 it was availability of a CBCT machine. The reasons why the 0-10 years qualified group are more likely to prescribe 3D imaging are a matter of speculation. Nevertheless, this may be partly a matter of the confidence levels of the recently qualified. These practitioners may, understandably, be seeking certainty that they are aware of potential anatomical difficulties in advance of surgery so avoiding surgical complications. Those with more experience are perhaps more likely to rely on their familiarity with the range of clinical circumstances that may be presented to them at the time of surgery.

Another factor that may be relevant is the relationship which younger dentists have with information and communications technology. Dentists in this group have been brought up with a familiarity and reliance on computers and communications devices. Their natural preference may, therefore, be for the computer based solutions. Their easy proficiency may lead them to choose these views, perhaps in the belief that the more technological the method, the easier and more convenient it will be to use and the better it must be.

In case 2 the only significant predictor for the use of 3D imaging was the availability of a CBCT machine. This case was the well-formed mandible and it might be argued that the case for 3D imaging is weaker. The data demonstrate that dentists as a whole make a judgement on the appropriate view based on the difficulty of the case (Section 3.4.1 page 94). Therefore, many dentists in the sample did not choose 3D imaging based on the relative surgical ease of case 2. The remaining dentists that did prescribe 3D imaging were more likely to be those with a CBCT machine available and thus this became the strongest predictor. A simple explanation for this is perhaps the financial pressure to make use of a very expensively bought or leased piece of equipment. Nevertheless, a more likely explanation might be that those who have bought an expensive CBCT machine have also committed themselves to ownership in psychological terms. They may therefore believe that they are prescribing the best possible image for their patients and that the quality of the image outweighs concerns about increased radiation dose regardless of the difficulty of the case.

An additional, positive association was found between the use of 3D imaging for case 2 and training by the FGDP(UK) course. Of the 12 dentists in this group, only 2 had a CBCT machine available. Therefore this does not seem to be the explanation. It is perhaps a tendency for consistency amongst those who have taken the FGDP(UK) course which is the driver. This has been discussed in section 3.6.3.1 beginning on page 120.

### 3.6.3.3 The use of initial conventional radiography prior to 3D imaging in relation to the demographic variables.

The European Association for Osseointegration guidelines state as follows, "Clinicians should decide on the basis of the clinical examination and treatment requirements, and on information obtained from conventional radiographs whether or not cross-sectional imaging will be of benefit" [189]. Similarly, the SEDENTEXCT guidelines state as a general principle, "CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography" [190]. These guidelines could be interpreted as meaning that conventional radiography should always be carried out so that the decision to use higher dose 3D imaging can be made. One argument against this would be that, in some cases, it is clear from the history and clinical examination alone that conventional radiography is inadequate to answer the clinical question. In those cases, the prescription of conventional radiography prior to 3D imaging would only add to the radiation dose with no additional benefit. Nonetheless, in 2009 Horner et al [191] stated "basic principles" on the use of dental cone beam CT by consensus of the membership of the European Academy of Dental and Maxillofacial Radiology. These authors' position is that, in a population based approach, initial conventional imaging will lead, on balance, to dose savings collectively. The logic of this stance is that some cases will not proceed to higher dose 3D imaging because conventional imaging alone may be sufficient to make the decision that dental implant therapy is an unrealistic option for that patient.

An investigation of dentists' practice in this regard was, therefore, of interest. Those dentists in the sample who had prescribed conventional radiography prior to 3D imaging were identified. For case 1, 15.56% (n=21) prescribed conventional views prior to 3D imaging. For case 2, 5.19% (n=7) prescribed conventional views prior to 3D imaging. The larger number of dentists who followed this method for case 1 is

consistent with decision making on conventional radiographs because this was the atrophic case. It is likely that they felt that more information was necessary based on the results of the conventional radiographs. Case 2 was the well-formed mandible and the smaller number would again be consistent with this decision making process since it is more likely that the dentists would feel that they had sufficient information from the conventional views. Nevertheless, these figures suggest that very few respondents follow this protocol.

No associations were found with the demographic variables. This may be because this protocol is associated with a variable that was not investigated such as exposure to an individual who teaches this method. Alternatively, it may simply be that these individuals had reasoned that this is a pragmatic protocol for imaging in these circumstances.

#### 3.6.3.4 The use of radiographic guides in relation to the demographic variables

Radiographic guides are considered good practice in maximising the information obtained from imaging. In the case of the edentulous mandible they can indicate the magnification of the view and the intended position of dental implants. In some cases they can later be modified to provide a surgical guide. [31] [192] For case 1, 96.3% (n=130) of the respondents used a guide at some stage in their prescription. For case 2, the figure was 82.96% (n=112). The difference is probably explained by case 2 being the easier surgical case and thus the information requirements were fewer. Nevertheless, in both cases the use of guides was very high.

Chi square analysis revealed a negative association with those who place more than 100 dental implants per year. They were less likely to use a radiographic guide. This group of more experienced surgical implant practitioners are also more likely to use the same view for both cases (section 3.6.3.1 page 120). Most radiographic guides will complicate implant assessment because they will require an impression to be taken, preparation of the guide in a dental laboratory and an additional visit to fit the guide. It will also incur a laboratory fee. It seems reasonable conjecture that the experience of this group of practitioners has led them to a simple, convenient, uncomplicated and consistent imaging strategy that provides enough information for planning their surgery given their experience of the range of clinical circumstances that may be presented to them.

### 3.6.3.5 Comparisons with other studies.

No studies were identified where radiographic prescription prior to implant placement was related to demographic data. Nevertheless, two studies were identified where radiographic prescription in general was investigated and presented findings relevant to this study. In a Swedish study in 1996, Svenson et al found that those dentists who had been qualified for the shortest time had different attitudes to the prescription of radiographs.[193] These authors found that those who had been qualified for 0-4 years took more frequent radiographic examinations. They speculated that these younger dentists, “had a more carefree attitude towards radiation hazards”, and postulated that, “inexperienced dentists may feel insecure in their professional role. They therefore take more radiographs just to be 'safe', and their attitude towards hazards is modified to legitimize this 'overuse' of radiography”. The investigators also remarked, “In Sweden, taking too many radiographs has never been the subject of legal action, but taking too few has”. In 2003, Tugnait et al also found that younger dentists behave differently with regard to radiography, taking more panoramic views. In keeping with the findings of this study these authors also found that there was no significant difference in radiographic prescription between male and female dentists. [97]

### 3.6.3.6 The problem of multiple comparisons

The problem of multiple comparisons is discussed in section 3.4.5 on page 101. Use of the Bonferroni correction and other methods to adjust for multiple comparisons remain a matter of debate. For example, Perneger [194] believes that application of the Bonferroni correction is a violation of common sense and writes, “Bonferroni adjustments imply that a given comparison will be interpreted differently according to how many other tests were performed”, and adds, “Surely this is absurd”. This author further argues that whilst such methods make false positive findings less likely, they simultaneously make false negative findings more likely. In reply, Bender [195] argues that, “The use of multiple test procedures is mandatory” but advocates the use of other statistical methods to correct for multiple comparisons on the grounds that the Bonferroni correction is overly conservative. Notwithstanding, Perneger’s conclusion seems sensible, “Describing what was done and why, and discussing the possible interpretations of each result, should enable the reader to reach a reasonable conclusion”. [194]

#### 3.6.4 Limitations of this study

Other than those already referred to in this thesis, there were a number of limitations to this study. One limitation is that the cases were presented with photographs and a clinical description on a web page. Whilst this is closer to reality than a simple written question about how to image the edentulous mandible, it is still not the same as direct clinical examination.

The prescription of the respondents may well have been different from their normal clinical practice simply because they were answering a survey. For example, following the pilot study, one respondent asked me if she had selected the “correct” answer. In some cases, therefore, the responses may have reflected a desire to deliver the “right answer” rather than a reflection of their normal clinical practice. Furthermore, the respondents did not have to take into account the inconvenience of selection of some views. For example, in some cases, selection of a CBCT examination would require a referral letter to be written, inconvenience to the patient and delay before the view is received. Equally, the prescription of a radiographic guide would often require an impression, laboratory costs and further delay. None of these inconveniences were encountered when simply clicking an option from a web page. Therefore there was no discouragement to the selection of these views as there would be in reality.

The cases selected may not have elicited the full range of prescriptions which dentists may select. In some patients a poor tolerance of intra oral films, for example, may have led to different prescriptions. This was not accounted for in this survey. Further, only two cases were presented, a well-formed ridge and a resorbed one. More extreme situations or a mid-range case may have elicited different prescriptions. Nevertheless, this had to be balanced against the disadvantages of a longer survey and the potentially deleterious effect that this may have had on the response rate [77].

Respondents were allowed to see the results of each of their choices before choosing subsequent views. This was an attempt to reflect normal clinical circumstances. Notwithstanding, some views had unavoidable artefacts such as the impression compound which held the angles of the mandibles in place in the phantoms. Also, all the views were presented as static images on a computer screen. A CBCT image, for example, would normally be delivered with software which allows the images to be fully explored. Further, there was no control over screen resolution, type of monitor or viewing conditions. Conventional film views, such as the periapical radiographs, would normally be viewed on an x-ray viewer, perhaps with magnification and exclusion of

light. It is conceivable that these limitations may have led respondents to a different conclusion about the need for subsequent images. Nonetheless, these images were the stimulus for further decision making rather than the focus of the study. In this regard, the limitation of the quality of the images was less of a priority than in an image quality assessment.

The length of a questionnaire is a crucial factor in the response rate [77]. Therefore, the demographic information questions were kept as brief as was thought to be reasonable. The result is that the demographic information is unavoidably limited. For example, the respondents were asked if they had postgraduate qualifications but not the details of which postgraduate qualifications. The respondents were asked how many implant cases they complete per year but not how many edentulous cases. Notwithstanding, the choice of demographic questions was designed to be a satisfactory compromise between the thoroughness of the information and the length of the questionnaire. Furthermore, additional questions increase the problem of multiple comparisons. (See section 3.4.5 page 101)

The question about training on the survey website was, "What was your main training in dental implantology?" It is therefore probable that there will be some overlap and that answers to this question concealed multiple sources of training. For example, one of the participants in the pilot study undertook training on an independent course and later took the FGDP(UK) course. This dentist regarded the FGDP(UK) course as their "main" training although both courses had been undertaken. Also, the question about availability of x-ray equipment was, "What x-ray equipment do you have at your usual place of work?". Some dentists in the sample were primarily hospital based but carried out implant surgery, part time, in practice. Their answers may well have referred to their hospital posts as their "usual" place of work. Nevertheless, the equipment available at their hospital would be expected to have an influence on their prescriptions. Many dentists refer for 3D imaging and these, largely hospital based, dentists might be expected to favour those facilities with which they are familiar.

The question about postgraduate qualifications was an open one and was simply, "Do you have a postgraduate dental qualification?". Therefore, the postgraduate qualifications did not necessarily relate to dental implantology. Nevertheless, one would expect those who had studied for any recognised postgraduate qualification to think differently about their practice, perhaps in a more analytical way. In that respect, the question is relevant regardless of the type of qualification.

The dental school of qualification would be expected to have an influence on the radiographic practices of dentists. Therefore, it is possible that those who practice in the North West of England, who are likely to have qualified at a North West Dental School, may prescribe differently from those in other areas. Nevertheless, dental implantology is a postgraduate subject and training is carried out on a national and, sometimes, an international basis. For example, the FGDP(UK) training course is held at two English Centres, London and Leeds, and is attended by dentists from all parts of the UK. Implant manufacturers are international companies and their training might be expected to be common to all countries in which they operate. Many dentists have also taken independent training outside of the UK. Therefore, whilst the study was carried out in the North West of England, the findings may have relevance to a wider population of implant practitioners.

There were limitations to the survey of non-responders. This group had already demonstrated that they were reluctant to respond and so it was inevitable that there would be shortcomings in this part of the study. The survey was carried out by telephone. Therefore, whilst the non-responders were asked essentially the same question as case 2 of the main survey, they did not have the benefit of seeing the detailed case description and photograph. Some of the non-responders relayed their response through their receptionists and so it is possible that some information was lost in the process. For example, the use of radiographic guides in conjunction with the views may or may not have been mentioned. It was felt unrealistic, with a group of reluctant responders, to attempt follow up confirmation by relaying another message through the receptionist. For this reason the comparison with the responders was made without including the use of guides. There was also the problem of "non-responding non-responders". Only twelve of the thirty one non-responders replied to the post survey questionnaire and, therefore, there remained nineteen members of the sample for whom no information was collected. Notwithstanding, the response to the main survey was in excess of 80% and therefore the potential for non-response error was restricted to less than 20% of the sample.



### 3.7 Conclusions

This study has investigated radiographic prescription prior to dental implant placement in the anterior edentulous mandible in order to support an overdenture. The sample was drawn from dental practitioners in the North West of England who surgically place dental implants. A review of the literature failed to identify other studies which presented realistic clinical scenarios to dentists and recorded the sequence of image choices prior to dental implant placement. Therefore, very few comparisons can be made with the results of this study. Those studies of radiographic prescription prior to dental implant placement which do exist were carried out before the widespread availability of CBCT technology and so comparisons are no longer meaningful.

The use of a radiographic phantom to produce a range of available images and the use of the interactive capabilities of the internet probably went further than any previous questionnaire studies in attempting to reproduce clinical decision making. An 80% response rate and a favourable assessment of response bias suggest that these data are a reliable representation of the radiographic prescribing patterns of this population.

The radiographic prescriptions were tested for associations with demographic variables. Three groups of practitioners were identified that were associated with certain radiographic choices. First, the 0-10 years qualified respondents seem to form a separate group. They are more likely to have a postgraduate qualification, more likely to have a CBCT machine available and less likely to have described their training as "Independent course". This group was significantly associated with the prescription of 3D imaging. Secondly, the more experienced implant surgeons, who place more than 100 implants per year, were significantly associated with the non-use of radiographic guides and prescription of the same view for both cases regardless of difficulty. The sample as a whole, however, changed their prescription according to the difficulty of the case. Thirdly, those who have a CBCT machine available were more likely to use it regardless of the difficulty of the case.

The results show no agreement on radiographic prescription and the idiosyncratic nature of independent dental practice may be an important factor in the chaotic pattern of prescriptions which was found. Further, dental implant practitioners may be unaware of existing guidelines for selection of radiographic views prior to dental implant placement. For example, very few dentists prescribe conventional radiographic views

before making the decision to prescribe 3D imaging. Notwithstanding, if practitioners are aware of these guidelines, they are open to interpretation and could be construed to support a wide range of radiographic prescriptions. (Page 119). There is a need for widely disseminated, evidence based radiographic selection criteria for dental implantology which are clear and specific.

### 3.8 Implications for the next stage of this research

This study considered only the current prescription of implant practitioners. An investigation into the efficacy of radiographic imaging strategies prior to dental implant placement would be valuable to progress this research to assist in the development of guidelines. In particular, the higher levels of efficacy of diagnostic imaging, as suggested by Fryback and Thornbury [46], would be of interest. These might include diagnostic thinking efficacy, and therapeutic efficacy and patient outcome efficacy.

- 4 Part 3 – Systematic review. Conventional radiography and cross sectional imaging when planning dental implants in the anterior edentulous mandible to support an overdenture**



## 4.1 Introduction

The perforation of the lingual cortical plate when preparing osteotomies prior to dental implant placement in the edentulous anterior mandible is potentially life threatening. This is discussed more fully in the introduction to this thesis. (Paragraph 1.2 page 2) A systematic review was conducted to evaluate the available evidence which may assist with prescription of imaging when planning implant placement

### 4.1.1 Aim and objectives

#### Aim

The aim of this systematic review is to assess the impact of imaging methods prior to dental implant placement in the edentulous anterior mandible and to inform guideline development.

### 4.1.2 Objectives

The objectives for this review are to determine if the pre-operative availability of cross sectional imaging, such as cone beam CT, has a diagnostic impact, therapeutic impact or impact on patient outcome when placing two dental implants in the anterior mandible to support an overdenture. This is not a technical or diagnostic accuracy question, but is addressed by the higher levels of Fryback and Thornbury's hierarchy, namely, diagnostic thinking efficacy, therapeutic efficacy and patient outcome efficacy.

### 4.1.3 Review questions

The review questions are defined as follows:

1. Does the use of cross sectional imaging prior to dental implant placement in the anterior edentulous mandible have any impact on **diagnostic thinking**, compared to conventional imaging alone, when an implant retained overdenture is planned?
2. Does the use of cross sectional imaging prior to dental implant placement in the anterior edentulous mandible have any impact on **treatment planning**,

compared to conventional imaging alone, when an implant retained overdenture is planned?

3. Does the use of cross sectional imaging prior to dental implant placement in the anterior edentulous mandible have any impact on **outcome**, compared to conventional imaging alone, when an implant retained overdenture is planned?

## 4.2 Study designs

An ideal study design to answer this question would be a randomised controlled clinical trial in which patients would be randomised to receive, preoperatively, either conventional, two dimensional imaging alone or conventional with cross sectional imaging. Relevant measures such as preoperative assessment, treatment plan and outcome could then be recorded. Difficulties with this study design include large sample size requirements necessitating a possible multi centre approach, expense and the length of time required to complete such a study.[196, 197]

Another study design that could assist in answering the question would be the diagnostic before-after study. In the “before” part of this study design, a panel of dentists would be given conventional, two dimensional images and other clinical information. They would then be asked to make an assessment and plan the case. In the “after” part of the study, the same dentists would be given additional cross sectional images and asked to assess and plan the case again. The “before” and “after” results can then be compared and analysed. This observational design has a number of limitations including subconscious observer bias and possible discrepancy between the observers’ stated treatment plan and clinical reality. [196, 197] Nevertheless they have the advantage of being less expensive and more conveniently undertaken.[196]

Other study designs such as cohort and case-control studies are possible. Nonetheless, they also suffer from limitations such as lack of randomisation and may be cumbersome, time consuming and expensive to conduct.

## 4.3 Current evidence for the impact of cross sectional imaging

A search of Pubmed/Medline, OVID/Embase and the Cochrane database of Systematic Reviews did not reveal any existing systematic reviews which addressed

the review questions. A rapid scoping exercise was carried out in order to gauge the extent of the volume of the literature.

#### 4.4 Method

##### 4.4.1 The review team

The design and implementation of the review was the responsibility of the author of this thesis.

A supporting team was assembled which consisted of:

- ▶ A consultant in dental radiology
- ▶ A consultant in restorative dentistry
- ▶ An expert in evidence based dental practice
- ▶ A lecturer in biostatistics
- ▶ A specialist librarian

Documentation for this systematic review was made available on a dedicated webpage.<sup>\*\*\*\*\*</sup> This facilitated exchange and communication between members of the review team.

#### 4.5 Identification of studies

##### 4.5.1 Inclusion criteria

Inclusion criteria were set in advance of a literature search. Studies were included in this review if they met the following criteria:

###### Participants/ Population

- ▶ Human
- ▶ *In vivo or in vitro*
- ▶ Complete mandibular edentulism
- ▶ Implants were planned for the interforaminal region to support a complete lower overdenture.

---

<sup>\*\*\*\*\*</sup> [http://www.andrewshelley.com/systematic\\_review.html](http://www.andrewshelley.com/systematic_review.html)

The possibility was recognised that insufficient studies might be identified which investigated dental implant placement in the anterior mandible prior to provision of an overdenture. It was therefore agreed that, if insufficient studies were identified, that those which investigated dental implant placement anywhere in the mouth, but including the anterior mandible, would be included.

#### 4.5.2 Interventions

- ▶ Cross sectional imaging, of all types, prior to dental implant placement. This would include, for example, conventional tomography, medical (multi slice) CT and cone beam CT

#### 4.5.3 Comparators

- ▶ Conventional, two dimensional radiography prior to dental implant placement.

#### 4.5.4 Outcomes

- ▶ Diagnostic thinking, therapeutic efficacy or patient outcome as defined by Fryback and Thornbury. [46]

#### 4.5.5 Study design

Studies were included where the primary purpose was cross sectional imaging for assessment prior to dental implant placement rather than being primarily for the construction of a computer generated surgical guide.

The following study designs were considered

- ▶ Before-after studies
- ▶ Randomised controlled studies
- ▶ Other observational study designs



#### 4.5.6 Language

Studies were in the English language or had an English language abstract.

#### 4.5.7 Publication types

- ▶ Peer reviewed journals
- ▶ Non peer reviewed journals
- ▶ Reports
- ▶ Book chapters
- ▶ Conference abstracts
- ▶ Theses
- ▶ Informal reports and on-going studies where full data was available.

#### 4.6 Pilot study

A preliminary rapid scoping exercise was carried out. Studies were identified by a cursory electronic search of PubMed/Medline, OVID/Embase, the Cochrane CENTRAL database and by searching the reference sections of the identified studies. Thirteen studies were found for consideration and are referred to below as the “rapid scope studies”. An assessment against the stated inclusion criteria was made, based on titles and abstracts. Six of these studies were found to meet the inclusion criteria and seven were considered to be “near misses”. The “near misses” included studies which, whilst first appearing to be higher level evaluations, were diagnostic accuracy studies.[54] Another example of a “near miss” is a study which compared true cross sectional images from computed tomograms with three dimensional reconstructions from the same data set.[58] In the absence of more detailed consideration of articles, one study was considered as meeting the inclusion criteria although the title and abstract suggested that it might not include dental implants placed in the anterior mandible.[55] The rapid scope studies are listed in Table 18 on page 140 with reasons for “near misses”.

These studies were used to pilot and refine the search strategy of bibliographic databases by conducting trial searches as described by Torgerson.[198] A form was created that listed the rapid scope studies and was used to trial variations on the search strategy. An example is shown in Table 19 on page 141. The aim was to return all of those studies which met the inclusion criteria and exclude, at least, some of those that did not. The intention was to include search terms only when there was a logical justification and to use broad rather than specific terms to avoid the introduction

of bias. Sensitivity in the search was favoured over specificity in order to avoid missing studies which might be included in the review.

The pilot study was undertaken in two parts. First, free text terms alone were piloted to find the best balance of specificity and sensitivity. Secondly, a specialist librarian was consulted and the exercise was repeated following the introduction of controlled vocabulary. In the case of the Medline database search, the controlled vocabulary consisted of MeSH<sup>++++</sup> headings. In the case of the Embase database, these were Emtree<sup>++++</sup> headings.

Additional trial searches were carried out in the pilot study of the search strategy. These included reference tracking, citation tracking, hand searching, thesis searching and searches for other sources of grey literature. Details of the pilot study are recorded on the webpage set up for this review.<sup>§§§§</sup>

In the final search strategy of bibliographic databases, each search consisted of four sections. The first section was to identify studies which concerned dental implants. The second was to identify radiology studies. The third used terms to find studies that investigated planning or assessment of cases. The fourth section was intended to find comparative studies. Within each section there were free text terms and controlled vocabulary which were combined with the Boolean operator OR. The sections were then combined with the Boolean operator AND.

The three bibliographic databases, PubMed/Medline, OVID/Embase and the Cochrane CENTRAL database, allowed different search terms. For example, the OVID/Embase database software allowed searching of adjacent terms. This was not possible in the PubMed/Medline software. For each database, trial searches were used to refine the search strategies and to find the most appropriate balance of sensitivity and specificity. The Cochrane CENTRAL database is very much smaller than Medline, having some 600,000 entries compared with over 20,000,000 in both Medline and Embase. In this case, only free text terms were used.

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<sup>++++</sup> MeSH – Medical Subject Headings. Controlled vocabulary and thesaurus of the US National Library of Medicine.

<sup>++++</sup> Emtree - Controlled vocabulary and thesaurus of Elsevier Life Science.

<sup>§§§§</sup> [http://www.andrewshelley.com/systematic\\_review.html](http://www.andrewshelley.com/systematic_review.html)

The final search strategies are presented in Table 20 page 142, Table 21 page 143 and Table 22 page 144.

Rapid scope studies which met the inclusion criteria	
<b>Diniz, A.F., et al.,</b> Changes in the pre-surgical treatment planning using conventional spiral tomography. <i>Clinical oral implants research</i> , 2008. 19(3): p. 249-53.	
<b>Fortin, T., et al.,</b> Panoramic Images versus Three-Dimensional Planning Software for Oral Implant Planning in Atrophied Posterior Maxillary: A Clinical Radiological Study. <i>Clinical implant dentistry and related research</i> , 2011.	
<b>Frei, C., D. Buser, and K. Dula,</b> Study on the necessity for cross-section imaging of the posterior mandible for treatment planning of standard cases in implant dentistry. <i>Clinical oral implants research</i> , 2004. 15(4): p. 490-7.	
<b>Reddy, M.S., et al.,</b> A comparison of the diagnostic advantages of panoramic radiography and computed tomography scanning for placement of root form dental implants. <i>Clinical oral implants research</i> , 1994. 5(4): p. 229-38.	
<b>Schropp, L., A. Wenzel, and L. Kostopoulos,</b> Impact of conventional tomography on prediction of the appropriate implant size. <i>Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics</i> , 2001. 92(4): p. 458-463.	
<b>Schropp, L., et al.,</b> Comparison of panoramic and conventional cross-sectional tomography for preoperative selection of implant size. <i>Clinical oral implants research</i> , 2011. 22(4): p. 424-9.	
Rapid scope studies which did not meet the inclusion criteria (near misses)	Reasons for "near miss"
<b>Chen, L.C., et al.,</b> Comparison of different methods of assessing alveolar ridge dimensions prior to dental implant placement. <i>Journal of Periodontology</i> , 2008. 79(3): p. 401-5.	Compares CBCT with direct calliper measurement
<b>Dreiseidler, T., et al.,</b> Comparison of cone-beam imaging with orthopantomography and computerized tomography for assessment in presurgical implant dentistry. <i>The International journal of oral &amp; maxillofacial implants</i> , 2009. 24(2): p. 216-225.	A diagnostic accuracy study rather than impact of imaging method
<b>Jacobs, R., et al.,</b> Predictability of reformatted computed tomography for pre-operative planning of endosseous implants. <i>Dento maxillo facial radiology</i> , 1999. 28(1): p. 37-41.	Compared planning on preoperative CT with decision making at time of surgery
<b>Jacobs, R., et al.,</b> Predictability of a three-dimensional planning system for oral implant surgery. <i>Dento maxillo facial radiology</i> , 1999. 28(2): p. 105-111.	Compared planning on 2D images from CT with 3D reconstructions from CT
<b>Schropp, L., et al.,</b> Calibration of radiographs by a reference metal ball affects preoperative selection of implant size. <i>Clinical oral investigations</i> , 2009. 13(4): p. 375-81.	Evaluated calibration of panoramics. Not a comparative study.
<b>Vazquez, L., et al.,</b> Efficacy of panoramic radiographs in the preoperative planning of posterior mandibular implants: a prospective clinical study of 1527 consecutively treated patients. <i>Clinical oral implants research</i> , 2008. 19(1): p. 81-5.	Evaluated outcome but no comparator with panoramics
<b>Webber, R.L. and J.K. Messura,</b> An in vivo comparison of diagnostic information obtained from tuned-aperture computed tomography and conventional dental radiographic imaging modalities. <i>Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics</i> , 1999. 88(2): p. 239-247.	Essentially an image quality assessment. No outcomes were measured

**Table 18 - Rapid scope studies showing reasons for near misses**

<b>Search strategy</b>	PubMed v1	PubMed v2	PubMed v3	PubMed v4
<b>Number of results returned</b>	3338	1287	1297	1221
<b>Meet inclusion criteria</b>				
Diniz 2008	✓	✓	✓	✓
Fortin 2011	X	X	✓	✓
Frei 2004	✓	✓	✓	✓
Reddy 1994	✓	✓	✓	✓
Schropp 2001	✓	✓	✓	✓
Schropp 2011	✓	✓	✓	✓
<b>Do not meet inclusion criteria</b>				
Chen 2008	✓	✓	✓	✓
Dreiseidler 2009	✓	✓	✓	✓
Jacobs 1999 – 1	✓	✓	✓	✓
Jacobs 1999 – 2	✓	✓	✓	✓
Schropp 2009	✓	✓	✓	✓
Vazquez 2008	✓	✓	✓	✓
Webber 1999	✓	X	X	X

✓ Returned in search  
 X Not returned in search

**Table 19 - Form used for testing of search strategies with example trial searches**

Terms to find dental implant studies	MeSH terms	1. DENTAL PROSTHESIS, IMPLANT SUPPORTED[mh:exp]
	Free text terms	2. DENTAL IMPLANTATION[mh:exp] 3. DENTAL IMPLANTS[mh:exp] Endosseous implant*[textword]
	Combined with OR	4. Implant dentistry[textword] 5. Oral implant*[textword] 6. Dental implant*[textword] 7. 1 or 2 or 3 or 4 or 5 or 6 or 7
Terms to find radiology studies	MeSH terms	8. RADIOGRAPHY, DENTAL[mh:exp] 9. TOMOGRAPHY, X-RAY[mh:exp] 10. RADIOLOGY[mh:exp] 11. IMAGING, THREE DIMENSIONAL[mh:exp]
	Free text terms	12. Imag*[textword] 13. Tomograph*[textword] 14. Radiolog*[textword] 15. Radiograph*[textword]
	Combined with OR	16. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
Terms to find studies that investigate planning or assessment of cases	MeSH terms	17. COMPREHENSIVE DENTAL CARE[mh:exp] 18. DENTIST'S PRACTICE PATTERNS[mh:exp] 19. "OUTCOME ASSESSMENT (HEALTHCARE)"[mh:exp]
	Free text terms	20. Planning[text word] 21. Plan*[text word] 22. Assessment[text word] 23. Assess*[text word]
	Combined with OR	24. 18 or 19 or 20 or 21 or 22 or 23 or 24
Terms to find comparative studies	MeSH terms	25. COMPARATIVE EFFECTIVENESS RESEARCH[mh:exp] 26. COMPARATIVE STUDY[mh:exp]
	Free text terms	27. Compar*[textword] 28. Change*[textword]
	Combined with OR	29. 262 or 27 or 28 or 29

Overall combination of each section with AND, 8 and 17 and 25 and 30

**Table 20 - PubMed/Medline search**

Terms to find dental implant studies	Emtree terms	1. exp tooth implant/ 2. exp tooth prosthesis/ 3. exp tooth implantation/
	Free text terms	4. (Dental adj5 implant*).ti,ab. 5. (Implant adj5 dentistry).ti,ab. 6. (Oral adj5 implant*).ti,ab. 7. (endosseous adj5 implant*).ti,ab.
	Combined with OR	8. 1 or 2 or 3 or 4 or 5 or 6 or 7
Terms to find radiology studies	Emtree terms	9. exp tomography/ 10. exp three dimensional imaging/ 11. exp dental radiology/ 12. exp tooth radiography/
	Free text terms	13. Imag*.ti,ab. 14. Tomograph*.ti,ab. 15. Radiolog*.ti,ab. 16. Radiograph*.ti,ab.
	Combined with OR	17. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
Terms to find studies that investigate planning or assessment of cases	Emtree terms	18. exp outcome assessment/ 19. exp clinical practice/ 20. exp dental procedure/
	Combined with OR	21. 18 or 19 or 20
Terms to find comparative studies	Emtree terms	22. exp comparative study/ 23. exp comparative effectiveness/
	Free text terms	24. ((compar* or chang*) and (outcome* or plan*)).ti,ab
	Combined with OR	25. 22 or 23 or 24
		Overall combination of each section with AND, 8 and 17 and 21 and 25

Table 21 - OVID/Embase search

Terms to find dental implant studies	Free text terms	1. Dental implant*
	Combined with OR	2. Implant dentistry 3. Oral implant*
Terms to find radiology studies	Free text terms	4. 1 or 2 or 3
	Combined with OR	5. Imag*
Terms to find studies that investigate planning or assessment of cases	Free text terms	6. Tomograph*. 7. Radiolog* 8. Radiograph*
	Combined with OR	9. 5 or 6 or 7 or 8
Terms to find comparative studies	Free text terms	10. Planning 11. Assessment
	Combined with OR	12. 10 or 11
Terms to find comparative studies	Free text terms	13. Compar* 14. Chang*
	Combined with OR	15. 13 or 14
Overall combination of each section with AND, 4 and 9 and 12 and 15		

**Table 22 - Cochrane CENTRAL database search**



## 4.7 Final search strategy

### 4.7.1.1 Bibliographic databases

The following bibliographic databases were searched:

- ▶ Pubmed/Medline 1946 to February week 3 2013
- ▶ Ovid/Embase 1947 to February week 3 2013
- ▶ Cochrane Central Register of Controlled Trials (CENTRAL) 1898 to February week 3 2013

### 4.7.1.2 Additional searches

Further sources of studies were searched as follows:

- ▶ Reference tracking

The reference sections of relevant studies identified in the search of bibliographic databases were hand searched. In addition, the reference sections of relevant published guideline documents were similarly searched. [36-40, 189, 191, 199-202]

- ▶ Citation tracking

The Web of Knowledge Science Citation Index was used to identify studies which had cited the rapid scope studies.

- ▶ Hand searching

Of the six studies identified by rapid scoping, four were from the journal "Clinical Oral Implants Research". The contents pages of this journal were searched to identify further studies.

- ▶ Conference proceedings

The International Association of Dental Research (IADR) website publishes an online archive of its conference proceedings. This database was searched for relevant studies.

- ▶ Trials search

Two online resources were used to search for relevant studies. These were ClinicalTrials.gov<sup>\*\*\*\*\*</sup> and the WHO International Clinical Trials Registry <http://www.who.int/trialsearch><sup>+++++</sup>

- ▶ Thesis searching

Two online resources were used to search for relevant studies. These were “Proquest Dissertations and Theses”<sup>#####</sup> and “EthOS ElectronicTheses”<sup>§§§§§§</sup>

- ▶ Other grey literature searching

The Opengrey website was searched for relevant studies.<sup>\*\*\*\*\*</sup> The review was also registered with PROSPERO, the International Prospective Register of Systematic Reviews.<sup>+++++</sup> This enabled other workers to contact the review team with further information on any relevant studies. The PROSPERO listing also linked to the dedicated webpage which enabled the exchange of documents between reviewers and allowed others to make direct contact.<sup>#####</sup>

No language or date restrictions were applied to the searches. Details of all studies were imported into EndNote software.<sup>§§§§§§</sup> Each stage of the search was recorded in a separate database and made available on the dedicated webpage.<sup>#####</sup> This enabled members of the review team to download the databases and verify each stage of the search and study selection process. A diagram of the results of the search and study selection are shown in Table 26 on page 155.

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<sup>\*\*\*\*\*</sup> [www.clinicaltrials.gov](http://www.clinicaltrials.gov)

<sup>+++++</sup> [www.who.int/trialsearch](http://www.who.int/trialsearch)

<sup>#####</sup> [www.proquest.co.uk](http://www.proquest.co.uk)

<sup>§§§§§§</sup> [ethos.bl.uk/](http://ethos.bl.uk/)

<sup>\*\*\*\*\*</sup> [www.opengrey.eu/](http://www.opengrey.eu/)

<sup>+++++</sup> [http://www.crd.york.ac.uk/PROSPERO/display\\_record.asp?ID=CRD42013004267](http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42013004267)

<sup>#####</sup> [http://www.andrewshelley.com/systematic\\_review.html](http://www.andrewshelley.com/systematic_review.html)

<sup>§§§§§§</sup> EndNote X4.0.2 [www.endnote.com](http://www.endnote.com). Thomson Reuters. New York. USA

## 4.8 Study selection

### 4.8.1 Stage one

Firstly, all duplicate studies were removed. The author then reviewed titles to exclude those studies which were clearly irrelevant to the systematic review. This was done by comparison of the titles with the inclusion criteria. Remaining studies passed to stage two.

### 4.8.2 Stage two

The author reviewed abstracts to identify relevant articles that would be retrieved for full text review in stage three. This was done by comparison of the studies with the inclusion criteria. Where studies were clearly irrelevant, no further documentation was carried out. Where a study narrowly failed to meet the inclusion criteria, the reason was recorded. In those cases, the decisions were re-examined by a second reviewer, the expert in evidence based dental practice. In cases where the abstract provided insufficient detail, the study passed to stage three where the full text was examined.

### 4.8.3 Stage three

Where studies appeared to meet the inclusion criteria, or where a decision could not be made on the title and abstract alone, full papers were obtained for detailed assessment against the inclusion criteria. Stage three was carried out independently by the author and the expert in evidence based dental practice. It was agreed, in advance, that any disagreement would be resolved by consensus. If consensus could not be reached, then a third reviewer would be consulted.

Reviewers were not blinded to authors, institution or study results during the study selection process. This has been demonstrated to be of limited value whilst considerably increasing the difficulty of the process of study selection.[203, 204]

## 4.9 Data extraction strategy

Studies found in the rapid scoping exercise presented different outcome measures. A common measure was an increase or decrease in length or width of a planned dental implant. Nevertheless, a difficulty arose because dental implant sizes are available in discrete steps and this is dependent on the type of implant system used. For example, in one study, Brånemark system implants were available in widths of 3.3mm, 3.75mm, 4mm and 5mm. In another, Straumann implants were available in widths of 4.1mm and 4.8mm. Other studies recorded change in treatment decisions about bone grafting or sinus augmentation surgery. It was, therefore, necessary to design a data extraction form that captured all variations and commonality of outcome between the studies so that analysis could be planned. In addition, other characteristics of the studies had to be recorded to enable synthesis. The intention was that further referral to original publications would be kept to a minimum once data extraction had been carried out.

A pilot study was carried out to develop the data extraction form. At this stage, it had become clear that one of the six original rapid scope studies, that were thought to meet the selection criteria, did not include implants placed in the anterior mandible.[55] Therefore, five remaining rapid scope studies were used to pilot the data extraction form.[53, 56, 59, 61, 62] The starting point was the data extraction form used by Albon et al in their neuroimaging review.[205] Details of the pilot study are recorded on the webpage set up for this review. Two versions of the data extraction form were developed. The first was a paper version. Finally, a version of the form was produced in Microsoft Excel so that data could be more expediently copied, manipulated and analysed. The Microsoft Excel version is reproduced in Table 23 on page 149 and Table 24 on page 150. This shows the data extraction form used for the study by Reddy et al.[59]

Data extraction was first carried out independently by two reviewers. It was planned that all discrepancies would be resolved by discussion. Where this was not possible, a third reviewer would be involved.

1	<b>Data Extraction Form v2</b>	
2	Where the required information is <b>not stated</b> in the study report write <b>NS</b>	
3		
4	Name of assessor	AMS
5		
6	<b>Study details</b>	
7	Author; year, trial name	Reddy 1994
8	Country(ies) and years of recruitment	probably USA
9	Study design	Before after study
10	Area of the mouth studied	NS
11	Conventional imaging technique used	Panoramic
12	X sectional or 3D imaging technique used	Medical CT (1981 vintage GE CT9800)
13	Setting (practice, hospital etc)	NS
14	Comments:	
15		
16	<b>Patient characteristics</b>	
17	Population	NS
18	Number of patients in study	10
19	Age (provide all information from study eg range, SD etc)	NS
20	Gender – state percentage male (%)	NS
21	State presenting problem if not partial or complete edentulism	partial or full edentulism with "compromised ridges"
22	Inclusion/exclusion criteria	
23	Comments:	
24		
25	<b>Evaluator characteristics</b>	
26	Number of evaluators	4
27	Types of evaluator (surgeon, radiologist etc)	Dentists
28	Comments	
29		
30	<b>Interventions</b>	
31	Number of excluded patients	NS
32	Number of patients after exclusions	10
33	Number of patients dropped out	NS
34	Number of patients after drop outs	NS
35	Implant manufacturer(s)	NS
36	Lengths and widths of implants available for selection	8-16mm
37	Number of implants placed	NS but at least 10
38	How many anterior mandible?	NS
39	How many posterior mandible?	NS
40	How many anterior maxilla?	NS
41	How many posterior maxilla?	NS
42	Did evaluators carry out a clinical examination?	No (unclear, possibly as part of "treatment planning" but not stated
43	If no clinical examination carried out, was other clinical information available to evaluators (eg. study casts, clinical findings etc)	
44	Washout period?	"At a later time"
45	Comments:	

**Table 23 - Data Extraction Form (Microsoft Excel) – for study by Reddy et al [59]  
part 1 of form**

47	Outcomes for analysis	
48	What were the outcome measures? (complete the sections which apply below)	Implant length
49		
50	If outcome measure is simply selection of a different implant	
51	In how many sites was a <b>different implant</b> selected after X sectional or 3D imaging evaluated?	
52		
53	If outcome specifies selection of a different length or width	
54	In how many sites was a <b>different length</b> of implant selected after X sectional or 3D imaging evaluated?	
55	In how many sites was a <b>different width</b> of implant selected after X sectional or 3D imaging evaluated?	
56		
57	If outcome specifies selection of a longer, shorter, wider or narrower implant	
58	In how many sites was a <b>longer</b> implant chosen after X sectional or 3D imaging evaluated?	stated as mean 10.3 before and 10.8 after
59	In how many sites was a <b>shorter</b> implant chosen after X sectional or 3D imaging evaluated?	
60	In how many sites was a <b>wider</b> implant chosen after X sectional or 3D imaging evaluated?	
61	In how many sites was a <b>narrower</b> implant chosen after X sectional or 3D imaging evaluated?	
62		
63	If outcome specifies prescription of additional procedures such as bone grafting, sinus lifting etc.	
64	In how many sites was bone grafting prescribed after X sectional or 3D imaging but not after conventional imaging?	
65	In how many sites was bone grafting prescribed after conventional imaging but not after X sectional or 3D imaging?	
66	In how many sites were other surgical procedures prescribed after conventional imaging but not after X sectional or 3D imaging?	
67	In how many sites were other surgical procedures prescribed after conventional imaging but not after X sectional or 3D imaging?	
68		
69	Comments:	
70		
71	Can outcome data for anterior mandible only be analysed?	No
72		
73	Reddy 1994	
74		
75		
76		
77		
78		
79		
80		
81		
82		
83		
84		
85		
86		
<span>Reddy 1994</span> / <span>Schropp 2001</span> / <span>Frei 2004</span> / <span>Diniz 2008</span> / <span>Schropp 2011</span>		
Ready		

**Table 24 - Data Extraction Form (Microsoft Excel) – for study by Reddy et al [59]**  
**part 2 of form**

#### 4.10 Quality assessment strategy

A quality assessment tool for before-after studies has been developed by Meads and Davenport and was adapted for use in this review.[206] First, a pilot study was carried out using the same five rapid scope studies which were used in the pilot study of the data extraction form. Details are recorded on the webpage set up for this review. The final quality assessment form is presented in Table 25 on page 152.

Had other study designs been found in the search, the authors had identified other quality assessment tools which could have been used. For example the Cochrane Collaboration's tool for assessing risk of bias in randomised controlled studies was available.[207]

Quality assessment was first carried out independently by two reviewers. It was planned that all discrepancies would be resolved by discussion. Where this was not possible, a third reviewer would be involved.

Author		Year				
Study title						
No.	Item	N/A	Yes	Unclear	No	
1	Was the spectrum of patients representative of patients who will receive imaging in practice?					
2	Were the selection criteria clearly described?					
4	Is the period between conventional imaging and 3D imaging short enough to be reasonably sure that the target condition did not change between the two tests?					
5	Did the whole sample or a random selection of the sample receive verification using a reference standard of diagnosis? ( <b>Yes</b> for whole sample or random selection. <b>No</b> if neither.)					
6	Did the patients receive the same 3D imaging regardless of conventional imaging?					
8	Was the execution of the conventional imaging described in sufficient detail to permit replication of the test?					
9	Was the execution of the 3D imaging described in sufficient detail to permit its replication?					
10	Were the conventional imaging results interpreted without knowledge of the results of the 3D imaging?					
11	Were the 3D imaging results interpreted without knowledge of the conventional imaging?					
12	Were the same clinical results available when imaging results were interpreted as would be available when the imaging is used in practice?					
13	Were uninterpretable/intermediate imaging results reported?					
14	Were withdrawals from the study explained?					
A	Were patients recruited consecutively?					
C	Was the study and/or collection of clinical variables conducted prospectively?					
B	What was the explanation for patients who did not receive 3D imaging? ( <i>Green for good quality, red for poor quality.</i> )					
D	Who performed the clinical evaluation and image analysis? ( <i>Green for good quality, red for poor quality.</i> )					
Overall subjective quality assessment ( <i>Green for good quality, red for poor quality.</i> )						

Numbering is unchanged from original sources. Numbered items are from Quadas 1.  
 Questions 3 & 7 were removed by Meads and Davenport  
 Letters are additional questions from Meads and Davenport

**Table 25 - Quality assessment form modified from Meads and Davenport[206]**



#### 4.11 Synthesis

Tables were made of study characteristics and outcomes. (Table 28 page 159 and Table 30 page 161) A further table was made to indicate the number of implants placed in the anterior mandible in each study. (Table 29 page 160)

Graphical representation of the results was made in an attempt to reveal trends in the results of the included studies. Following discussion with a second reviewer, a judgement was made as to whether each study suggested change in the treatment plans following the availability of cross sectional imaging. The studies were placed into one of three, colour coded categories as follows:

Strongly suggests change in “after” part of study  
Strongly suggests no change in “after” part of study,  
No strong suggestion

Three graphical representations were made. The first was to colour code the table of outcomes. Each row contained a study and was colour coded appropriately (Table 30 page 161). Some studies had bigger sample sizes of implants than others. Therefore, a second graphical representation was made, using the same colour coding, but accounting for the number of implants placed in each study. Each column is proportional to the number of implants placed (Figure 27 page 162 ) Finally, the studies had a varying number of evaluators. A final graphical representation was, therefore, made using the colour coding but with each column proportional to the number of evaluators (Figure 28 page 162)

Pooled, quantitative analysis was not possible because of the small number of studies identified, their low quality and their heterogeneity. Analysis was therefore qualitative and conclusions were based on trends suggested in the tables and the graphical representations.

## 4.12 Results

### 4.12.1 Identification of studies

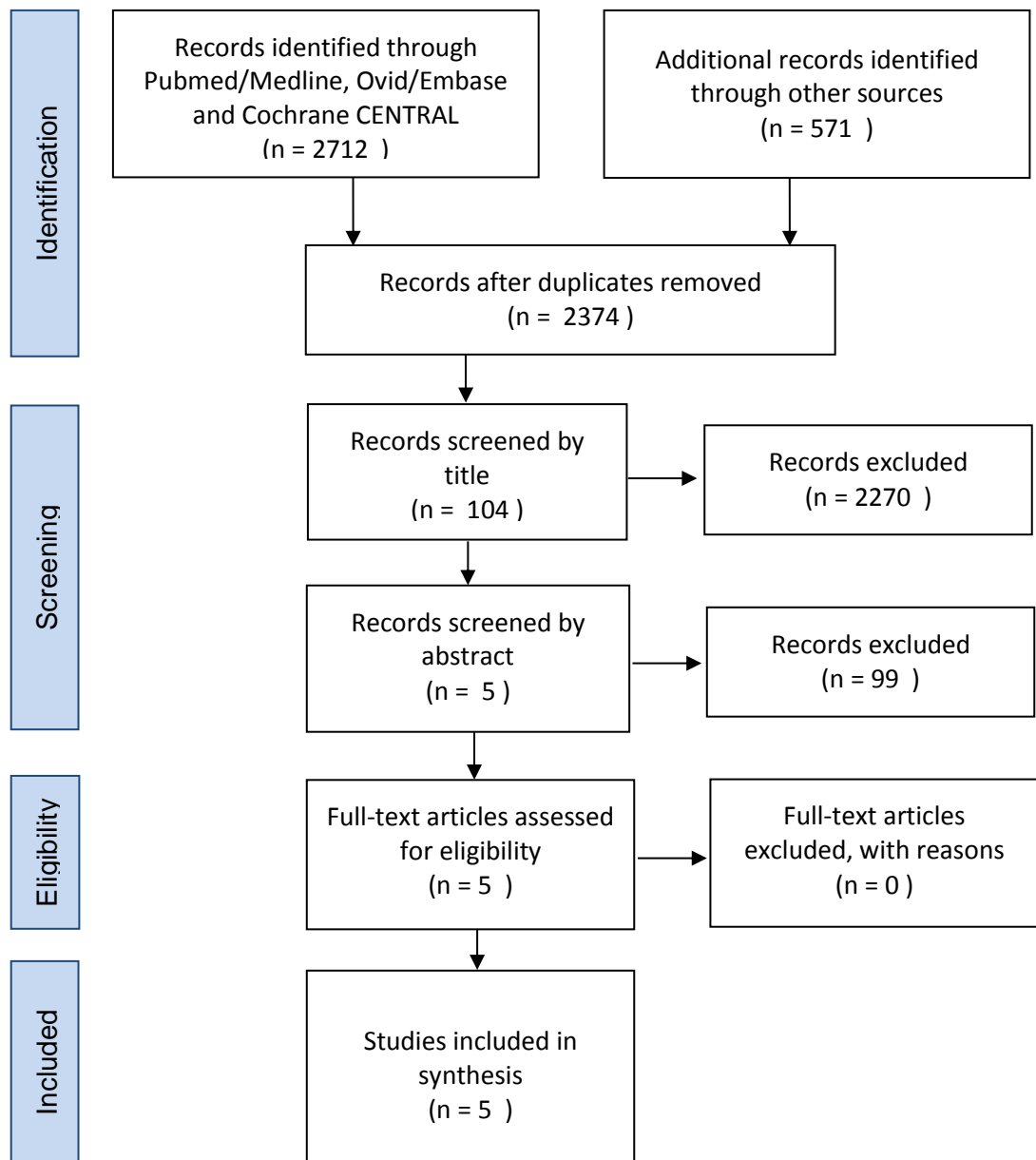
After removal of duplicates, 2,374 potentially relevant studies were identified. There were 2,270 studies which were excluded on the basis of title and a further 99 were excluded on the basis of abstracts. Five “near misses” were identified which were excluded following discussion with a second reviewer. In these cases, the reason for rejection was recorded. Full papers were obtained for the remaining five studies which all met the inclusion criteria. This result was in accordance with the results of the rapid scoping exercise. A full record of the search process is recorded on the webpage set up for this review.

No studies were identified that related solely to placement of implants in the anterior mandible. In one study, the area of the mouth to be studied was stated as “posterior mandible”.<sup>[56]</sup> After discussion, the authors agreed to include this study in the review.

No relevant systematic reviews were identified during the search process. No randomised controlled trials were returned and there were no cohort or case control studies. All five studies, which were identified in the search, were of the before-after design. A PRISMA<sup>\*\*\*\*\*</sup> diagram of the search process, with results and reasons for exclusion, is presented in Table 26 on page 155.

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\*\*\*\*\* PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses



**Table 26 - PRISMA diagram of results of searches and study selection [208]**

4.12.2 Data extraction

The full results of the data extraction exercise are recorded on the webpage set up for this review. All discrepancies were resolved by discussion and so it was not necessary to involve a third reviewer.

4.12.3 Quality assessment

The quality assessment form was used as shown in Table 25 on page 152. All discrepancies were resolved by discussion and so it was not necessary to involve a third reviewer. A summary table of this subjective quality assessment is presented in Table 27 on page 156. The full results of the quality assessments for the five studies are recorded on the webpage set up for this review.

<p><b>Reddy, M.S. et al 1994</b>                      A comparison of the diagnostic advantages of panoramic radiography and computed tomography scanning for placement of root form dental implants.</p>	
<p><b>Schropp, L. et al 2001</b>                      Impact of conventional tomography on prediction of the appropriate implant size.</p>	
<p><b>Frei, C. et al 2004</b>                      Study on the necessity for cross-section imaging of the posterior mandible for treatment planning of standard cases in implant dentistry.</p>	
<p><b>Diniz, A.F.N. et al 2008</b>                      Changes in the pre-surgical treatment planning using conventional spiral tomography.</p>	
<p><b>Schropp, L. et al 2010</b>                      Comparison of panoramic and conventional cross-sectional tomography for preoperative selection of implant size.</p>	

**Table 27 - Overall subjective quality assessments on a visual analogue scale.**

**Green represents good quality - Red represents poor quality**

## 4.13 Synthesis

### 4.13.1 Study characteristics

All five studies were of the uncontrolled before-after observational study design. In these studies, dentists' treatment plans were compared before and after the availability of cross sectional imaging. In every case, the "before" imaging was panoramic radiography with the addition, in two cases, of periapical radiography. In one study, medical multi-slice CT was used in the "after" part of the investigation. In the other four studies, the "after" imaging was conventional spiral tomography. No studies were identified which investigated the impact of Cone Beam CT imaging technology. The country of recruitment of subjects was not always clearly stated but was probably one study from Brazil, two from Denmark, one from Switzerland and one from the USA. Where the setting was made clear this was a University Dental Hospital. None of the reports stated that the study was carried out in a primary care or practice setting. In most studies, dental implants were placed at any site in the mouth, though one study assessed only those placed in the posterior mandible. The number of patients treated in each study varied from 10 to 121. A table of study characteristics is presented in Table 28 on page 159.

It was possible to separate the data for implants placed in the anterior mandible only in the 2011 study by Schropp et al.[61] In this study, only three implants were placed in the anterior mandible. In all other studies the number of implants placed in the anterior mandible was unclear. Therefore, further analysis of implants placed in the anterior mandible only was not performed. A table is presented to show the possible numbers of implants placed in the anterior mandible. (Table 29 page 160) Unfortunately, in the 1994 study by Reddy et al, the number of implants placed is not recorded.[59] Nevertheless, the authors do report the number of patients as being ten. Therefore, ten implants are represented as being the minimum number placed.

### 4.13.2 Outcomes

No single, consistent outcome measure was found. In four of the studies, implant length was considered [53, 59, 61, 62] with, in three cases, implant width.[53, 61, 62] In the other study, the outcome measure was simply "change" or "no change" in the

treatment plan.[56] In one of the studies, the necessity for bone grafting or sinus lifting was also recorded.[53] In another, the authors recorded the implant selection after the availability of two dimensional images, after the availability of three dimensional images and then the selection of implants at the time of surgery.[62]

The number of evaluators who planned the cases was consistently very small. In two of the studies evaluation was carried out by a single dentist. The maximum number of evaluators in any identified study was four. A colour coded table of outcomes is presented in Table 30 on page 161.

#### 4.13.3 Graphical representation of results

Two graphical representations are presented. The first accounts for the number of implants placed in each study. Each column is proportional to the number of implants placed (Figure 27 page 162). In the second, each column is proportional to the number of evaluators (Figure 28 page 162). No clear pattern emerges for reported impact on implant selection in relation to number of implants or number of evaluators in the studies.

All studies were of the “before-after” design

Reference	Population	No.pts treated	Site	“Before” imaging	“After” imaging	Outcome measures	Aims of study
Reddy et al 1994[59]	Not stated  Probably USA	10	Not stated	Panoramic	Medical multi-slice CT	Implant length	Ten subjects were treatment planned using panoramic images alone and panoramic plus CT images to determine the validity of both examinations and the confidence of the investigators in treatment planning with these images.
Schropp et al 2001[62]	Dental Hospital patients Denmark	47	All sites	Panoramic and periapical	Spiral tomography (Scanora)	Implant length and width	The aim of this study was to evaluate the efficacy of conventional cross-sectional tomographic examination as an adjunct to panoramic and periapical examination in the prediction of the appropriate implant size (length and width) for treatment with single tooth implants.
Frei et al 2004[56]	Not stated  Probably Switzerland	50	Posterior mandible	Panoramic	Spiral tomography (Cranex Tome)	Change or no change in treatment plan	To investigate whether cross-sectional imaging influences the planning and therapy of standard implant cases in the posterior mandible.
Diniz et al 2008[53]	Not stated  Probably Brazil	29	All sites	Panoramic and periapical	Spiral tomography (Cranex Tome)	Implant length, width, bone grafting or other surgical procedures necessary	To investigate variation in the pre-surgical treatment planning after using conventional spiral tomography in addition to conventional radiographic exams.
Schropp et al 2011[61]	Dental Hospital patients Denmark	121	All sites	Panoramic	Spiral tomography (Scanora)	Implant length and width	To compare panoramic and conventional cross-sectional tomography for preoperative selection of implant size. The aim of the study was to evaluate in how many cases the planned dimensions differed.

**Table 28 - Study characteristics**

Study	No. implants placed in the anterior mandible	Comment
<b>Reddy, M.S. et al 1994[59]</b>	Not possible to state	It is possible that no implants were placed in the anterior mandible.
<b>Schropp, L. et al 2001[62]</b>	0-2	7 of 9 mandibular sites were premolar sites. Therefore maximum 2 anterior mandible but both could have been molar sites. No further detail given.
<b>Frei, C. et al 2004[56]</b>	0	All were lower premolar sites
<b>Diniz, A.F.N. et al 2008[53]</b>	0-49	Paper states 62 mandibular sites and 49 anterior sites. No further detail. All anterior sites could have been maxillary and all mandibular sites posterior or vice versa. No further detail given.
<b>Schropp, L. et al 2011[61]</b>	3	Specific information given in paper

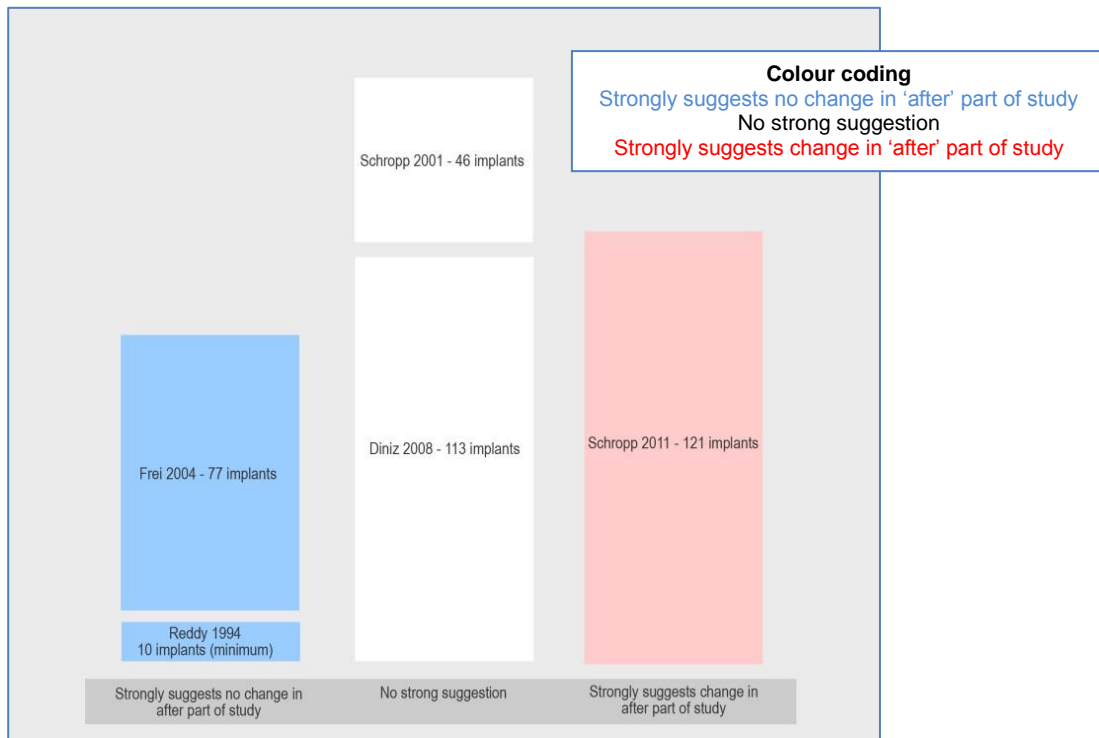
**Table 29 - Number of implants placed in the anterior mandible in each study**



Reference	No. implants placed	No. evaluators	Site	“Before” imaging	“After” imaging	Outcome measures	Results
Reddy et al 1994[59]	10 patients but number of implants not stated	4	NS	Panoramic	Medical multi-slice CT	Mean implant length	Mean implant length before = 10.3 Mean implant length after = 10.8
Schropp et al 2001[62]	46	1	All sites	Panoramic and periapical	Spiral tomography (Scanora)	Implant length and width	Longer implant selected 14/46 Shorter implant selected 11/46 Wider implant selected 5/46 Narrower implant selected 8/46
Frei et al 2004[56]	77	1	Posterior mandible	Panoramic	Spiral tomography (Cranex Tome)	Change or no change in treatment plan	Change in treatment plan 3/77
Diniz et al 2008[53]	113	2	All sites	Panoramic and periapical	Spiral tomography (Cranex Tome)	Implant length, width, bone grafting or other surgical procedures necessary	Longer implant selected 20/113 Shorter implant selected 25/113 Wider implant selected 7/113 Narrower implant selected 7/113 Decision to bone graft N→Y 8/11 Decision to bone graft Y→N 3/113 Decision other surgery N→Y 6/113 Decision other surgery Y→N 1/113
Schropp et al 2011[61]	121	3	All sites	Panoramic	Spiral tomography (Scanora)	Implant length and width	Different implant selected 113/121 Different length 83/121 Different width 80/121 Longer implant selected 68/121 Shorter implant selected 21/121 Wider implant selected 41/121 Narrower implant selected 41/121

Table 30 - Study outcomes

**Colour coding**  
 Strongly suggests no change in 'after' part of study  
 No strong suggestion  
 Strongly suggests change in 'after' part of study



**Figure 27 - Synthesis according to number of implants placed in the studies. Column heights are proportional to number of implants in each study. Colour coding suggests impact on the treatment plan.**



**Figure 28 - Synthesis according to number of evaluators in the studies. Column heights are proportional to number of evaluators in each study. Colour coding suggests impact on the treatment plan.**

#### 4.14 Discussion

A review was performed to investigate the impact of cross sectional imaging prior to dental implant placement in the anterior mandible when implant retained overdentures are planned. A search strategy was developed in an attempt to identify the totality of the relevant literature. This identified only five studies. Quality assessment was carried out using a tool adapted from a recent review of neuroimaging.[205] This revealed significant deficiencies in design in all five studies. Data was extracted using a piloted data extraction form. Nonetheless, heterogeneity suggested that meta-analysis was inappropriate and only a limited narrative synthesis was possible. Currently available evidence is, therefore, of limited usefulness in answering the review question and the impact of cross sectional imaging in this situation remains unclear.

The results of this review are discussed below:

- ▶ 4.14.1 Development of the quality assessment tool. Page 163
- ▶ 4.14.2 Quality of evidence. Page 166
- ▶ 4.14.3 Trends revealed in the results. Page 167
- ▶ 4.14.4 Applicability of review to dental implant placement in the anterior mandible. Page 167
- ▶ 4.14.5 Comparison of the included studies. Page 168
- ▶ 4.14.6 Strengths and limitations of this assessment Page 172
- ▶ 7.1 Recommendations for further research. Page 283

##### 4.14.1 Development of the quality assessment tool

This systematic review evaluates diagnostic and therapeutic impact rather than diagnostic accuracy. The existing quality assessment tools QUADAS<sup>xxx</sup> and QUADAS 2 are designed for the quality assessment of diagnostic accuracy studies and are therefore not appropriate to this review. The rapid scoping exercise returned only observational studies of the “before-after” design. No other study designs were identified such as randomised controlled clinical trials or other observational study designs. In 2009, Albon et al carried out a similar systematic review of the impact of structural neuroimaging in psychosis.[205] Similarly, the authors expected to identify

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<sup>xxx</sup> QUADAS - Quality Assessment of Diagnostic Accuracy Studies

only observational before-after studies and they found that no validated quality assessment tools existed for systematic review of this study design. In response, two of the authors, Meads and Davenport, reported the development and validation of a quality assessment tool for before-after studies.<sup>[206]</sup> This was an adaptation of the original QUADAS tool. This is presented in Table 31 on page 165. Meads' and Davenport's quality assessment tool was discussed with the lead author of the paper and used as a starting point for the development of a quality assessment tool for this review.<sup>[209]</sup> In order to maintain validity, any modifications were restricted to presentation only, thus preserving the content of the tool developed by Meads and Davenport. A major change in presentation to Meads' and Davenport's form was introduced because, unlike all other questions, two of the questions were open and did not elicit answers of "yes", "no" or "unclear". Therefore, a visual analogue scale was introduced in the form of a coloured gradient to indicate a subjective judgement of quality for those questions. A tick mark could then be placed at any point along the scale with red signifying poor quality and green good quality. The same coloured gradient was used behind the "yes", "no" or "unclear" questions to allow a common visual interpretation of both types of questions. Consequently, an overall quantitative assessment score for a whole study was not considered possible because of the open questions. In addition, some questions were considered to carry more weight than others. Therefore, a similar visual analogue scale was also used to record an overall judgement of the study's quality. The final quality assessment form is presented in Table 25 on page 152. The original QUADAS question numbering was retained so that, if necessary, reviewers could refer back to the explanatory notes provided with QUADAS.

There are very few, if any, similar reviews of before-after studies.<sup>[206]</sup> The methodology, therefore, is still in development. The further refinement of Meads' and Davenport's quality assessment tool may inform future systematic reviews of before-after studies and the pioneering methodology may prove to be more important than the results.

Original QUADAS item	Additions for the structural neuroimaging review
1. Was the spectrum of patients representative of the patients who will receive the test in practice?	
2. Were selection criteria clearly described?	A. Were patients recruited consecutively?
3. Is the reference standard likely to correctly classify the target condition?	Removed for the neuro-imaging review
4. Is the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests?	
5. Did the whole sample or a random selection of the sample, receive verification using a reference standard of diagnosis?	
6. Did patients receive the same reference standard regardless of the index test result?	
7. Was the reference standard independent of the index test (the index test did not form part of the reference standard)?	Removed for the neuro-imaging review
8. Was the execution of the index test described in sufficient detail to permit replication of the test?	
9. Was the execution of the reference standard described in sufficient detail to permit replication of the test?	D. Who performed the clinical evaluation and image analysis?
10. Were the index test results interpreted without knowledge of the results of the reference standard?	C. Was the study and/or collection of clinical variables conducted prospectively?
11. Were the reference standard results interpreted without knowledge of the results of the index test?	
12. Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?	
13. Were uninterpretable/intermediate test results reported?	
14. Were withdrawals from the study explained?	B What was the explanation for patients who did not receive CT or MRI?

**Table 31 - QUADAS tool amended by Meads and Davenport [206]**

Other, minor, modifications in presentation were made and a pilot study was carried out using the same five rapid scope studies which were used in the pilot study of the data extraction form. Details of the pilot study are recorded on the webpage set up for this review.

#### 4.14.2 Quality of evidence

No randomised controlled studies were found in the literature search. Only five studies were identified. These were of the uncontrolled before-after design. Uncontrolled observational studies, such as these, already have intrinsic bias. The Cochrane EPOC<sup>xxxi</sup> group comment, “It is difficult, if not impossible, to attribute causation from such studies.”[210] Reeves et al further state, “Potential biases are likely to be greater for non-randomised studies compared with randomised trials, so results should always be interpreted with caution when they are included in reviews and meta-analyses”.[211]

The risk of bias is increased in these studies which suffer from having very few evaluators. The largest number of evaluators was four [59] and two of the studies had only one evaluator. [56, 62] Further, these studies have clinical and methodological diversity and thus significant heterogeneity. Whilst four of the studies used conventional spiral tomography for the ‘after’ part of the study, one used medical, multi-slice, computed tomography. Three of the studies include implants placed in all sites in the mouth, one included only those placed in the posterior mandible and one did not state the sites of the implants. The only common outcome measure, for four of the five studies, was implant length although in some of these studies this is combined with other outcome measures such as implant width and cannot be separated for analysis.

Heterogeneity, the limitations of observational studies in general, the shortcomings of these studies in particular and the small number of included studies suggested that meta-analysis was inappropriate. Reeves et al commented, “Before undertaking a meta-analysis, review authors must ask themselves the standard question about whether primary studies are ‘similar enough’ to justify pooling”.[211] Fitzpatrick-Lewis et al make a more definite recommendation as follows, “Do not meta-analyse results

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<sup>xxxi</sup> EPOC - Cochrane Effective Practice and Organisation of Care Group

from observational studies”. [212] Analysis of the included studies in this systematic review is therefore qualitative. Notwithstanding, it is difficult to draw any firm conclusions even from a qualitative synthesis of these studies. Conclusions that are drawn should be regarded as speculative.

#### 4.14.3 Trends revealed in the results

A subjective judgement, agreed amongst the reviewers, was that only one study suggested that there was a change in the “after” part of the studies. [61] The other four studies suggested that there was no change or there was no strong suggestion. (Table 30 page 161). In Figure 27 on page 162 and Figure 28 on page 162 the column heights are proportional to the number of implants placed and the number of evaluators respectively. Both of these graphical representations suggest that, overall, there is no evidence of impact of cross sectional imaging prior to dental implant placement. Nevertheless, an interpretation of these studies might be that preoperative, cross sectional imaging has an impact where cases are more challenging. For example, in Frei’s study, narrow ridges were excluded from the study and very little difference was observed after cross sectional imaging was introduced (4%). Conversely, in the study of Schropp in 2011, there were no exclusions and patients were those who had been referred to a University Dental Hospital. It is reasonable to assume that these were more challenging cases. In this study, treatment plan changes were made in 93% of sites. Further, in the study of Diniz, statistically significant changes were observed in those more difficult cases which were considered for bone grafting or other surgical procedures. Nonetheless, this is a very speculative conclusion given the limitations of these studies.

#### 4.14.4 Applicability of review to dental implant placement in the anterior mandible

Only one paper allowed separation of the data for dental implant placement in the anterior mandible. [61] In this paper, only three implants were placed in the region. No other authors were explicit about the number of implants placed in the anterior mandible and it is possible that no other implants were placed in this region in any of the other studies. Accordingly, the findings of this review should be interpreted with caution when applied specifically to any area of the mouth. An analysis of the site of implant placement in each of the studies is presented in Table 28 on page 159.

One paper stated that implants were placed only in lower first and second premolar sites.[56] It is the convention that the lower first premolar to canine region represents the border between the anterior and posterior sextants of the mouth and inclusion criteria for this review stated that the studies should, at least, include the “anterior mandible”. Notwithstanding, in the other identified studies, the number of implants placed in the anterior mandible was very small or not stated. Therefore, there must be doubt about the weight of evidence applicable solely to the anterior mandible in any of the included studies. (Table 29 on page 160) Further, it was considered that similar treatment planning considerations would exist for a lower first premolar as for an adjacent canine. Therefore, in view of the limited evidence available, on balance, the reviewers agreed to include this study in the review.

#### 4.14.5 Comparison of the included studies

Two studies, Frei et al 2004 and Schropp et al 2011, were superficially very similar yet reported very different outcomes.[56, 61] In these ‘before and after’ studies, evaluators were asked to choose implant length and diameter. In both studies, the evaluators were shown panoramic images in the ‘before’ part of the study. In the ‘after’ part of the studies, evaluators were, additionally, shown cross sectional images produced by conventional spiral tomography. Despite these similarities, in the study of Frei et al, evaluators changed their selection in the ‘after’ part of the study in only 3 out of 77 cases. These authors concluded, “surgeons hardly need the information from the cross-sectional images in treatment planning.” In the study of Schropp et al, evaluators changed their implant selection in 113 out of 121 cases. Their conclusion was, “selected implant size differed considerably when planned on panoramic or cross-sectional tomography”. A comparison of these two studies is, therefore, of interest.

One relevant factor in the difference between these two studies may be that the sites selected for dental implants were different. Schropp et al 2011, included both maxillary and mandibular sites. The actual figures are not stated but, from a published graph, they can be estimated to be approximately 93 maxillary sites and 29 mandibular sites. In the study by Frei, all the sites were posterior mandibular sites.

In the Schropp 2011 study there were three evaluators. These were a radiologist, a periodontist and a prosthodontist. The experience of these evaluators in planning and surgically placing implants is not stated. Nevertheless, one would expect that the radiologist, at least, would have little practical experience of placing implants. In the



Frei study there is only one observer who is stated to be a surgeon. If this surgeon had extensive experience of planning implants and then placing them, then it might be expected that this experience would lead the surgeon to a practical interpretation of radiographs which is different from, for example, a radiologist. On the other hand the Frei study, with its sole evaluator, represents the opinion of only one surgeon. It may have been that the personality of this person was resistant to changing plan. We cannot know, but both studies are vulnerable to bias because of the small number of evaluators. For example, a recent questionnaire study reported the huge differences in radiographic prescription between different implant practitioners.[213] A small number of evaluators, therefore, is very likely to encounter the problem of an individual's idiosyncratic treatment plan. The differences between the evaluators in these two studies may well have made a significant contribution to the differences in results.

In these two studies, the methods by which the evaluators selected implant sizes were different. In the 2011 study by Schropp there was an element of automation.[61] All images were digitised and evaluators used computer software to mark the boundaries of where implants should be placed. From these boundaries, corrected for magnification, the nearest smaller implant was selected. The evaluators did not choose the implant sizes directly. In the study by Frei, the evaluator was given the original images and asked to plan the case and select dental implants. On this basis, the Frei study represents a more realistic situation, where an operator is most likely to plan directly from original images.

The difficulty of the cases may have been a factor. In Frei's study, cases with a "narrow ridge" were excluded. No such exclusions are stated in Schropp's 2011 study. Therefore the range of cases may have included more difficult situations where sectional imaging may have been more valuable. Also the setting for the Schropp study was a University Dental Hospital. Whilst the setting for the Frei study is not stated, it may be presumed that patients of a University Dental hospital may present more surgical difficulty than in other settings.

Another comparison of interest is the two studies by Schropp et al from 2001 and 2011.[61, 62] These studies seem very similar and are by the same lead author. The setting was the same University Dental Hospital and it seems likely that the same x-ray machines were used. Conventional imaging in the 'before' part of the study was followed by the addition of spiral tomography in the 'after' part of the study. Sites from

the whole mouth were included in both studies and no exclusions were stated. The outcome measure in both studies was the selection of implant length and width.

In 2011, Schropp et al found that in 113 of 121 sites, implant selection changed when cross sectional imaging became available. Change was, therefore, reported at 93% of sites. In Schropp's 2001 study, 46 sites were included. The treatment plan changed in 32, or 70%, of the sites. This raises the question of why there is a difference in the results in these two very similar studies. Again, a major difference is likely to be the evaluator. In the 2011 study, there were three evaluators, a radiologist, a periodontist and a prosthodontist. In the 2001 study there was a single evaluator, stated to be a surgeon. The 2001 results, therefore, represent one person's, possibly idiosyncratic, choices of imaging. This may be very different from the selection of the three evaluators in the 2011 study.

Another difference between the two studies is the method of selection of implant size. In 2011 the method was partly automated. The evaluators outlined the borders of the implant using computer software. In the 2001 study, treatment planning was carried out directly on the available images. Another difference between the two studies is that the 'before' part of the study in 2001 included periapical radiographs as well as panoramic radiographs. In 2011, only panoramic radiographs were included. Interestingly, Schropp et al report in 2001 that most changes in implant selection were made in the mandible. This would be at odds with the findings of Frei et al in 2004 where only three changes were made in 77 implant sites (4%).[56]

The study by Diniz et al in 2006 is similar to the study of Schropp et al in 2001 in that the 'before' part of the studies presented panoramic and periapical images.[53, 62] In the 'after' part of both studies, images from conventional spiral tomography were added. In Diniz's study, the outcome measure was also implant length and width but, in addition, evaluators were asked if bone grafting or, "other surgical procedures", were needed. "Other surgical procedures" were defined as bone augmentation, sinus lifting, nerve repositioning or distraction osteogenesis. From a total of 113 implants placed in this study, the authors report that length changed in 45 cases (40%) and width in 14 cases (12%). Unfortunately the total number of changes is not presented. It is not known how many times both implant length and width was changed in the 'after' part of the study. For example, if all implants which changed width also changed length, then the total number of changes would be 45 (40%). If there were no implants in which both width and length changed, then the total number of changes would be 59 (52%).

It is therefore difficult to compare this study with others on the basis of the total number of changes made in implant selection. This could be between 40% and 52%. Notwithstanding, this is clearly a different result from the similar study carried out by Schropp et al in 2001. Diniz et al carried out statistical analysis of these results using the Wilcoxon signed rank test and, on this basis, reported that neither changes in length nor changes in width were statistically significant. ( $P=0.576$  and  $P=1$  respectively) These authors did report a statistically significant difference in the prescription of both bone grafting ( $P= 0.001$ ) and other surgical procedures ( $P=0.001$ ) using the same statistical test.

In both studies the selection of implants was made directly on radiographic films and implants in all sites of the mouth were included. The setting for the study is not explicit in the study by Diniz but it may be inferred from the text that the patients had all been referred to a University Dental Hospital setting. This is also the case in the study by Schropp in 2001.[62] In Diniz's study the conventional spiral tomography machine was a Cranex Tome.[53] In Schropp's case a Scanora machine was used. Slice thicknesses are not reported. Nevertheless, these are very similar machines and it is not thought to be likely that this explains the differences in results. These differences seem most likely to have arisen because of the difference in the evaluators. Whilst in both cases the evaluators are stated to be surgeons, in Schropp's 2001 study there is only one evaluator and in Diniz's study there are two.[53, 62]. There is no detail in either study of the experience of the surgeons although in the study of Diniz they are described as, "experienced dental implant surgeons". It might be assumed that the evaluators in Schropp's study are Danish, or at least European trained. In Diniz's study it is likely that they are Brazilian or trained in South America. It seems likely that the small number of evaluators in these studies is a major factor in the differences in their results. For example, we cannot know if these individuals had, perhaps, a predisposition or resistance to newer technologies in radiographic imaging.

The oldest study, by Reddy from 1994, is in some ways the most modern of the identified studies.[59] It is the only study which evaluates the impact of true three dimensional imaging. In this study, the 'before' image was a panoramic view. The 'after' images were medical, multi slice, CT images together with a panoramic view. There were four evaluators, simply referred to as "dentists", who selected the length of dental implants for 10 cases. Unfortunately, the sites in which the implants were placed are not reported. Further, the results are presented only as mean values of implant length and no other information is given. The mean value in the 'before' part of the

study was 10.3mm and in the 'after'; part of the study 10.8mm. This was neither statistically nor clinically significant. Nevertheless, these results may have concealed large increases in length which were balanced, when taking a mean, by similarly large decreases in length. It is, therefore, difficult to draw conclusions from this study.

#### 4.14.6 Strengths and limitations of this assessment

Only five, low quality, uncontrolled before-after studies were identified for this review. The limitations of these are discussed in paragraph 4.14.2 on page 166. Thorough systematic review techniques were used to identify a wide range of possible studies to ensure that no relevant studies were missed. Nevertheless, it is possible that publication bias may have restricted the evidence base available for this research. When there is enthusiasm for new technology, there may also be a reluctance to publish studies where no benefit is found.

It must be acknowledged that, whilst all of the identified studies assessed the impact of imaging on selection of implant size, none evaluated the impact on implant position. Clearly, the same size of implant could be placed in either a safe position or one which perforates the lingual plate, potentially causing a life threatening haemorrhage. Therefore, whilst a larger implant might be more likely to perforate the lingual plate, the more crucial issue is implant position.

The purpose of this review was to inform practice when planning dental implants in the anterior mandible. Of some 367 dental implant placements in total in the five identified studies, it can only be said with certainty that three were placed in the anterior mandible. Different treatment planning considerations exist for different areas of the mouth. For example in the posterior maxilla there may be poor quality of bone and a pneumatized, maxillary sinus. In the posterior mandible the concern is often the available bone height above the inferior dental bundle. In the anterior maxilla, the priority might be aesthetic placement and in the anterior mandible there are potential anatomical complications. Therefore, these studies may be only partly helpful in informing practice in a specific area of the mouth such as the anterior mandible.

Whilst it is not always stated in these studies, it is likely that most were carried out in the University Dental Hospital environment. In the UK, Gibson and Barclay reported that the majority of implant placement takes place in the independent practice environment.[51] No studies were identified in which it was stated that the research

was based in independent practice. Those patients treated in dental hospitals might be regarded as a special population. For example, it is reasonable to assume that they will often have been referred to a dental hospital because implant placement is of special difficulty.

No studies were returned from the search which assessed the impact of Cone Beam CT technology. This became widely available around 2005 and might now be regarded as having superseded conventional tomography and, for head and neck imaging, multi-slice, medical CT. Nevertheless, despite two of the studies being published in 2008 and 2010, the impact of Cone Beam CT was not considered.[53, 61] Four of these studies used conventional spiral tomography which produces very different images from cone beam CT. In that regard these studies are only partly helpful with regard to currently used technology.

#### 4.15 Conclusion

There is very little evidence to evaluate the impact of cross sectional imaging prior to dental implant placement in the anterior mandible. Those studies which exist are generally low quality observational studies of the uncontrolled before-after design. No studies were identified which evaluated the impact of the latest Cone Beam CT technology.

Five studies were selected for this review and, with one exception, they were unclear in reporting the sites in which implants were placed. Therefore conclusions may not be drawn which apply specifically to implants placed in the anterior mandible.

The five studies reported wide differences in their results. An important factor to explain these differences may be the variation in practice of the individual evaluators. Two studies had only a single evaluator and the maximum number was four. The results may therefore have reflected idiosyncratic practices of individual evaluators.

Little can be concluded from a synthesis of these studies because of their small number, clinical diversity and high risks of bias. Notwithstanding, it may be inferred that cross sectional imaging has an impact on the more challenging cases. There is a need for high quality studies to investigate the impact of current cross sectional imaging technology prior to dental implant placement in the anterior mandible.

The higher levels of evaluation of the efficacy of diagnostic imaging are levels three to six. These were described by Fryback and Thornbury and concern the impact of diagnostic imaging.[46] In terms of efficacy at these higher levels of evaluation, this review has found no evidence to support any specific imaging modality when planning dental implant placement in any region of the mouth. Therefore, those who argue that cross-sectional imaging should be used for the assessment of all dental implant sites are unsupported by evidence.[42] This is, of course, also true for those who argue that conventional radiography is preferred. The questionnaire study presented in this thesis has suggested that implant practitioners in the North West of England base their imaging decisions on other factors.[213] For example, younger practitioners are more likely to prescribe three dimensional imaging than experienced practitioners. Those who have a cone beam CT machine available are more likely to prescribe three dimensional imaging regardless of the difficulty of the case.

There are no other examples of systematic reviews of studies at higher levels of diagnostic efficacy in any aspect of dentistry. Therefore, the method developed in this review may serve as a model for future systematic reviews of such studies.

#### 4.16 Dissemination

This systematic review was registered with the University of York Centre for Reviews and Dissemination PROSPERO website.<sup>xxxii</sup> In addition, a dedicated webpage has been set up in order to exchange information between members of the review team and to canvas for on-going studies.<sup>xxxiii</sup> This review has been published in the journal "Dentomaxillofacial Radiology"[214]

#### 4.17 Implications for the next stage of this research

None of the identified studies evaluated the impact of CBCT. Therefore, there is a need for studies which evaluate current technology. All of the studies included in this review assessed the impact of imaging modality on the selection of implant size but none evaluated the impact on osteotomy position. Therefore, they do not fully address

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<sup>xxxii</sup> International Prospective Register of Systematic Reviews (PROSPERO) website

[www.crd.york.ac.uk/PROSPERO/](http://www.crd.york.ac.uk/PROSPERO/)

Registration number CRD42013004267

<sup>xxxiii</sup> [www.andrewshelley.com/systematic\\_review.html](http://www.andrewshelley.com/systematic_review.html)

the risk of haemorrhage. In other words, these studies are applicable only to Fryback and Thornbury's level four, treatment planning efficacy. A study to address the impact of imaging modality on the risk of haemorrhage would be at Fryback and Thornbury's level five, patient outcome efficacy. There is a need for such a practical study which evaluates the impact of different imaging modalities when drilling osteotomies for dental implant placement. A before-after study, using "drillable models" of the anterior mandible, is a potential research methodology to address this issue.

The studies which were identified for this review investigated between ten and 121 dental implant placements. Nevertheless, the maximum number of evaluators was four while two studies had only one evaluator. These studies were at high risk of bias as the results reflected the possible idiosyncratic views of a very small number of evaluators. There is a need for a study with an appropriate sample size calculation and a more representative spread of participants. There is uncertainty in these studies about where dental implants have been placed. The differing treatment planning considerations in each area of the mouth suggest that studies should be conducted which are limited to one area of the mouth or are explicit about the results in each area.

The majority of dental implant placements in the UK are carried out in the independent practice environment. Almost all such research is carried out in the University Dental Hospital setting where the participants might be regarded as forming a special group. There is, therefore, a need for practice based research into the impact of diagnostic imaging on dental implant placement.





**5 Part 4 - Development of a dental simulation for use in a before-after study**



## 5.1 Introduction

Fryback and Thornbury's higher levels of evaluation of efficacy of diagnostic imaging address impact. These are: diagnostic thinking efficacy (level three), therapeutic efficacy (level four), patient outcome efficacy (level five) and societal efficacy (level six).[46] A systematic review has found very little evidence to enable evaluation of the impact of cross sectional imaging prior to dental implant placement either in the anterior mandible or in other sites. [214] With regard to lingual perforation when drilling osteotomies in the anterior edentulous mandible, there are no studies which address the impact of imaging methods. For this, a practical study is required in which participants prepare osteotomies in mandibles with the guidance of different image types. A possible study design is the 'before-after' study. [196] Such a study would require the availability of a range of identical mandibles for which multiple images would be available. The same panel of implant practitioners would then be able to prepare osteotomies in identical cases with or without the availability of cross sectional images. This chapter describes the development of a realistic dental simulation which allows presentation of a range of identical mandibles for which a range of different image types is available.

### 5.1.1 Aim and objectives

#### Aim

To develop a lifelike dental simulation which provides drillable models of edentulous mandibles with corresponding images. The simulation would be used to conduct a practical exercise with a panel of dentists who would be asked to drill osteotomies prior to dental implant placement in the lower canine regions to support an overdenture.

#### Objectives

1. To develop a dental simulation which:
  - ▶ Presents drillable models which realistically represent hard and soft tissue
  - ▶ Reproduces clinical circumstances as far as possible
  - ▶ Is portable so that it can be quickly set up in participants' dental practices
  - ▶ Can be easily fixed to a dental chair

- ▶ Enables drillable models of different mandibles to be quickly exchanged.
- ▶ Reduces the time required by participants by having bone exposed by a typical surgical flap

2. To produce images which:

- ▶ Are realistic
- ▶ Correspond exactly to the drillable models of the mandibles
- ▶ Are presented in a format in which they would normally be viewed in practice
- ▶ Reduce the time required by participants by having typical measurements made in advance.

## 5.2 Method

### 5.2.1 Image selection

A previous study has demonstrated that most practitioners in the North West of England who place dental implants base their radiographic prescription around either panoramic radiographs or CBCT images.[213] The 2013 guideline document 'Selection Criteria in Dental Radiography' further recommends the transsymphyseal view as a two dimensional radiographic technique which gives an image of the midline of the mandible and is similar to a cross sectional view. [32, 34] Therefore, for this simulation, the two dimensional images selected were the panoramic view and the transsymphyseal view. The selected cross sectional images were derived from CBCT. The sites of the proposed dental implants were chosen to be 10 mm either side of the midline of the mandibles. [31, 192] For the panoramic view, 5mm steel balls were placed at the sites of the proposed implants. For the transsymphyseal view, a 5mm steel ball was placed at the midline. This enabled measurements to be taken using the steel ball as a reference diameter. For the CBCT imaging, gutta percha markers were placed at the sites of the proposed implants.

### 5.2.2 Acquisition and presentation of the images.

Two edentulous mandible specimens were acquired from private historical collections. A further two were acquired from the collection of the Royal College of Surgeons of England Museum. These four specimens were used in accordance with the Human Tissue Authority Licence for research of the University of Manchester.<sup>xxxiv</sup> All were at least 100 years old at the time of the introduction of the UK's Human Tissue Act in 2004. The four mandibles were selected to represent a range of difficulty of implant placement. (Figure 29 page 181)



**Figure 29 - The four edentulous mandibles selected for reproduction in the dental simulation. ID assigned - clockwise starting upper left, HD, RL, RS, MG**

The mandibles were placed in x-ray water phantoms to produce images. The x-ray water phantoms are described in Section 3.2.1 on page 57 and Figure 10 on page 61. However, in brief, the x-ray phantoms consisted of containers in the stylised form of the lower third of the head and the neck and contained water as a soft tissue equivalent. They allowed a human spine and mandible to be positioned within them and were supported by a tripod system.

<sup>xxxiv</sup> Human Tissue Authority Licence No. 12172. Granted to the University of Manchester under Section 16 (2) (e) (ii) of the Human Tissue Act 2004.

The following images were acquired for each specimen. Details of the x-ray machines and exposure factors for these images are shown in Appendix L on page 313.

- ▶ Conventional images
  - A panoramic view with 5mm steel balls at the proposed sites of implants.
  - A transsymphyseal view with a 5mm steel ball.[32]
  
- ▶ Three dimensional image
  - A Cone Beam CT image with gutta percha markers at the proposed sites of the implants.

The panoramic and CBCT images were in digital format. The transsymphyseal images were taken on conventional film but were scanned into digital format.<sup>xxxv</sup> Using the proprietary software 'One Volume Viewer'<sup>xxxvi</sup>, cross sectional CBCT images of the mandibles were prepared perpendicular to the line of the arch at the sites of the proposed dental implants.

#### Preliminary study to establish typical measurement requirements

In order to reduce the time required for the practical exercise, it was intended to mark measurements on the available images in advance. A preliminary study was conducted to establish typical measurement requirements. Four dental practitioners were recruited who regularly place dental implants in private practice. They were not selected for the main study to avoid possible future bias. The practitioners were sent, electronically, a full set of images for each mandible in a Microsoft Word document.<sup>xxxvii</sup> They were asked to print the document, examine the images and to mark the measurements they would require to assist dental implant placement in the lower canine regions. The results for each image were reassembled onto a single page so that a judgement could be made of the typical measurements requested. An example is shown in Figure 30 on page 183.

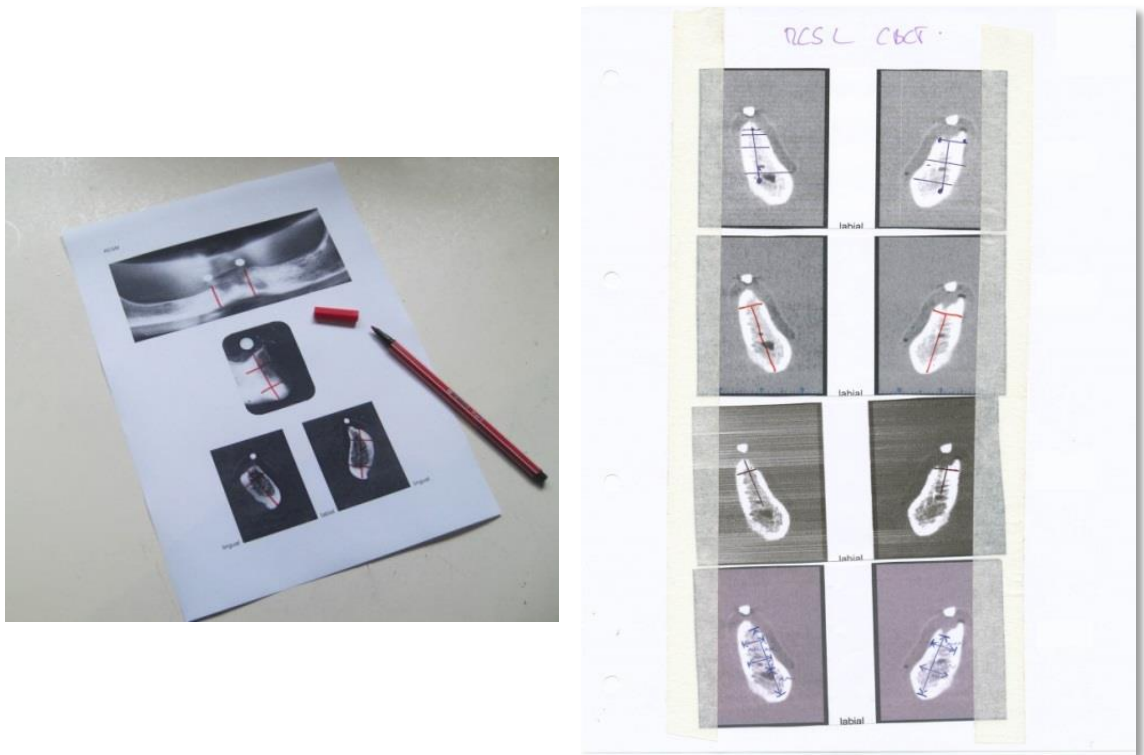
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<sup>xxxv</sup> Canoscan 8800F – Canon Inc. Tokyo, Japan.

Scanning parameters - positive colour film mode, 300dpi

<sup>xxxvi</sup> One Volume Viewer – J Morita Mfg. Corp. Kyoto, Japan

<sup>xxxvii</sup> Word – Microsoft Inc. Redmond, WA. USA.



**Figure 30 - Example of results of the preliminary measurement study and images reassembled for analysis**

### Presentation of the images

The dimensions of each typical measurement were calculated. For the CBCT images, 'One Volume Viewer' was used. For the panoramic and transsymphyseal images, measurements were calculated using the software 'Image J'<sup>xxxviii</sup> with the 5mm steel balls as a reference diameter. All the digital images were saved as .jpeg<sup>xxxix</sup> files and the measurements were marked on them using Adobe Photoshop software.<sup>xi</sup> Finally the images were compiled for presentation in a .pdf document using Adobe Acrobat software.<sup>xl</sup> The images were presented on a laptop computer, a Sony Vaio PCG-71911M<sup>xii</sup>. The images were presented with one image per page with the exception of the CBCT images which were presented with left and right side on one

<sup>xxxviii</sup> Image J. National Institute of Health, Bethesda, Maryland. USA

Public Domain software available from <http://rsbweb.nih.gov/ij/index.html>

<sup>xxxix</sup> Jpeg – Joint photographic experts group

<sup>xi</sup> Adobe Systems, San José, Ca, USA.

<sup>xii</sup> The Sony Corporation, Tokyo, Japan.

page. For clarity of viewing each image was available with and without the superimposed measurements.

The set of images presented in the “before” part of the study are presented in Table 32 on page 184. The set of images presented in the “after” part of the study are presented in Table 33 on page 184. The full set of images is illustrated in Figure 31 on page 185.

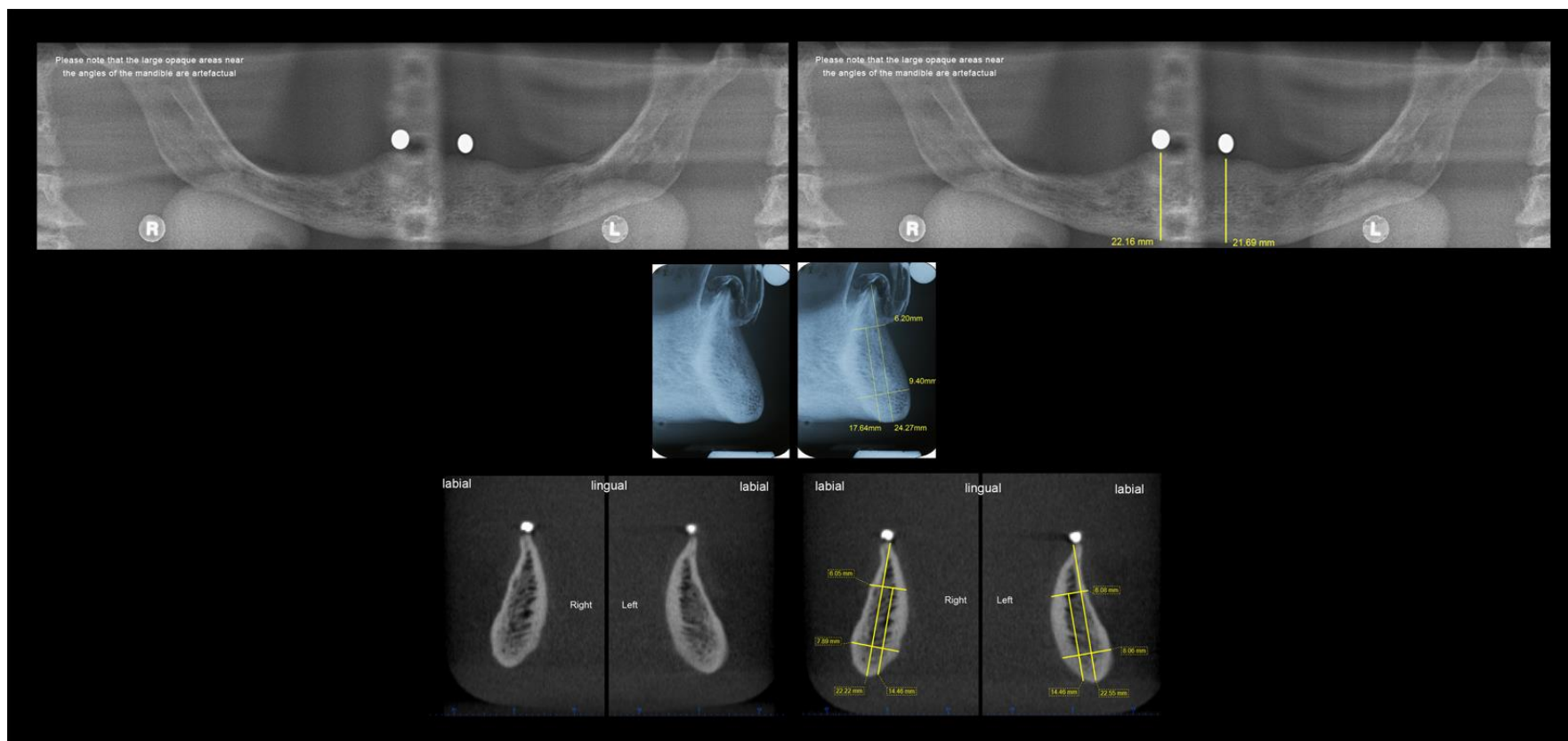
Digital Images	
Panoramic	Full image without measurements
	Full image with measurements
Transsymphyseal	Full image without measurements
	Full image with measurements
Conventional images	
Transsymphyseal	Original films presented on an illuminated radiographic viewer with manufacturers' transparencies available

**Table 32 - Images available for the ‘before’ part of practical exercise  
- two dimensional images only**

Digital Images	
CBCT	Full data set using ‘One Volume Viewer’
	Pre-prepared cross sectional images at sites of proposed implants without measurements
	Pre-prepared cross sectional images at sites of proposed implants with measurements
Panoramic	Full image without measurements
	Full image with measurements
Transsymphyseal	Full image without measurements
	Full image with measurements
Conventional images	
Transsymphyseal	Original films presented on an illuminated radiographic viewer with manufacturers' transparencies available

**Table 33 - Images available for the ‘after’ part of practical exercise  
- two dimensional and CBCT images**





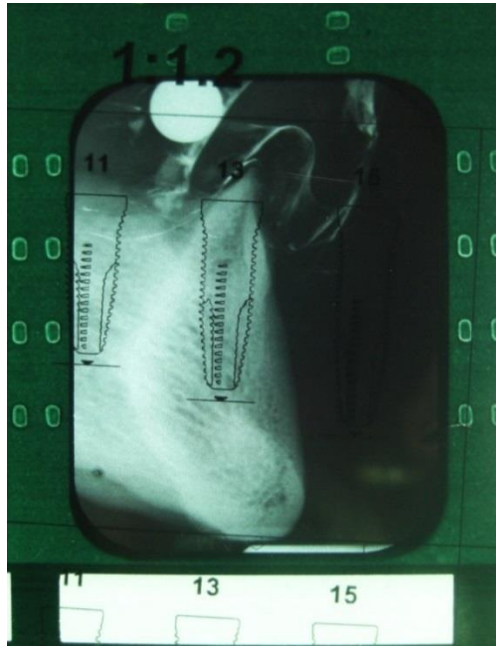
**Figure 31 - A full set of images, for one of the four mandibles, presented to participants.**

**Top row - Panoramic radiographs without and with measurements**

**Middle row - Transsymphyseal view without and with measurements**

**Bottom row - CBCT cross sectional images at the sites of implant placement without and with measurements**

In addition to the digital images presented in the pdf document, the CBCT images could be fully explored on the same laptop computer using the manufacturer's software, "One Volume Viewer". The original transsymphyseal images were made available on conventional film. These could be further examined using the implant manufacturer's transparency of implant sizes and shapes with appropriate allowance for image magnification. (Figure 32 page 186)



**Figure 32- Use of a manufacturer's transparency to take measurements directly from conventional film**

### 5.2.3 Production of the bone analogue material

A material was produced which was intended to reproduce the look, radiopacity and feel of bone when drilling. A mixture of barium sulphate<sup>xlii</sup>, sodium bicarbonate<sup>xliii</sup> and water was added to polyurethane casting resin<sup>xliv</sup>. The proportions by weight are shown in Table 34 on page 187. The result, cast into an impression of an edentulous mandible and sectioned, is shown in Figure 33 on page 187. The material was again cast into an impression of a mandible and a plain film radiograph was taken using a supero-inferior projection. (See Appendix Lon page 313 for exposure factors and machine details – set for periapical view) The results are shown in Figure 34 on page 188.

<sup>xlii</sup> Barium Sulphate, APC Pure, Audenshaw, Manchester. UK

<sup>xliii</sup> Sodium Bicarbonate, Tesco Stores Ltd, Cheshunt. UK..

<sup>xliv</sup> SG2000 Fast Cast Polyurethane Resin System. MB Fibreglass, Newtownabbey, N.Ireland.

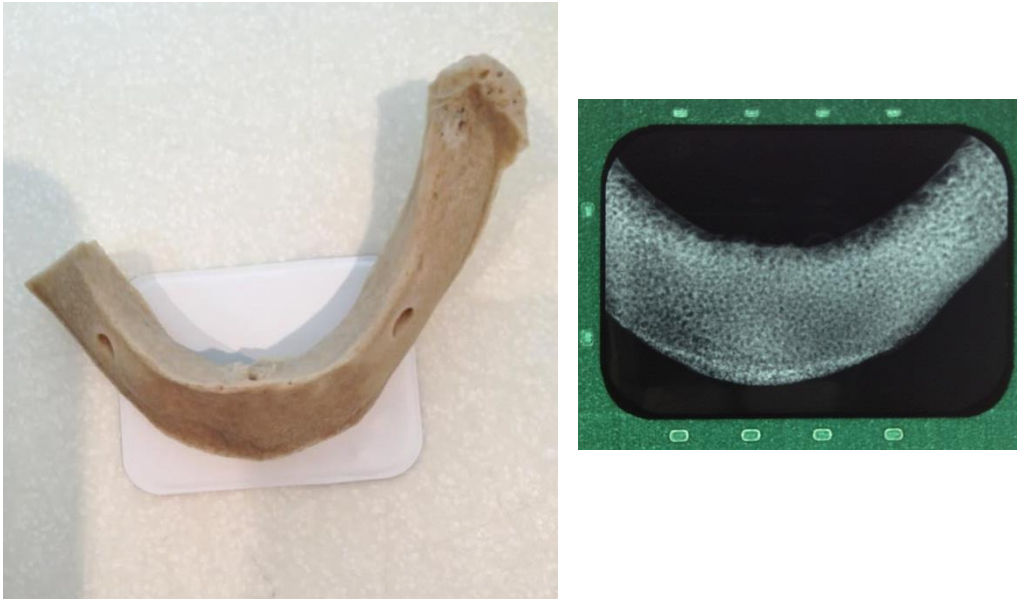


**Figure 33 - Sectioned cast of mandible in the bone analogue material**

**Bone analogue material by weight**

<b>Polyurethane resin</b>	64.00%
<b>Barium sulphate</b>	32.00%
<b>Water</b>	3.20%
<b>Sodium bicarbonate</b>	0.80%

**Table 34 - Composition of the bone analogue material**



**Figure 34 - Radiograph of a cast of a mandible in a polyurethane resin, barium sulphate, water and sodium bicarbonate mixture**

#### 5.2.4 Formation of the bone analogue material

Impressions were taken of the full volume of the anterior part of the mandible specimens using a clinical, addition cured, silicone putty impression material.<sup>xlv</sup> Figure 35 page 189) Duplicates of the mandible specimens were cast from these impressions. The mix of unset material was very fluid which allowed it to be easily poured. The two parts of the impression were held together with elastics and mounted vertically. This allowed the casts to be poured from one side. Visualisation of material on the opposite side demonstrated that the impression was fully cast. After setting, the two parts of the impression were separated and the duplicates of the mandibles removed. Final finishing consisted of removing any flash of material with a scalpel. (Figure 36 page 189)

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<sup>xlv</sup> Provil Novo Putty fast set. Heraeus Kulzer GmbH, Hanau, Germany



**Figure 35 - Impression taking of edentulous mandible specimens**



**Figure 36 - Pouring casts of edentulous mandibles in the laboratory using the bone analogue material**

### 5.2.5 Formation of the soft tissue analogue

With written consent, a number of clinical reference photographs of lower edentulous ridges were taken which represented a plausible match to the four dried edentulous mandible specimens. (Figure 37 page 190) The subjects were all patients of the author's practice. These photographs were used as references to create wax master models representing soft tissue around the duplicate mandibles. These were crafted by hand in modelling wax.<sup>xlvi</sup> An example is shown in Figure 38 on page 191.



**Figure 37 - Clinical reference photographs of edentulous ridges**

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<sup>xlvi</sup> Kemdent Anutex Eco Modelling Wax, Associated Dental Products Ltd, Swindon, UK



**Figure 38 - Wax master model containing duplicate mandible**

Three dentists were asked to recreate the exposure of bone produced by raising surgical flaps in the wax models. (Figure 39 page 192) All three were on the UK's specialist list for oral surgery with considerable experience of dental implant placement. Two taught on postgraduate programmes in dental implantology. The dentists were told that the case had been planned to receive dental implants in the lower canine regions and asked to reveal the bone to the same extent that they would do in the clinical situation. The panel were supplied with the full range of images that were available for each mandible. These were a panoramic view, a transsymphyseal view and CBCT images, produced as described in section 5.2.2 on page 181. The reference photograph was also provided. The panel could also fully explore the CBCT images using the proprietary software 'One Volume Viewer'.

The results of this exercise were recorded by taking an impression in silicone impression putty. These impressions were then cast in dental plaster. There were three panel members and four mandibles and, therefore, twelve recordings in total. (Figure 40 page 192)

The part of the cast representing soft tissue was painted pink so that it could be easily distinguished from the part representing underlying bone. The author could then make a judgement of a typical surgical flap for each of the edentulous mandibles. (Figure 40 page 192)



**Figure 39 - A dentist recreating surgical flaps in a wax model**



**Figure 40 - Casts of the results of the surgical flap preliminary study**

In addition to the preliminary study on surgical flaps, four textbooks of surgical implantology were consulted. [31, 215-217] The results of the surgical flap exercise, together with the advice in the textbooks, were used to make a judgement on a typical



flap for each of the cases. Final wax master models were made, one for each of the four mandibles, with bone exposed as suggested by this preliminary study. These final models also included an indication of the intended sites of dental implants by cutting small notches on the labial and lingual of each site. (Figure 45 page 195) Identification marks were also cut into the wax so that the final drillable models could be easily distinguished from each other.

A material was selected as a soft tissue analogue. This was a silicone rubber<sup>xlvii</sup> with a Shore hardness of 40 which was, subjectively, similar to soft tissue. A pink colour was chosen to represent soft tissue. A test radiograph demonstrated that the material was largely radiolucent. (Figure 41 page 193)



**Figure 41 - Radiograph of the soft tissue analogue material**

Each master wax model was invested in commercially available, synthetic die stone<sup>xlviii</sup>. (Figure 42 page 194) The investment was then sprayed with a separating medium, Ease Release 200<sup>xlix</sup>. The master models were invested in an inverted position. This allowed the duplicate mandibles to be placed firmly into the die stone maintaining their correct position within the drillable model. (Figure 43 page 194) The soft tissue analogue silicone was then poured around the duplicate mandibles. (Figure 44 page 194) After setting, the final drillable models were released from the silicone mould and finished by removing any flashes of material with a scalpel and scissors. Figure 45 on page 195 shows a final drillable model and illustrates how the soft tissue analogue material can be separated from the duplicate mandible with a periosteal elevator in a similar way to clinical surgery.

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<sup>xlvii</sup> Smooth-Sil® 940 Platinum Cure Silicone Rubber. Smooth-On Inc. Pennsylvania. USA

<sup>xlviii</sup> Skillstone Gold+. Skillbond Direct Ltd. High Wycombe, Bucks. UK.

<sup>xlix</sup> Ease Release 200. Mann Release Technologies Inc. Easton, PA. USA



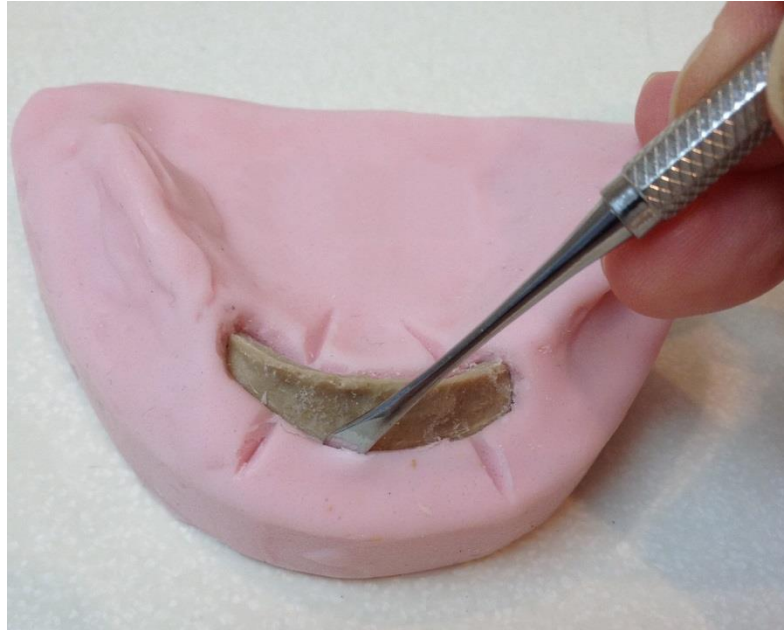
**Figure 42 - Investment of wax model in die stone**



**Figure 43 - Mandible analogue placed in inverted position**



**Figure 44 - Pouring of silicone soft tissue analogue**



**Figure 45 - Example of a final drillable model used in the study**

#### 5.2.6 Phantom head

A commercially available phantom head was acquired which was portable and could be easily set up in dental surgeries.<sup>1</sup> This is illustrated in Figure 46 page 196. A model of an edentulous upper ridge was placed better to reproduce the clinical situation. The manikin could be secured to a dental chair head rest by means of Velcro straps. It could be further posed in a comfortable position for operators by means of universal joints. Within the manikin, the holder for the lower model was adjustable so that the drillable models could be quickly exchanged and securely placed.

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<sup>1</sup> Nissin Dental Simulation System, Simple Manikin II. Nissin Dental Products Inc. Kyoto, Japan



**Figure 46 - Phantom head (Nissin Simple Manikin II)**

## 5.2.7 Evaluation of the dental simulation

### 5.2.7.1 Method

Two dental practitioners were selected through personal contacts. These practitioners were chosen on the basis that they were experienced implant surgeons working in the practice environment.

The practitioners were presented with:

- ▶ The phantom head
- ▶ Four drillable models each containing duplicate mandibles
- ▶ A set of images for each drillable model (Figure 31 page 185)
- ▶ Manufacturer's transparencies for assessment of transsymphyseal images on conventional film. (Figure 32 page 186)
- ▶ A set of implant surgery instruments
- ▶ An implant motor with a straight and a contra-angle handpiece<sup>li</sup>

For two of the cases, the participants were presented with the conventional images only. (Table 32 page 184) For the other cases they were presented with both the conventional and the cross sectional images. (Table 33 page 184)

The panel were asked to consider the available images and then drill osteotomies for implant placements in the lower canine regions. The panel were asked to select implants and drill osteotomies for the Neoss Dental Implant System<sup>liii</sup>. (Figure 47 page 198) They were then asked to complete an evaluation survey. There were three questions as follows:

- 1 Do you think that the presentation of the case and the artefacts is a reasonable reproduction of clinical circumstances? Would you suggest any improvements?
- 2 Is the method of presentation of the images sensible? Would you suggest any improvements?
- 3 Do you have any general comments about the way the study has been conducted or any suggestions to improve the process from the participant's point of view?

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<sup>li</sup> W&H Dental Implant Motor & Handpiece, W&H Dentalwerk, Bürmoos, Austria,

<sup>liii</sup> Neoss Ltd, Harrogate, Yorkshire.



**Figure 47 - Osteotomies being prepared in the evaluation of the dental simulation**

#### 5.2.7.2 Results

The practitioners agreed that the dental simulation was a realistic reproduction of clinical circumstances and did not offer any suggestions for improvements. One found it helpful to have the CBCT viewing software available so that the surgical site could be explored. The other panel member felt that pre-prepared sections provided sufficient information. One panel member completed the exercise in 40 minutes and the other in 60 minutes including time for setting up the materials.

### 5.3 Discussion

The process of development of the bone analogue material was an incremental one. Initially, polyurethane casting resin was used. This is a commonly used bone analogue in training models for surgery.[218-220] To give the material the appearance and feel of trabecular bone, a “blowing agent” was used. Blowing agents are used commercially to create foaming in polymers. In this case, sodium bicarbonate was mixed with a small amount of water and added to the unset polyurethane resin. The exothermic setting reaction of the polyurethane resin heated the mixture releasing bubbles of carbon dioxide. This material produced an appearance similar to that of trabecular bone. The surface of the material remained unaffected by the blowing agent so giving an intact outer layer similar to cortical bone. The material was further developed by adding barium sulphate<sup>liii</sup> to produce radiopacity. The addition of barium sulphate also produced a slight resiliency in the material which was considered to be more bone-like than the polyurethane, water and sodium bicarbonate mixture alone.

There were several requirements for the soft tissue analogue. The soft tissue analogue material would form the base of the models as well as represent soft tissue around the duplicate mandibles. Therefore, the material needed to be stiff enough to firmly engage into a phantom head but flexible enough to be manipulated in a similar way to soft tissue. The material also had to be non-adhesive to the bone analogue material thereby allowing participants to separate the soft tissue from the bone. They would then be able to explore under a flap as they would be able to do in the clinical situation. There was also a need for the soft tissue analogue material to be radiolucent or semi radiopaque. Therefore, if appropriate, radiography could show a distinction between the soft tissue and bone analogues.

The proposed before-after study is essentially an extended questionnaire with the addition of a practical exercise. It has been demonstrated that the time taken to complete questionnaires is an important part of the decision to participate.[78, 80, 105, 221] Therefore, for the purposes of this study, image measurements were made in advance so that the time asked of the participants was reduced as far as reasonably practical. Nonetheless, one panel member asked to use the CBCT software ‘One Volume Viewer’ so that they could take their own measurements. Therefore, it may be helpful to include this as an option when implementing such a study.

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<sup>liii</sup> Barium Sulphate, APC Pure, Audenshaw, Manchester. UK

To further reduce the time taken to complete the practical exercise, bone was exposed in advance on the models. This followed a preliminary study to determine a typical exposure of bone by a surgical flap. The results showed significant variation. One surgeon was consistently conservative whilst another was consistently more radical. Figure 48 on page 200 demonstrates the contrast in the extent of the exposed bone between the most conservative and the most radical surgeons for one of the cases.



**Figure 48 - Casts of the results of the surgical flap preliminary study to show the contrast between the most conservative and most radical flaps for the same case**

The implants selected for the study were Neoss dental implants. These were chosen because they offer a choice between parallel sided and tapered implants. There is also a large selection of lengths and widths available. It is therefore likely that participants will find that a Neoss dental implant will be available which is similar to their preferred implant system. On the other hand, some implant systems have a bewildering choice of different implant designs, connections and surfaces which could complicate decision making for this study. The Neoss system, therefore, was felt to be a good compromise between a representative implant selection and overwhelming choice.



## 5.4 Assessment of the prepared osteotomies

### 5.4.1 Method

#### 5.4.1.1 Assessment by imaging

It was envisaged that assessment of the osteotomies prepared by the participants would be carried out by taking CBCT images of the duplicate mandibles within the models. A method was devised whereby eight drillable models could be trimmed to size and mounted in a cylindrical container which fitted within one of the cylindrical fields of view available on the 3D Accuitomo 170 CBCT machine. (Figure 49 page 201) Different orientations of the drillable models and immersion in water were attempted.



**Figure 49 - Prepared drillable models mounted in a container to be placed in CBCT machine**

#### 5.4.1.2 Assessment by direct vision

As an alternative to the assessment of prepared osteotomies by imaging, a method was devised to make the assessment by direct vision. First, the duplicate mandibles were stripped from the soft tissue analogue material. (Figure 50 page 202) Secondly, they were inspected visually for perforations by passing a blunt probe into the osteotomy. (Figure 51 page 202) Finally, they were sectioned along the line of the osteotomies to identify near misses. (Figure 52 page 203) (Figure 53 page 203)



**Figure 50 - Removal of a duplicate mandible from the soft tissue analogue**



**Figure 51 - Inspection of a duplicate mandible for perforations by passing a blunt probe into the prepared osteotomy**



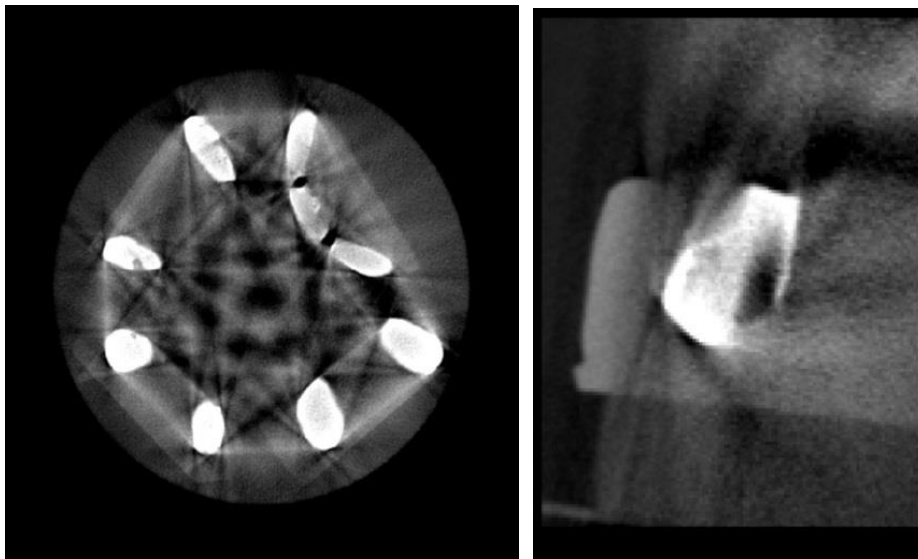
**Figure 52 - Sectioning of a duplicate mandible along the line of the osteotomy to allow inspection**



**Figure 53 - Duplicate mandible sectioned to allow inspection of the prepared osteotomy. This demonstrates a near miss.**

### 5.4.2 Results

The images produced by the imaging method were disappointing. (Figure 54 page 204) Artefact made it impossible to accurately identify which osteotomies had perforated the mandibles. Nonetheless, assessment of the osteotomies by direct vision proved to be simple and successful.

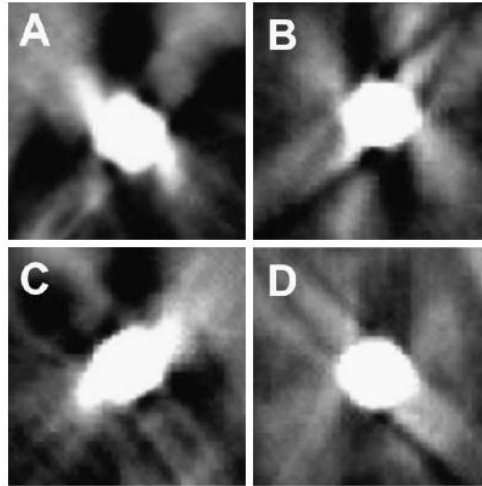


**Figure 54 - Results of imaging of drillable models in CBCT machine**

### 5.4.3 Discussion

The artefact produced using the imaging method was comparable to that seen by Draenert et al.[222] These authors placed titanium dental implants into polyurethane bone replicas and produced strikingly similar images. (Figure 55 page 205) It was assumed that the artefact in the study by Draenert et al was produced by the titanium. The “streak” artefacts seen in CBCT scans are due to a combination of causes, including beam hardening, extinction artefacts and the cone beam effect. This subject has been well reviewed by Schulze et al but in practice it is rarely possible to explain streak artefacts as being due to one specific cause.[223] In the study of Draenert et al, the bone analogue material was largely polyurethane and it might be speculated that artefact formation was promoted by the large difference in radiopacity between titanium and polyurethane. In the current study, however, barium sulphate was used in the bone analogue material and no implants were placed, yet the artefacts were still

severe. The large difference in X-ray attenuation between the samples and surrounding air might explain this, but the use of a soft tissue equivalent in the form of a water bath, did not improve the situation. One further contributory factor may be that the quite regular geometric arrangement of the osteotomy holes in the container could have accentuated artefact formation. Further research would be necessary to determine the reasons for the artefacts.



**Figure 55 - Artefact produced in the study by Draenert et al [222]**

Alternative methods of assessing the results of the drilling exercise proved to be very simple. After stripping out the duplicate mandibles from the soft tissue analogue, perforations could be easily identified visually or by passing a probe into the osteotomy site. Sectioning the mandible replicas at the site of the osteotomies proved to be a convenient method to identify near misses. (Figure 52 page 203) (Figure 53 page 203)

## 5.5 Conclusion

The development of a unique dental simulation has been described which can be used in a before-after study. Duplicate mandibles, which have a similar feel and appearance to bone when preparing osteotomies for dental implants, are mounted in a silicone soft tissue analogue in a phantom head. The duplicate mandibles are made from impressions of real mandible specimens. The original mandible specimens can be placed in an x-ray phantom so that multiple x-ray images can be produced which match the duplicate mandibles in the phantom head. A preliminary evaluation suggests that this dental simulation is as close a representation of implant surgery as realistically possible.

The postoperative evaluation of the prepared osteotomies was unsuccessful by imaging due to unforeseen artefact. Nevertheless, sectioning the duplicate mandibles and using direct vision proved to be a successful and practical method to assess the prepared osteotomies.

## 5.6 Implications for the next stage of this research

These methods may be useful in future studies which evaluate the impact of diagnostic imaging in implant surgery. The next part of this research describes the use of this model in a before-after study in the context of imaging prior to implant placement in the anterior edentulous mandible.

- 6 Part 5 - A before-after study using a dental simulation to evaluate the impact of cone beam CT imaging when placing dental implants in the anterior edentulous mandible**





## 6.1 Introduction

No evidence exists to evaluate the impact of cone beam CT imaging when placing dental implants in the anterior edentulous mandible to support a complete lower overdenture.[43, 44, 46, 214, 224] The primary research question for this study was, “What is the impact of cone beam CT imaging on the incidence of perforation of the lingual cortical plate when placing dental implants in the anterior edentulous mandible?”

### 6.1.1 Aim and objectives of this study

#### Aim

To evaluate the impact of cone beam CT imaging on the incidence of perforation of the lingual cortical plate when placing dental implants in the anterior edentulous mandible, using a ‘before-after’ study design.

#### Objectives

1. To recruit dentists who surgically place dental implants in the practice environment.
2. To ask the dentists to drill osteotomies in preparation for dental implants in the lower canine regions to support a complete overdenture, before and after the availability of cone beam CT images, employing the dental simulation described in “Part 4 - Development of a dental simulation for use in a before-after study” beginning on page 177.
3. To record perforations or “near miss” perforations when preparing osteotomies before and after the availability of cone beam CT images

## 6.1.2 Null hypotheses

### 6.1.2.1 Primary hypothesis

- ▶ There is no significant difference in the proportion of lingual perforations or “near miss perforations” before or after the availability of cone beam CT images

### 6.1.2.2 Supplementary hypotheses

- ▶ There is no significant difference in the preoperative selection of length, width or design of implant before and after the availability of CBCT
- ▶ There is no significant difference in the preoperative assessment of difficulty of implant placement before and after the availability of CBCT
- ▶ There is no significant difference in the perception of need for special surgical procedures before and after the availability of CBCT.

## 6.2 Materials and methods

### 6.2.1 Study design

There were three parts to the materials and methods in this study

- ▶ Preliminary study of case difficulty Page 212

A preliminary study was conducted to establish opinion on the difficulty of the four cases

- ▶ Pilot study Page 213

A pilot study was conducted to evaluate the conduct of the before after study.

- ▶ Definitive study Page 216

Materials and methods for the definitive study are described under the following headings

Sample size	Page 216
Recruitment of dentists to the study	Page 218
Ethical approval	Page 219
Presentation of case histories and photographs	Page 220
Implementation	Page 221
Data collection	Page 225

### 6.2.2 Preliminary study of case difficulty

#### Aim

A preliminary study was conducted to establish opinion on the difficulty of the four mandibles selected for the study and presented in Figure 29 on page 181.

#### Method

Four dental practitioners were recruited who regularly place dental implants in private practice. They were the same practitioners who were selected for the preliminary study of typical measurement requirements. They were not selected for the main study to avoid possible future bias.

The practitioners were given a full set of images for each mandible in a Microsoft Word document.<sup>liv</sup> These had been produced in the x-ray water phantoms and are described in Section 3.2.1 on page 57 and Figure 10 on page 61. Each set consisted of a panoramic view, a transsymphyseal view and CBCT images prepared perpendicular to the line of the arch at the sites of the proposed dental implants.

The images were sent to the participants electronically so that they could be seen on screen at much better quality than in a printed document. The practitioners were asked to rate the mandibles in order of difficulty of implant placement in the canine regions.

#### Results

Three of the four dental practitioners were in complete agreement and this order was adopted for use in the study. Identification had been assigned to the mandibles as presented in Figure 29 on page 181. This preliminary study of case difficulty suggested that the order of case difficulty, beginning with the most difficult, was MG, RS, RL & HD.

#### Conclusion

From the results of this preliminary study, mandibles MG and RS were assigned as “challenging”. RL and HD were assigned as “regular”.

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<sup>liv</sup> Word – Microsoft Inc. Redmond, WA. USA.

### 6.2.3 Pilot study

#### 6.2.3.1 Aims and Objectives

The aim of this pilot study was to evaluate the conduct of the before after study.

The specific objectives were to evaluate:

- ▶ Clarity of the instructions
- ▶ Available instrumentation
- ▶ The completeness of the questionnaire
- ▶ Confidentiality procedures
- ▶ Time to complete the exercise
- ▶ The assessment of the osteotomies prepared by the participants

#### 6.2.3.2 Method

Two dental practitioners were selected through personal contacts. These practitioners were chosen on the basis that they were experienced implant surgeons who place implants in the practice environment. They were not selected for the main study to avoid possible future bias. They were different practitioners from those who participated in the preliminary study of case difficulty.

The practitioners were presented with dental implant instruments, an implant motor, images presented on a laptop computer, original transsymphyseal films, manufacturer's transparencies, an x-ray viewer, the four drillable models in the phantom head, information sheets and recording sheets. The details of these are included in Table 38 on page 222 and Figure 57 on page 223 which present the final list of items available to participants. The panel were asked to consider the case histories, the available images and then drill osteotomies for implant placements in the lower canine regions. In two cases, the participants were presented with two dimensional images only. In the other two cases, CBCT images were also available. They were then asked to complete an evaluation survey. There were nine questions as follows:

- 1 How long did this exercise take you?
- 2 Are the instructions clear? Would you suggest any improvements?
- 3 Would it have been useful to have any other instrumentation available, eg drill stops or depth guides?
- 4 Are there any other questions which you think could usefully have been asked when assessing your treatment of these cases?
- 5 Do you have any general comments about the way the study has been conducted or any suggestions to improve the process from the participant's point of view?
- 6 Are you satisfied with the arrangements for data confidentiality?

## Results

Following the evaluation survey, the following changes were made to the study procedures:

- ▶ The wording of the question about the difficulty of the case was changed so that it was clear that a comparison should be made with other cases where implants are placed in the canine regions to support complete lower overdentures.
- ▶ A large print was made of the drill markings for easy reference
- ▶ The original transsymphyseal radiographs, with manufacturer's transparencies, were made available.
- ▶ A number of extra instruments were made available. These included drill stops, direction indicators, a lance drill, a depth probe and a straight handpiece with a bone bur for ridge reduction.
- ▶ A second implant selection sheet was included so that a final selection of implant could be recorded if this differed from the preoperative choice.

## Conclusions

This pilot study was helpful in refining the procedures for the definitive study. A number of changes were made to the instrument, recording sheets and information available to participants.

## 6.2.4 Definitive study

### 6.2.4.1 Sample size

The primary outcome to be measured was the number of perforations made when drilling osteotomies. The intended statistical test for this primary outcome was the McNemar test for related dichotomous variables. No previous data existed to inform sample size calculation, therefore, a judgement was made of the proportions of perforations which might be expected with and without the availability of CBCT. These assumptions are set out in Table 35 below.

		After availability of CBCT	
		Perforated	Safe
Before availability of CBCT	Perforated	30%	35%
	Safe	5%	30%

**Table 35 - Assumptions used in sample size calculation**

A sample size calculation was carried out based on the following parameters:

Probability of a type 1 error ( $\alpha$ )	0.05
Power ( $1 - \beta$ )	0.80
Proportion switching from safe to perforated	0.05
Proportion switching from perforated to safe	0.35

This calculation yielded sample size of 33 matched pairs

Sample size was restricted by the practicality and expense of producing drillable models and the time which would be required of each participant. Nevertheless, it was anticipated that eight participants could reasonably be recruited and that each participant would prepare two osteotomies in each of four different mandibular models on two occasions. This would require 64 mandibular models, each with two osteotomies and results in 64 matched pairs of data. Therefore, in comparison with an estimated sample size of 33 matched pairs, it was proposed that the proposed sample size of eight dentists and four different mandibles was within a reasonable margin of error with regard to adequate sample size.



The McNemar test analyses the proportion of participants who, after the availability of CBCT, switch from 'perforated to safe' or 'safe to perforated'. These are termed "discordant pairs". As a supplementary method of sample size estimation, a table was prepared which showed sample sizes for the McNemar test with representative proportions of discordant pairs. (Table 36 page 217 below) In this table, the cells were coloured green where the sample size was within the 64 matched pairs which were proposed for the study. Cells were coloured red where the sample size was greater than the proposed 64 matched pairs. It was considered to be a reasonable expectation that results showing an important clinical difference would lie within the green cells and that sample size was likely to be adequate.

Proportion of discordant pairs - safe before/perforated after

	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.05		469	155	85	57	42	33	27	23	19	17	15	13	12	11	10	9	8
0.10	469		783	234	120	77	55	42	33	27	23	20	17	15	14	12	11	10
0.15	155	783		1097	312	155	96	67	50	40	32	27	23	20	18	16	14	12
0.20	85	234	1097		1411	391	190	116	80	59	46	37	31	26	23	20	17	16
0.25	57	120	312	1411		1725	469	225	135	92	68	53	42	35	29	25	22	19
0.30	42	77	155	391	1725		2039	548	260	155	105	77	59	47	39	33	28	24
0.35	33	55	96	190	469	2039		2353	626	295	175	117	85	65	52	43	36	30
0.40	27	42	67	116	225	548	2353		2667	705	330	194	130	94	72	57	47	39
0.45	23	33	50	80	135	260	626	2667		2981	783	364	214	143	103	78	62	50
0.50	19	27	40	59	92	155	295	705	2981		3295	862	399	234	155	111	85	67
0.55	17	23	32	46	68	105	175	330	783	3295		3609	940	434	253	168	120	91
0.60	15	20	27	37	53	77	117	194	364	862	3609		3923	1018	469	273	180	129
0.65	13	17	23	31	42	59	85	130	214	399	940	3923		4236	1097	504	292	193
0.70	12	15	20	26	35	47	65	94	143	234	434	1018	4236		4550	1175	539	312
0.75	11	14	18	23	29	39	52	72	103	155	253	469	1097	4550		4864	1254	574
0.80	10	12	16	20	25	33	43	57	78	111	168	273	504	1175	4864		5178	1332
0.85	9	11	14	17	22	28	36	47	62	85	120	180	292	539	1254	5178		5492
0.90	8	10	12	16	19	24	30	39	50	67	91	129	193	312	574	1332	5492	

Green cells indicate sample sizes with in the planned 64 matched pairs  
 Red cells indicate sample sizes greater than the planned 64 matched pairs  
 Parameters - Probability of a type 1 error ( $\alpha$ ) = 0.05    Power ( $1 - \beta$ ) = 0.80

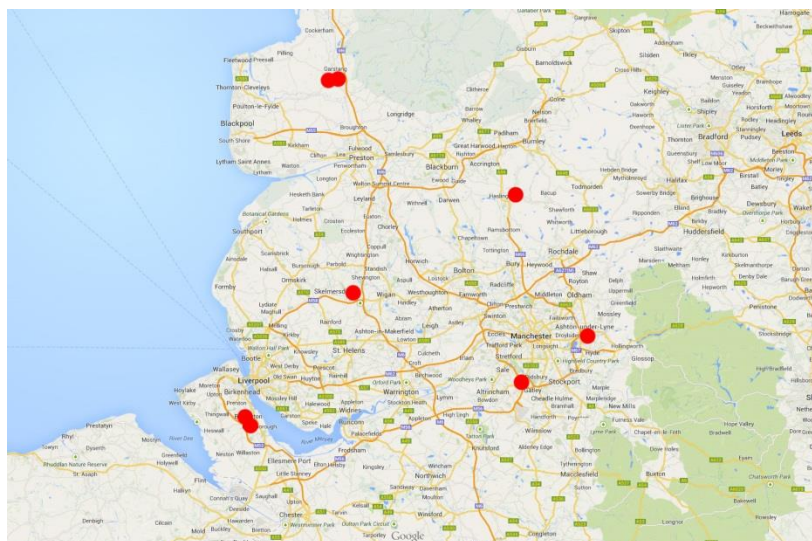
**Table 36 - Table to show sample size calculations for the McNemar test for representative proportions of discordant pairs**

#### 6.2.4.2 Recruitment of dentists to the study

A sample of eight dentists was recruited to the study. The results of the previous questionnaire study were consulted and dentists were approached who were early responders. (Section 3.3 page 83) It was known from the pilot study that significant time would be asked of the participants, therefore, those dentists who might be expected to be co-operative were approached. An attempt was made to make the sample representative of dentists who place dental implants in the practice environment in the North West of England. The demographic characteristics of this group were demonstrated in the previous questionnaire study. [213] (Section 3.3.2 page 86) Table 37 on page 218 compares the demographic characteristics of the sample of 8 dentists in this study with the results of the questionnaire study. Figure 56 on page 219 shows the even geographical spread of the participants in the region of the North West of England.

	Questionnaire study		This study	
<b>Male/Female</b>	♂121 ♀14	♂89.6% ♀10.4%	♂7 ♀1	♂87.5% ♀12.5%
<b>Age range</b>	26-66 years		36-62 years	
<b>Implants placed per year</b>	1-20 20-50 50-100 >100	34.8% 25.2% 17.8% 22.2%	1-20 20-50 50-100 >100	25.0% 25.0% 25.0% 25.0%
<b>Has postgraduate qualifications</b>	Yes No	63.0% 37.0%	Yes No	75.0% 25.0%
<b>Main training in implantology</b>	Independent University Other	46.7% 33.3% 20.0%	Independent University Other	25.0% 75.0% 0.0%
<b>Dental School of first qualification</b>	Manchester Liverpool Sheffield Other	30.4% 23.0% 6.7% 40.0%	Manchester Liverpool Sheffield Other	37.5% 37.5% 25.0% 0.0%

**Table 37 - Demographic characteristics of the sample of dentists in this study compared with previous questionnaire study**



**Figure 56 - Geographical spread of study participants**

In order to protect the anonymity of the participants, each one was assigned an identification number. These were allocated by taking eight random numbers between 1 and 100. The identification numbers were 23,37,40,44,53,59,76 & 90. The process of pseudonymisation is described in the confidentiality and anonymisation policy in Appendix E.

#### 6.2.4.3 Ethical approval

Ethical approval for this study was granted by the University of Leeds Dental Research Ethics Committee on 7<sup>th</sup> November 2013 under application number 060813/AS/107. (Appendix B page 294) A copy of the confidentiality and anonymisation policy is presented in Appendix E on page 299.

#### 6.2.4.4 The cases

Cases were developed from the four mandibles which had been acquired from private and museum collections. (Figure 29 page 181) Identification had been assigned to each mandible as follows: MG, HD, RL & RS. The same identification was used for the cases which were developed from them. The preliminary study of case difficulty had suggested that the order of case difficulty, beginning with the most difficult, was MG, RS, RL & HD. MG and RS were regarded as “challenging” cases. RL and HD were regarded as “regular cases”. Each case consisted of a duplicate mandible in a drillable

model with silicone soft tissue, presented in a phantom head as described in “Part 4 - Development of a dental simulation for use in a before-after study” beginning on page 177. Supporting materials were fictional case histories, photographs and images.

#### 6.2.4.5 Presentation of case histories and photographs

For each of the four mandibles in the study, a fictional case history and photograph were provided. The photographs were chosen to represent a plausible match to the mandibles. These were the same photographs which were used to craft the wax master models employed in the manufacture of the drillable models. (Figure 37 page 190). The four case histories were very similar and deliberately bland so that there was no medical history or other factors which might dictate the treatment plan or affect the drilling of osteotomies. They were written to be unmemorable so that they were unlikely to be recognised when presented for a second time. The initials of the fictional subjects were reversed for the second presentation of the same case. For example, Mrs MG became Mrs GM. An example is shown in Appendix M on page 315.

Each case history also presented a questionnaire. The participants were asked to give their opinion on the difficulty of the case based on the history, photographs and available images. The participants were asked to score case difficulty on a ten point scale. They were asked, “Thinking about complete overdenture cases where implants are placed in the lower canine regions, please indicate your opinion of the difficulty of implant placement in this case by circling one of the numbers below”. They were also asked to answer “Yes” or “No” to the statement, “I would carry out special surgical procedures in this case such as bone grafting”. If the participant answered “Yes” they were asked to briefly specify the surgical procedure they planned. (Appendix M page 315)

The participants were offered a selection of dental implants on the questionnaire and asked to choose from these for each case. This was simplified for the participants by creating tick lists of available implants with accompanying images. (Appendix M page 315) It was recognised that some operators might change their pre-operative selection of implant as a result of their findings when drilling osteotomies.[62] Therefore a second choice was available if the participants’ final selection was different from their preoperative selection.

#### 6.2.4.6 Implementation

Images were available for the “before” and “after” parts of the study as listed in (Table 32 page 184 and Table 33 page 184). However, in brief, only conventional images were assigned to the “before” part of the study. These were a panoramic and a transsymphyseal view. For the “after” part of the study, a CBCT image was added.

Each participant was visited in their practice on two occasions, four weeks apart. For each visit, the cases were randomised to be either a “before” or an “after” case. Stratification was carried out so that, for each visit, there were two “before” cases which would be a challenging and a regular case. Similarly, there would be two “after” cases which would also be a challenging and a regular case.

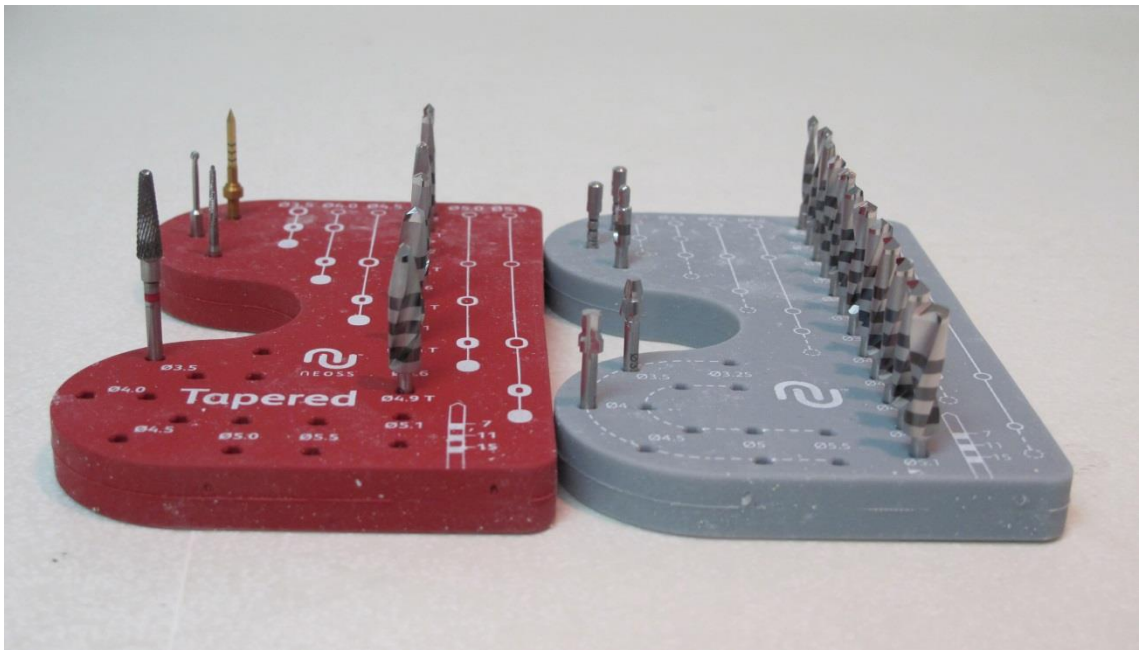
At each visit, the participants were provided with:

- ▶ A copy of the anonymisation and confidentiality policy (Appendix E page 299)
- ▶ Printed instructions for the exercise (Appendix N page 320).
- ▶ Drilling guides for the Neoss dental implant system (Appendix O page 321)
- ▶ The four case histories with the questionnaire. (Appendix M page 315)
- ▶ The phantom head (Figure 46 page 196)
- ▶ The four drillable models (Figure 45 page 195)
- ▶ Images corresponding to the four cases (Figure 31 page 185 and Figure 32 page 186)
- ▶ Implant surgery equipment and instruments as listed in Table 38 on page 222

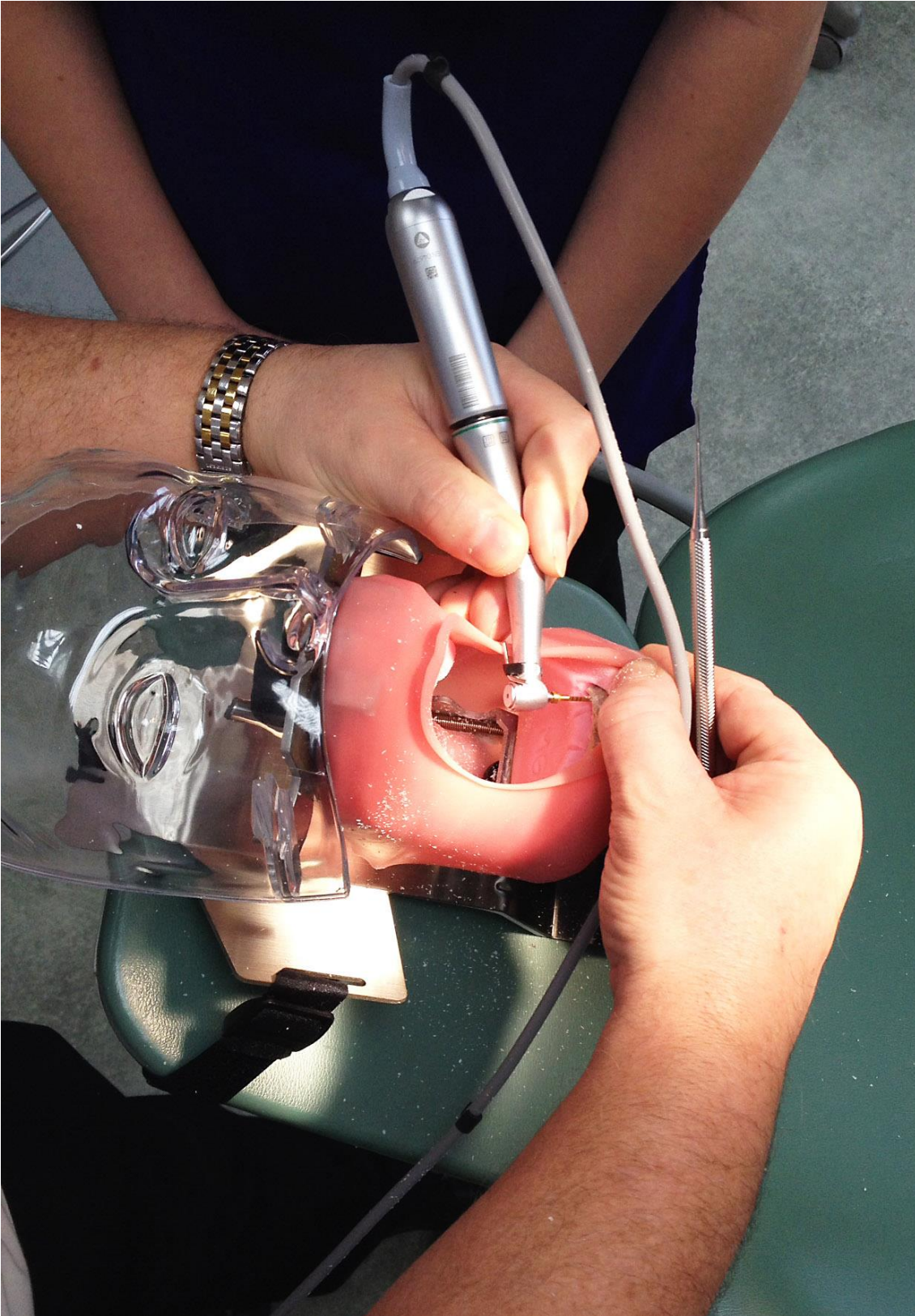
For each of the four cases, the participants were asked to examine the available images and complete the questionnaire up to the point of the pre-operative choice of implants. They were then asked to use the implant surgery equipment and instruments to prepare osteotomies for two dental implants in the canine regions marked on the drillable models within the phantom head. (Figure 45 on page 195) Lastly, the participants were asked to record their final choice of dental implant.

<b>A set of implant surgery instruments</b>	<b>Mirror</b> <b>Probe</b> <b>Periosteal elevator</b> <b>Large bur for bulk bone reduction</b> <b>Lance drill</b> <b>Round bur</b> <b>Lindemann side cutting bur</b> <b>Full set of drills for Neoss straight implants</b> <b>Full set of drills for Neoss tapered implants</b> <b>Drill stops for the full range of Neoss implants</b> <b>Implant direction indicators</b>
<b>Dental implant motor with handpieces</b>	Straight handpiece Contra-angle handpiece
<b>Full set of digital images</b>	Different images for visit one and visit two (Table 32 page 184 and Table 33 page 184)
<b>Conventional radiographs</b>	Transsymphyseal radiographs for each of the four cases
<b>X-ray viewer</b>	Light box to view conventional transsymphyseal radiographs
<b>Manufacturer's transparencies for assessment of radiographs</b>	For tapered implants For straight implants All implant sizes and magnifications
<b>Drillable models</b>	The same four cases at each visit
<b>Information sheets</b>	Reminder sheet for Neoss implant drill markings Neoss drilling guide – straight implants Neoss drilling guide – tapered implants Copy of the anonymisation and confidentiality policy Information sheet for 1 <sup>st</sup> or 2 <sup>nd</sup> visit (Appendix M page 318 Appendix N page 320)
<b>Recording sheets</b>	Case history with questionnaire (Appendix M page 315)
<b>Phantom head</b>	Including oral cavity cover, face mask and four exchangeable duplicate mandibles ( Figure 47 Page 198)

**Table 38 - Items available for participants at each visit**



**Figure 57 - Implant surgery instruments available for participants at each visit**



**Figure 58 - A participant prepares osteotomies on the dental simulation**



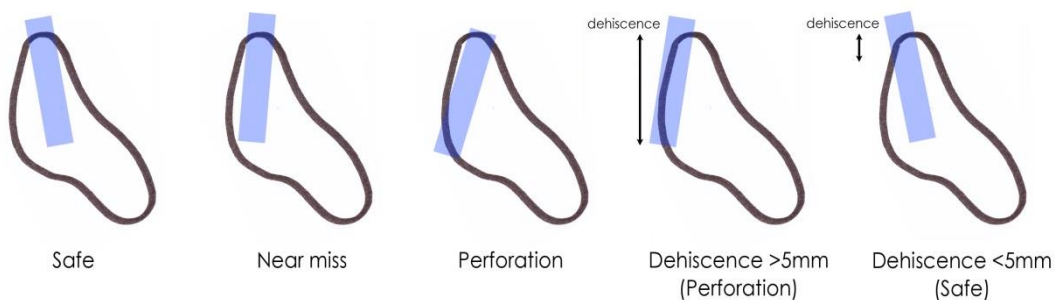
#### 6.2.4.7 Data collection

The duplicate mandibles were stripped from the silicone soft tissue analogue and explored for perforations or near misses as described in section 5.4.1.2 on page 201. This was carried out by the author after completion of all practical exercises by all dentists.

A blunt ended probe with a linear scale was used to assist in measurement and each osteotomy was classified as follows:

- ▶ Perforation – a discrete defect of the lingual surface or a dehiscence of the lingual surface greater than 5mm from the level of the crest of the ridge. A dehiscence was defined as a vertical defect, with no superior border, in the superior/inferior dimension.
- ▶ Near miss - an osteotomy that was closer than 1 mm from the lingual surface of the duplicate mandible
- ▶ Safe – an osteotomy that was no closer than 1 mm from the lingual surface of the duplicate mandible. Perforations or dehiscences through the labial surface were recorded as safe.

Figure 59 on page 225 illustrates each of these possibilities.



**Figure 59 - Diagram to show classification of safe and perforated osteotomies. Potential osteotomies are shown in blue.**

Examples of these from the study are shown in Figure 60 on page 226

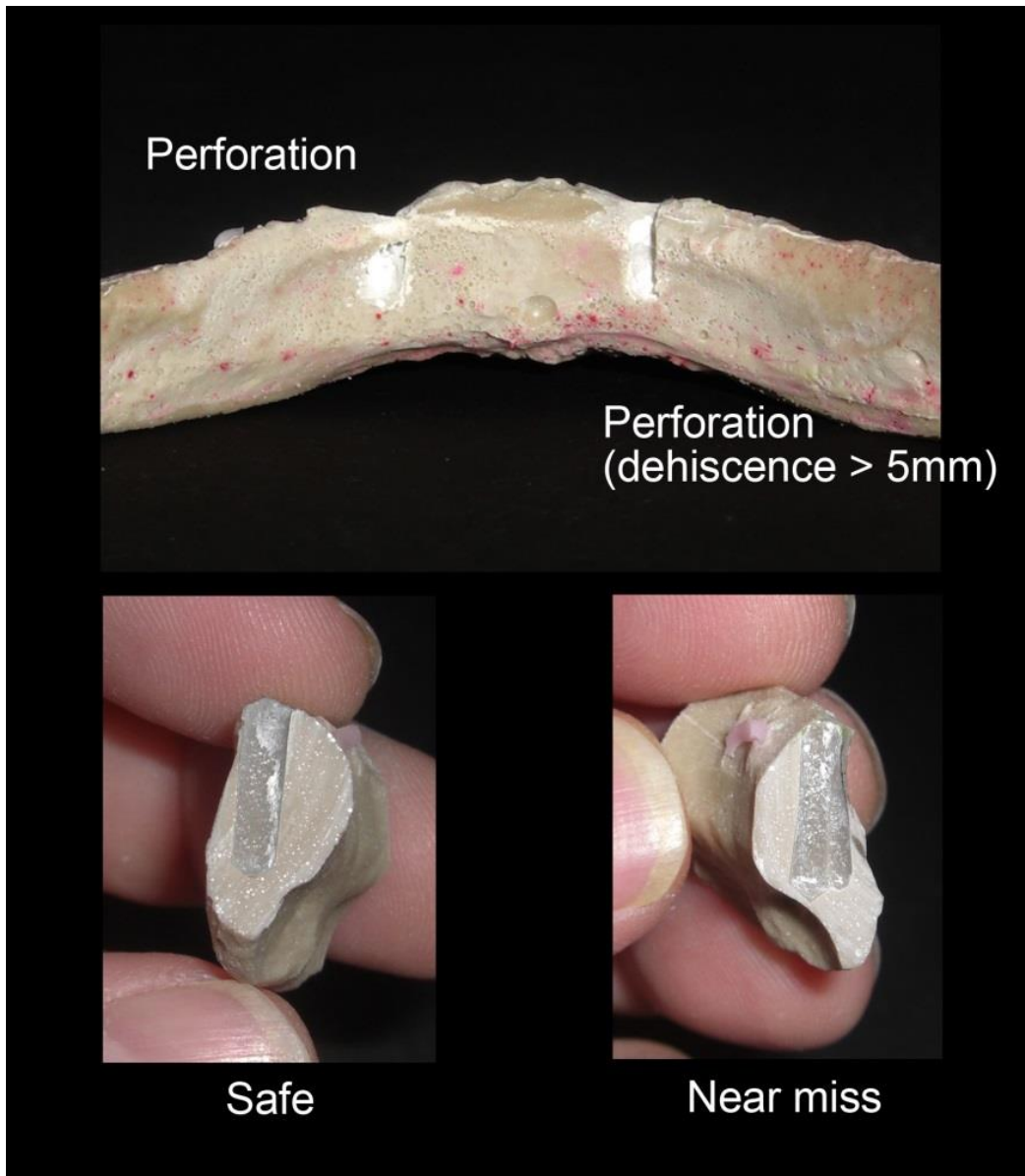


Figure 60 - Examples of perforations, a near miss and safe osteotomies

#### 6.2.4.8 Statistical Methods

Data were inputted into SPSS statistics 19<sup>iv</sup>. (formerly PASW<sup>vi</sup> statistics). Descriptive statistics were prepared followed by statistical analysis. (Section 6.3 beginning on page 228) In all cases, statistical significance ( $\alpha$ ) was initially set at  $P=0.05$  and later corrected for multiple comparisons. The problem of multiple comparisons is discussed above in section 3.6.3.6 on page 125.

Null hypotheses were tested as follows:

##### **Primary hypothesis:**

There is no significant difference in the proportion of lingual perforations or “near miss perforations” before or after the availability of cone beam CT images

This analysis was carried out using the McNemar test for dichotomous paired nominal data.

##### **Supplementary hypotheses:**

There is no significant difference in the preoperative selection of length, width or design of implant before and after the availability of CBCT

This analysis was carried out using the Wilcoxon signed rank test for related samples.

There is no significant difference in the preoperative assessment of difficulty of implant placement before and after the availability of CBCT

These data were tested for normality and equality of variance. The analysis was carried out using the paired samples T test.

There is no significant difference in the perception of need for special surgical procedures before and after the availability of CBCT.

This analysis was carried out using the McNemar test for dichotomous paired nominal data.

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<sup>iv</sup> SPSS Inc. Chicago, Illinois, USA

<sup>vi</sup> PASW - Predictive Analytics Software

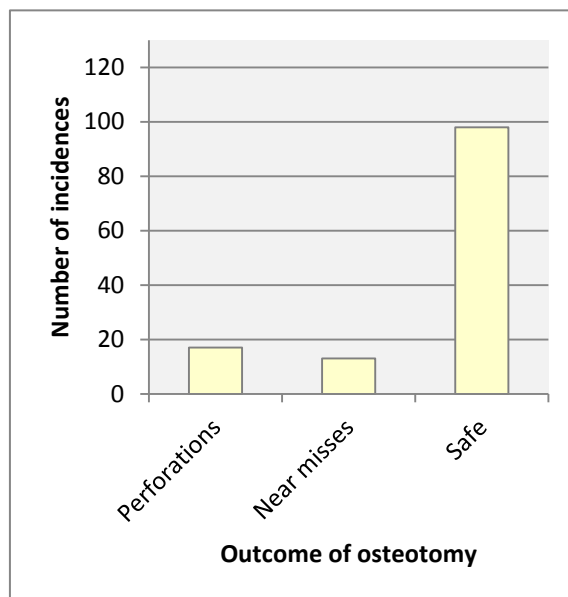
### 6.3 Results and statistical analyses

#### 6.3.1 Total perforations and near misses for all osteotomies

There were 64 pairs of osteotomies in total. The perforations and near misses for all 128 osteotomies are presented in Table 39 and Figure 61 below.

All dentists		%
Total perforations	17	13.28%
Total near misses	13	10.16%
Total safe	98	76.56%
<b>Total sites</b>	<b>128</b>	<b>100.00%</b>

**Table 39 - Results table for total perforations and near misses. All cases and all dentists**



**Figure 61 - Total perforations and near misses. All cases and all dentists**

These results are presented as an overall measure of the number of perforations and near misses which were created. No statistical analysis was carried out.

6.3.2 Perforations and near misses before and after availability of CBCT.

All cases and all dentists

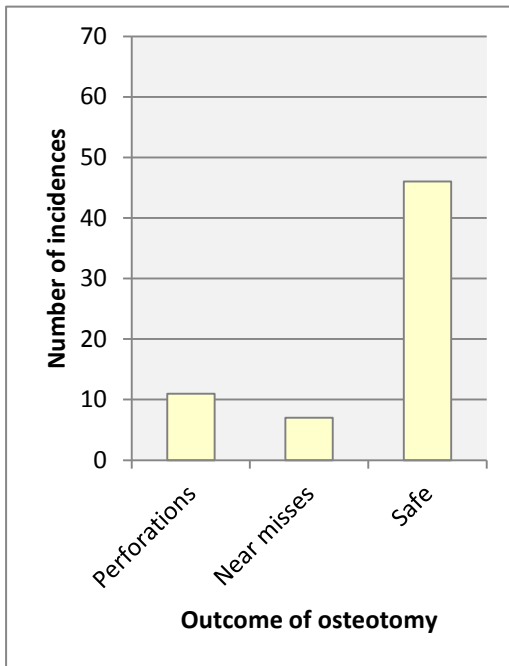
Perforations and near misses before and after the availability of CBCT images are presented in Table 40, Table 41, Table 42 and Figure 62 below.

All cases		
All dentists -before	%	
Perforations	11	17.19%
Near misses	7	10.94%
Safe	46	71.88%
<b>Total sites</b>	<b>64</b>	<b>100.00%</b>

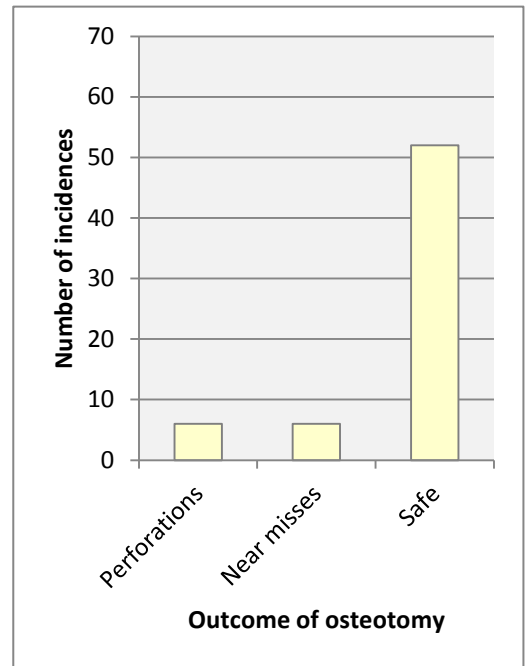
All cases		
All dentists - after	%	
Perforations	6	9.38%
Near misses	6	9.38%
Safe	52	81.25%
<b>Total sites</b>	<b>64</b>	<b>100.00%</b>

**Table 40 - Perforations and near misses before and after availability of CBCT. All cases and all dentists**

Before



After



**Figure 62 - Perforations and near misses before and after the availability of CBCT. All cases and all dentists**

Cross tabulations were prepared showing the numbers of participants who changed to or from a safe osteotomy after the availability of CBCT for all cases. One was prepared for perforations and near misses and another for perforations alone.

		After availability of CBCT	
		Safe	Perforated or near miss
Before availability of CBCT	Safe	41	5
	Perforated or near miss	11	7

**Table 41 - Cross tabulation of results for all cases considering perforations and near misses**

McNemar's test was used to test the null hypothesis that there was no difference in the proportion of perforations or "near miss perforations" before or after the availability of CBCT. (P=0.21).

		After availability of CBCT	
		Safe or near miss	Perforated
Before availability of CBCT	Safe or near miss	51	2
	Perforated	7	4

**Table 42 - Cross tabulation of results for all cases considering perforations only**

McNemar's test was used to test the null hypothesis that there was no difference in the proportion of perforations before or after the availability of CBCT. (P=0.18)

6.3.3 Perforations and near misses before and after availability of CBCT.

Regular cases and all dentists

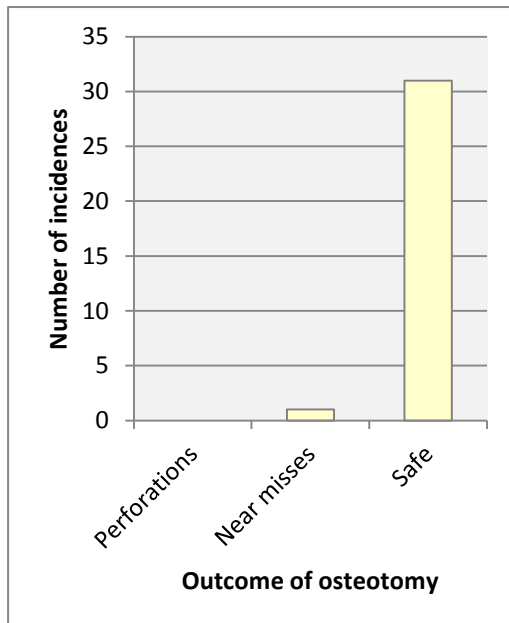
Perforations and near misses before and after the availability of CBCT images for the regular cases are presented in Table 43 and Figure 63 below.

Regular cases		
All dentists -before		%
Perforations	0	0.00%
Near misses	1	3.13%
Safe	31	96.88%
<b>Total sites</b>	<b>32</b>	<b>100.00%</b>

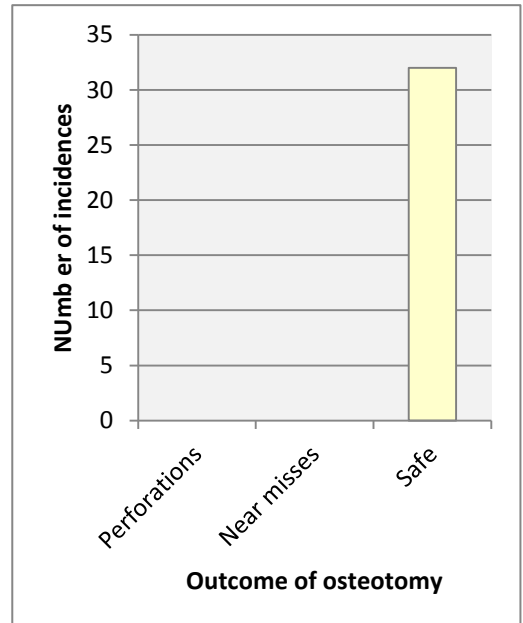
Regular cases		
All dentists - after		%
Perforations	0	0.00%
Near misses	0	0.00%
Safe	32	100.00%
<b>Total sites</b>	<b>32</b>	<b>100.00%</b>

**Table 43 - Perforations and near misses before and after availability of CBCT. Regular cases and all dentists**

Before



After



**Figure 63 - Perforations and near misses before and after the availability of CBCT. Regular cases and all dentists**

There were no perforations and only one near miss created by participants in the regular cases. No statistical analysis was carried out.

6.3.4 Perforations and near misses before and after availability of CBCT.

Challenging cases and all dentists

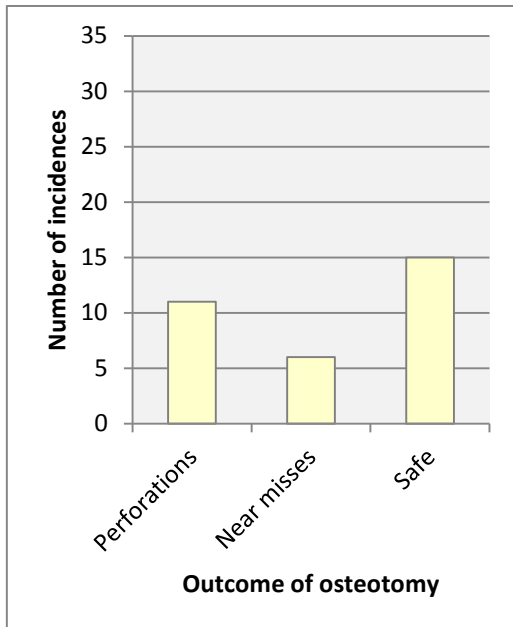
Perforations and near misses before and after the availability of CBCT images for the challenging cases are presented in Table 44, Table 45, Table 46 and Figure 64 below.

Challenging cases		
All dentists -before	%	
Perforations	11	34.38%
Near misses	6	18.75%
Safe	15	46.88%
<b>Total sites</b>	<b>32</b>	<b>100.00%</b>

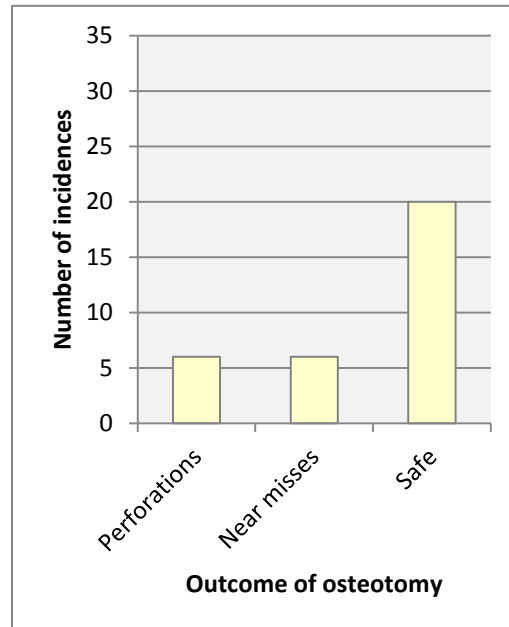
Challenging cases		
All dentists - after	%	
Perforations	6	18.75%
Near misses	6	18.75%
Safe	20	62.50%
<b>Total sites</b>	<b>32</b>	<b>100.00%</b>

**Table 44 - Perforations and near misses before and after availability of CBCT. Challenging cases and all dentists**

Before



After



**Figure 64 - Perforations and near misses before and after the availability of CBCT. Challenging cases and all dentists**



Cross tabulations were prepared showing the numbers of participants who changed to or from a safe osteotomy after the availability of CBCT for the two challenging cases. One was prepared for perforations and near misses and another for perforations alone.

		After availability of CBCT	
		Safe	Perforated or near miss
Before availability of CBCT	Safe	10	5
	Perforated or near miss	10	7

**Table 45 - Cross tabulation of results for challenging cases considering perforations and near misses**

McNemar's test was used to test the null hypothesis that there was no difference in the proportion of perforations or "near miss perforations" before or after the availability of CBCT when considering the challenging cases alone. (P=0.302).

		After availability of CBCT	
		Safe or near miss	Perforated
Before availability of CBCT	Safe or near miss	19	2
	Perforated	7	4

**Table 46 - Cross tabulation of results for challenging cases considering perforations only**

McNemar's test was used to test the null hypothesis that there was no difference in the proportion of perforations before or after the availability of CBCT when considering the challenging cases alone. (P=0.18).

### 6.3.5 Summary and consideration of multiple comparisons

These data were analysed four times with the McNemar test. It could be argued, therefore, that these analyses encounter the problem of multiple comparisons. This has been discussed earlier in this thesis. (Section 3.6.3.6 page 125) In short, multiple significance testing increases the probability of significant findings simply by chance. The Bonferroni correction sets significance at a more demanding level by dividing it by the number of analyses. [179] With four analyses, this leads to a new significance level of  $0.05/4 = 0.0125$ . Application of the Bonferroni correction suggests that it is even more likely that the differences in numbers of perforations or near miss perforations after availability of CBCT are chance findings. Table 47 below summarises the results of the McNemar tests for perforations and near misses.

Analysis		No. cases	P value
Perforations and near misses	All cases	64	P=0.21
Perforations only	All cases	64	P=0.18
Perforations and near misses	Challenging cases	32	P=0.302
Perforations only	Challenging cases	32	P=0.18

Statistical significance 0.05  
 Statistical significance accounting for the Bonferroni correction 0.0125

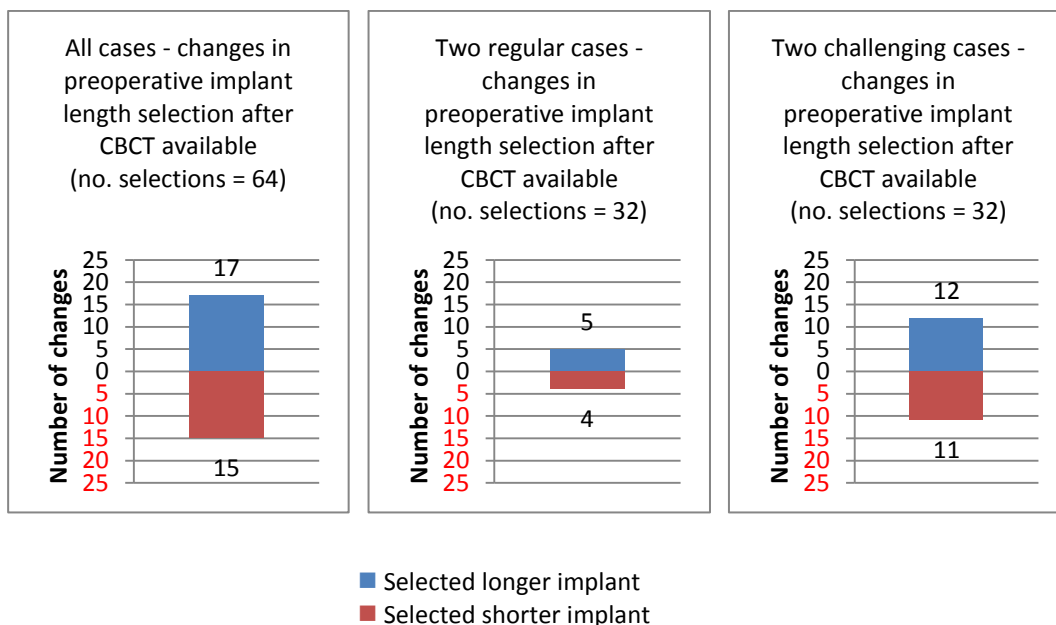
**Table 47- Summary of results of McNemar tests for perforations and near misses.**

6.3.6 Preoperative selection of implant length, all four cases, two regular cases and two challenging cases

The changes in participants' preoperative selection of implant length after the availability of CBCT are presented in Table 48 and Figure 65 below.

	Changes after availability of CBCT			
	Number of decisions	Total number of changes	No. times longer implant selected	No. times shorter implant selected
All four cases	64	32	17	15
Two regular cases	32	9	5	4
Two challenging cases	32	23	12	11

**Table 48 - Changes in preoperative selection of implant length after CBCT available**  
All four cases, two regular cases and two challenging cases



**Figure 65 - Changes in preoperative selection of implant length after CBCT available**  
All four cases, two regular cases and two challenging cases

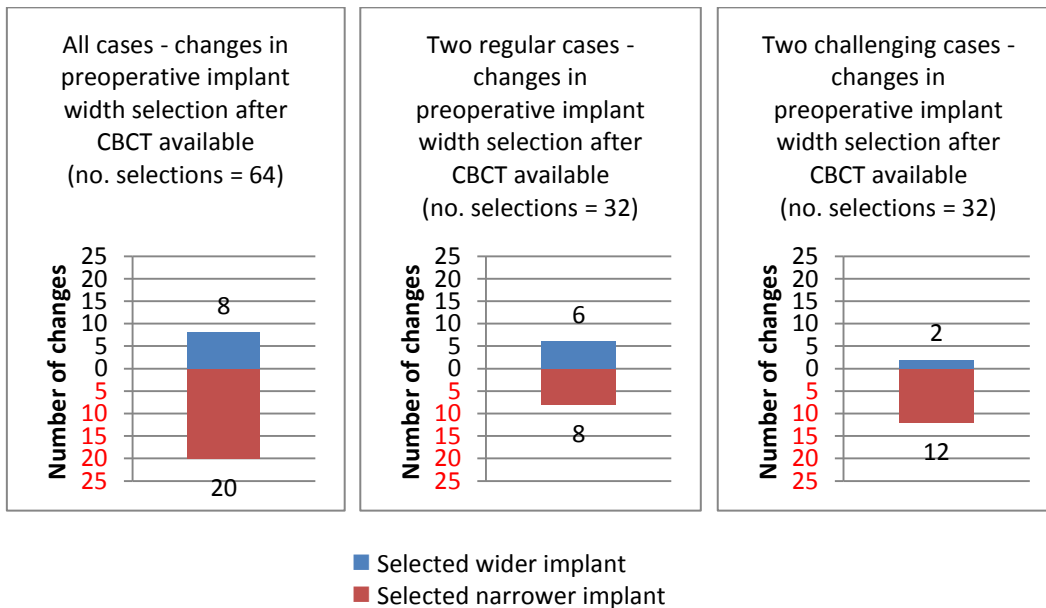
Statistical analysis was considered inappropriate for these findings

6.3.7 Preoperative selection of implant width, all four cases, two regular cases and two challenging cases

The changes in participants' preoperative selection of implant width after the availability of CBCT are presented in Table 49 and Figure 66 below.

	Changes after availability of CBCT			
	Number of decisions	Total number of changes	No. times wider implant selected	No. times narrower implant selected
All four cases	64	28	8	20
Two regular cases	32	14	6	8
Two challenging cases	32	14	2	12

**Table 49 - Changes in preoperative selection of implant width after CBCT available All four cases, two regular cases and two challenging cases**



**Figure 66 - Changes in preoperative selection of implant width after CBCT available All four cases, two regular cases and two challenging cases**

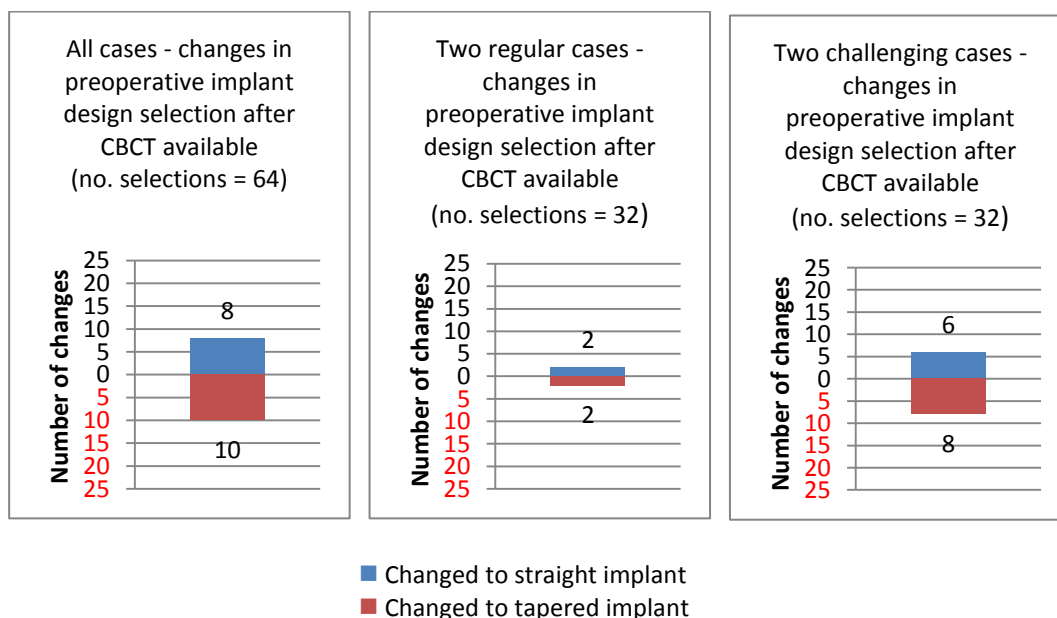
The Wilcoxon signed-rank test was used to test the null hypothesis that there was no significant decrease in the preoperative selection of implant width after the availability of CBCT when considering all cases (P=0.053, Z=-1.931) and when considering challenging cases alone (P=0.007, Z=-2.696)

### 6.3.8 Preoperative selection of implant design, all four cases, two regular cases and two challenging cases

The changes in participants' preoperative selection of implant design after the availability of CBCT are presented in Table 50 and Figure 67 below.

	Changes after availability of CBCT			
	Number of decisions	Total number of changes	No. times changed to straight	No. times changed to tapered
All four cases	64	18	8	10
Two regular cases	32	4	2	2
Two challenging cases	32	14	6	8

**Table 50 - Changes in preoperative selection of implant design after CBCT available. All four cases, two regular cases and two challenging cases**



**Figure 67 - Changes in preoperative selection of implant design after CBCT available. All four cases, two regular cases and two challenging cases**

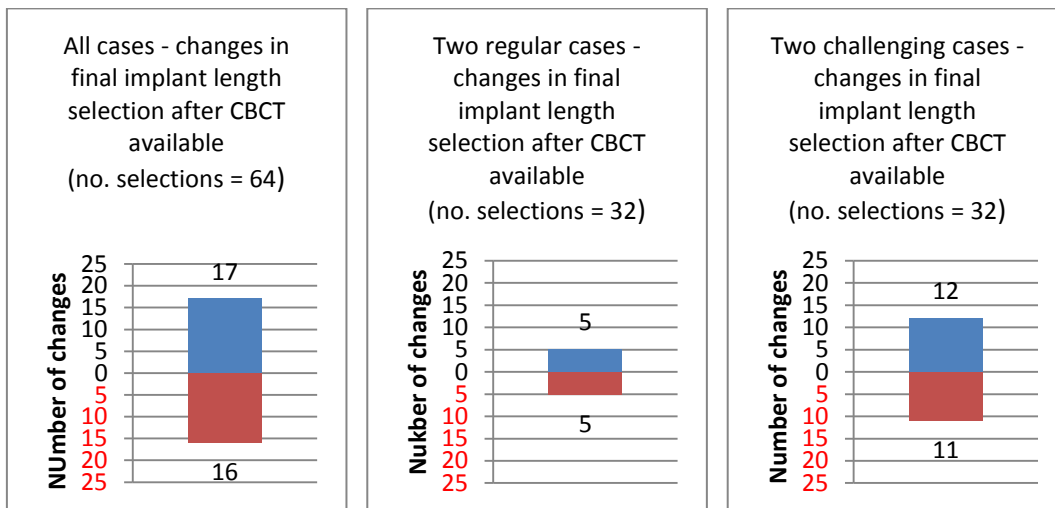
Statistical analysis was considered inappropriate for these findings

6.3.9 Final selection of implant length, all four cases, two regular cases and two challenging cases

The changes in participants' final selection of implant length after the availability of CBCT are presented in Table 51 and Figure 68 below.

	Changes after availability of CBCT			
	Number of decisions	Total number of changes	No. times longer implant selected	No. times shorter implant selected
All four cases	64	33	17	16
Two regular cases	32	10	5	5
Two challenging cases	32	23	12	11

**Table 51 - Changes in final selection of implant length after CBCT available**  
All four cases, two regular cases and two challenging cases



■ Selected longer implant  
■ Selected shorter implant

**Figure 68 - Changes in final selection of implant length after CBCT available**  
All four cases, two regular cases and two challenging cases

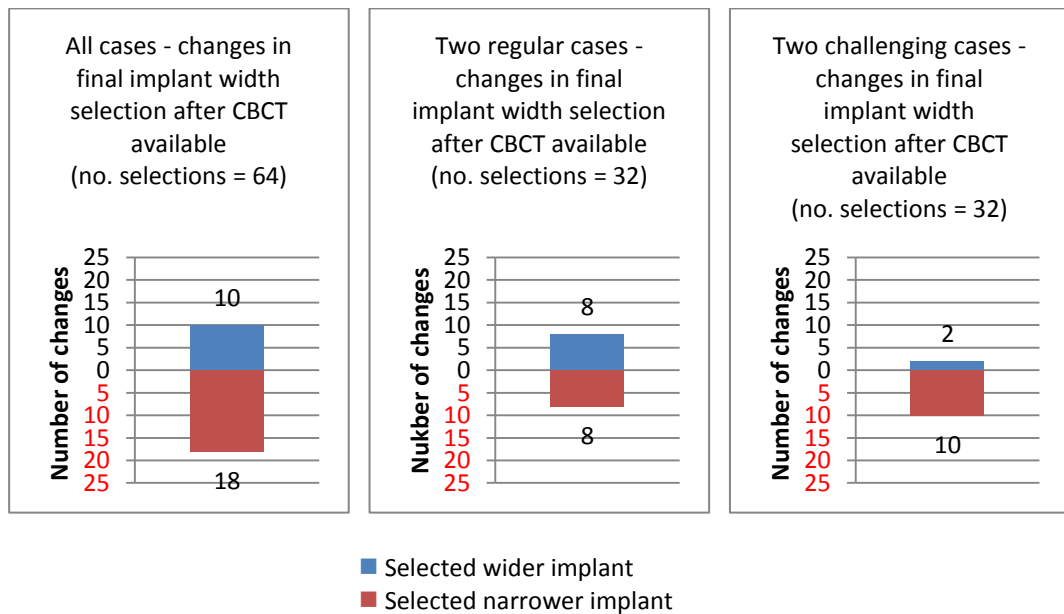
Statistical analysis was considered inappropriate for these findings

6.3.10 Final selection of implant width, all four cases, two regular cases and two challenging cases

The changes in participants' final selection of implant width after the availability of CBCT are presented in Table 52 and Figure 69 below.

	Changes after availability of CBCT			
	Number of decisions	Total number of changes	No. times wider implant selected	No. times narrower implant selected
All four cases	64	28	10	18
Two regular cases	32	16	8	8
Two challenging cases	32	12	2	10

**Table 52 - Changes in final selection of implant width after CBCT available  
All four cases, two regular cases and two challenging cases**



**Figure 69 - Changes in final selection of implant width after CBCT available.  
All four cases, two regular cases and two challenging cases**

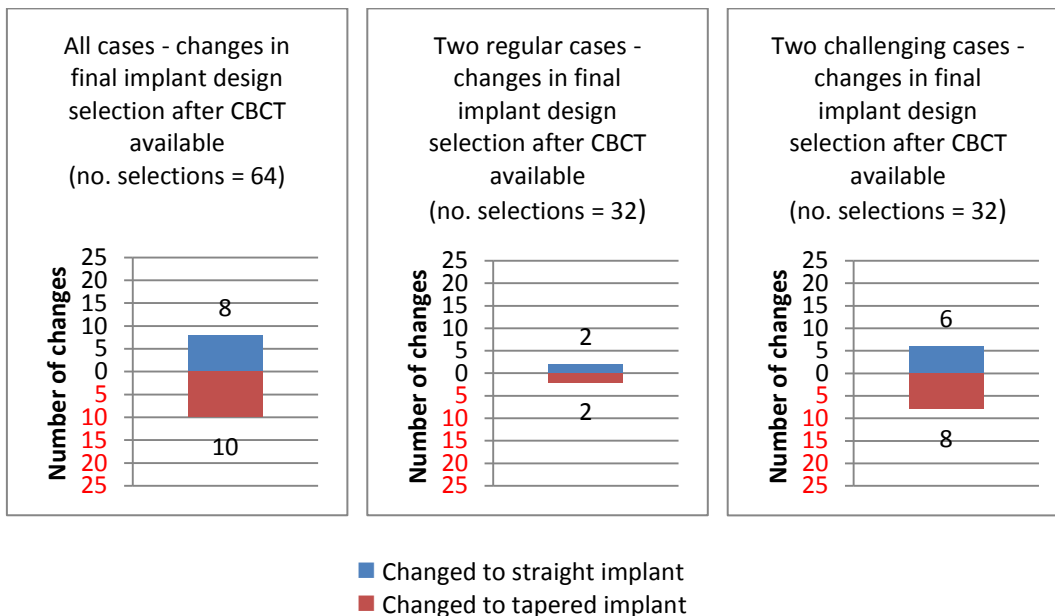
The Wilcoxon signed-rank test was used to test the null hypothesis that there was no significant decrease in the final selection of implant width after the availability of CBCT when considering all cases (P=0.131, Z=-1.512) and when considering challenging cases alone (P=0.021, Z=-2.309)

6.3.11 Final selection of implant design, all four cases, two regular cases and two challenging cases

The changes in participants' final selection of implant design after the availability of CBCT are presented in Table 53 and Figure 70 below.

	Changes after availability of CBCT			
	Number of decisions	Total number of changes	No. times changed to straight	No. times changed to tapered
All four cases	64	18	8	10
Two regular cases	32	4	2	2
Two challenging cases	32	14	6	8

**Table 53 - Changes in final selection of implant width after CBCT available**  
All four cases, two regular cases and two challenging cases



**Figure 70 - Changes in final selection of implant design after CBCT available.**  
All four cases, two regular cases and two challenging cases

Statistical analysis was considered inappropriate for these findings



### 6.3.12 Summary and consideration of multiple comparisons

These data were analysed four times with the Wilcoxon signed rank test. The Bonferroni correction was applied, setting a new level of significance of 0.0125. Table 54 on page 241 summarises the results of the Wilcoxon signed rank tests for implant selection.

Analysis		No. cases	P value
Preoperative selection of implant width	All cases	64	P=0.053
Final selection of implant width	All cases	64	P=0.131
Preoperative selection of implant width	Challenging cases	32	P=0.007
Final selection of implant width	Challenging cases	32	P=0.021

Statistical significance 0.05  
 Statistical significance accounting for the Bonferroni correction 0.0125

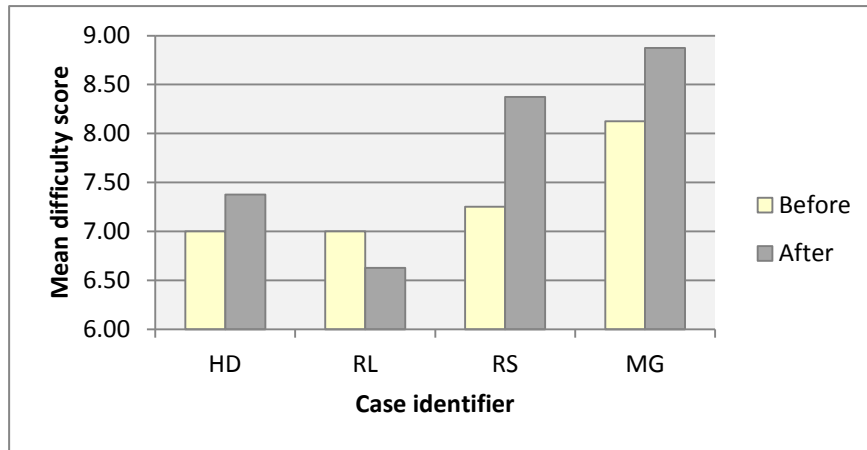
**Table 54 - Summary of results of Wilcoxon signed rank tests for implant selection.**

### 6.3.13 Preoperative assessment of case difficulty

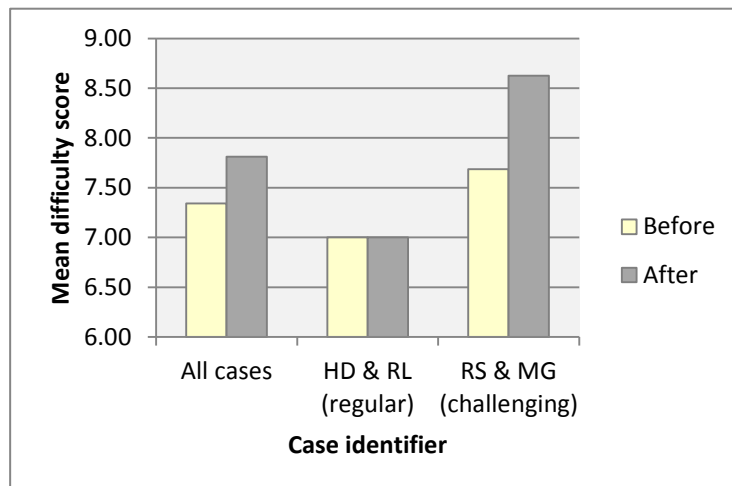
Visual inspection of their histograms, normal Q-Q plots and box plots suggested that the case difficulty scores were approximately normally distributed both before and after the availability of CBCT. There was a skewness of -0.593 (SE = 0.414) and a kurtosis of -0.425 (SE = 0.809) for scores before the availability of CBCT. There was a skewness of -0.696 (SE = 0.414) and a kurtosis of -0.031 (SE = 0.809) for scores after the availability of CBCT. A Shapiro Wilk's test did not confirm normal distribution (P=0.009 before the availability of CBCT and P=0.016 after the availability of CBCT). Nonetheless, on balance, approximate normal distribution was assumed. A Levene's test verified the equality of variances in the samples before and after the availability of CBCT (homogeneity of variance) (P=0.652). In view of this, the use of the paired sample t-test was considered to be appropriate.

Case identifier	Mean difficulty scores				Difference between means	SD of difference b/n means
	Before availability of CBCT		After availability of CBCT			
	Mean	SD	Mean	SD		
HD	7.00	1.69	7.38	1.60	0.38	0.92
RL	7.00	2.07	6.63	1.41	-0.38	1.77
RS	7.25	1.67	8.38	1.51	1.13	0.83
MG	8.13	1.81	8.88	1.46	0.75	1.49
HD & RL (Regular)	7.00	1.83	7.00	1.51	0.00	1.41
RS & MG (challenging)	7.69	1.74	8.63	1.45	0.94	0.30
All cases	<b>7.34</b>	<b>1.79</b>	<b>7.81</b>	<b>1.67</b>	<b>0.47</b>	<b>1.37</b>

**Table 55 - Table to show mean difficulty scores for the four cases before and after availability of CBCT**



**Figure 71 - Difference in mean difficulty scores for each of the four cases before and after availability of CBCT**



**Figure 72 - Difference in mean difficulty scores for all cases, regular cases and challenging cases before and after availability of CBCT**

A paired sample t-test test was used to test the null hypothesis that there was no difference in the mean preoperative assessment of difficulty of implant placement before and after the availability of CBCT for all cases. The results are shown in Table 56 below.

95% Confidence interval of the difference		t	Significance ( 2 tailed)
Lower	Upper		
-.96177	.02427	-1.939	0.062

**Table 56 - Paired sample t test to compare pre-operative assessment of case difficulty before and after the availability of CBCT for all cases**

A paired sample t-test test was used to test the null hypothesis that there was no difference in the mean preoperative assessment of difficulty of implant placement before and after the availability of CBCT for the challenging cases. The results are shown in Table 57 below.

95% Confidence interval of the difference		t	Significance ( 2 tailed)
Lower	Upper		
-1.56705	-.30795	-3.174	0.006

**Table 57 - Paired sample t test to compare pre-operative assessment of case difficulty before and after the availability of CBCT for challenging cases**

### 6.3.14 Summary and consideration of multiple comparisons

These data were analysed twice with a paired sample T test. The Bonferroni correction was applied, setting a new level of significance of 0.025. Table 58 below summarises the results of the paired sample T tests for preoperative assessment of case difficulty.

Analysis		No. cases	P value
Assessment of case difficulty	All cases	32	P=0.062
Assessment of case difficulty	Challenging cases	32	P=0.006

Statistical significance 0.05  
 Statistical significance accounting for the Bonferroni correction 0.025

**Table 58 - Summary of results of paired sample T tests for assessment of case difficulty**

### 6.3.15 Special surgical procedures

The only surgical procedure which participants prescribed was block bone grafting. In every case the participants said that they would refer to a more experienced colleague for this. The number of cases for which participants perceived the need for block bone grafting is recorded in Table 59 below. Eight participants examined the four cases before and after the availability of CBCT. Therefore, for this analysis, there were 32 pairs of observations. There were no instances in which the availability of CBCT led a participant to change a prescription from “bone grafting” to “no bone grafting”. Results are presented in Table 59 below.

Case identifier	Before availability of CBCT	After availability of CBCT
HD	0	0
RL	0	0
RS	0	1
MG	2	4

**Table 59 - Number of participants that prescribed block bone grafting before and after availability of CBCT for each case**

Cross tabulations were prepared showing the numbers of participants who changed to or from prescription of special surgical procedures after the availability of CBCT.

These were prepared for all cases and for challenging cases only. (Table 60 page 247 and Table 61 page 247)

		After availability of CBCT	
		No special surgical procedure prescribed	Special surgical procedure prescribed
Before availability of CBCT	No special surgical procedure prescribed	27	3
	Special surgical procedure prescribed	0	2

**Table 60 - Cross tabulation of results for all cases considering prescription of special surgical procedures**

McNemar's test was used to test the null hypothesis that there was no difference in the prescription of special surgical procedures before or after the availability of CBCT when considering all cases. ( $P=0.25$ ).

		After availability of CBCT	
		No special surgical procedure prescribed	Special surgical procedure prescribed
Before availability of CBCT	No special surgical procedure prescribed	11	3
	Special surgical procedure prescribed	0	2

**Table 61 - Cross tabulation of results for challenging cases considering prescription of special surgical procedures**

McNemar's test was used to test the null hypothesis that there was no difference in the prescription of special surgical procedures before or after the availability of CBCT when considering the challenging cases. ( $P=0.25$ ).

### 6.3.16 Summary and consideration of multiple comparisons

These data were analysed twice with the McNemar test. The Bonferroni correction was applied, setting a new level of significance of 0.025. Table 62 below summarises the results of the McNemar tests for prescription of special surgical procedures.

Analysis		No. cases	P value
Prescription of special surgical procedures	All cases	32	P=0.25
Prescription of special surgical procedures	Challenging cases	16	P=0.25

Statistical significance 0.05  
 Statistical significance accounting for the Bonferroni correction 0.025

**Table 62- Summary of results of McNemar tests for prescription of special surgical procedures.**



### 6.3.17 Results – Additional results

Results are presented which address the variation and consistency of individual dentists in preparing osteotomies and selecting dental implants. No statistical analysis of these data was carried out.

### 6.3.18 Variation in perforations and near misses amongst individual dentists

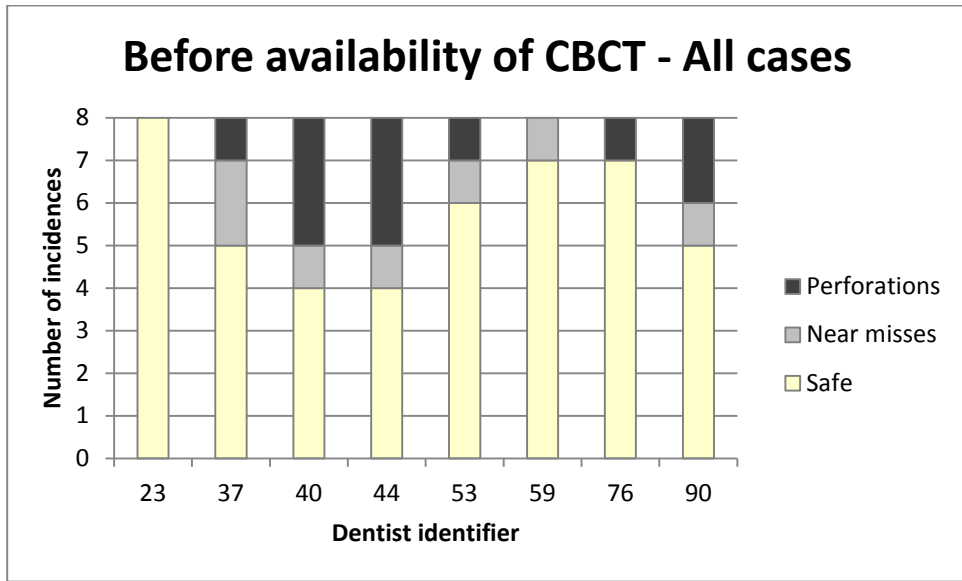
Perforations and near misses for individual dentists are shown before and after the availability of CBCT in Table 63 and Table 64 below and Figure 73 and Figure 74 on page 250.

Dentist no.	Safe	Near misses	Perforations
23	8	0	0
37	5	2	1
40	4	1	3
44	4	1	3
53	6	1	1
59	7	1	0
76	7	0	1
90	5	1	2

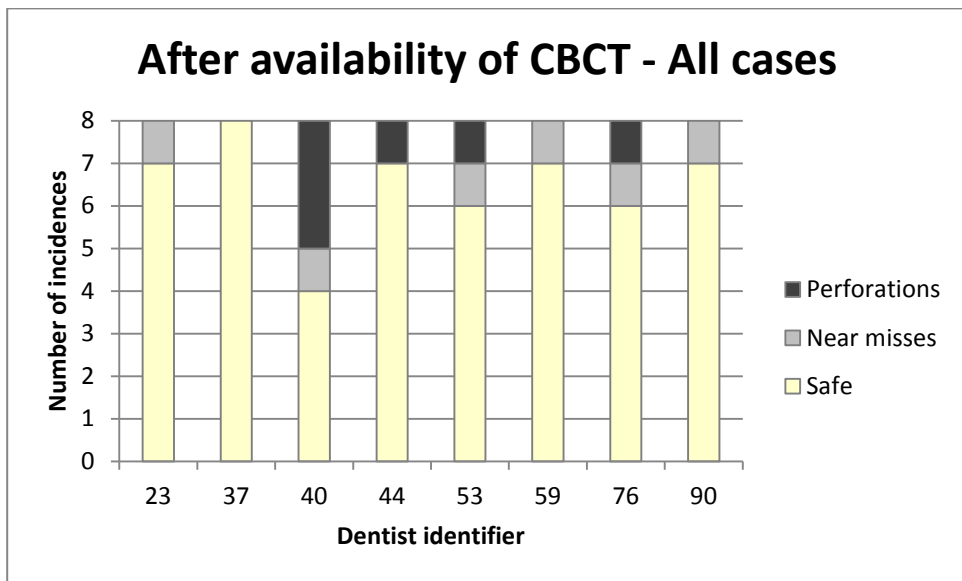
**Table 63 - Perforations and near misses for individual dentists before the availability of CBCT.  
All cases**

Dentist no.	Safe	Near misses	Perforations
23	7	1	0
37	8	0	0
40	4	1	3
44	7	0	1
53	6	1	1
59	7	1	0
76	6	1	1
90	7	1	0

**Table 64 - Perforations and near misses for individual dentists after the availability of CBCT.  
All cases**



**Figure 73 - Perforations and near misses for individual dentists before availability of CBCT.**  
All cases



**Figure 74 - Perforations and near misses for individual dentists after availability of CBCT.**  
All cases

These data suggested that some dentists might be regarded as “non-responders” to the availability of CBCT whilst others might be regarded as “responders”.

Dentists 23, 40, 53, 59 and 76 were regarded as non-responders. Dentists 37, 44 and 90 were regarded as responders. The perforations and near misses for these two groups are shown separately in Figure 75 and Figure 76 below.

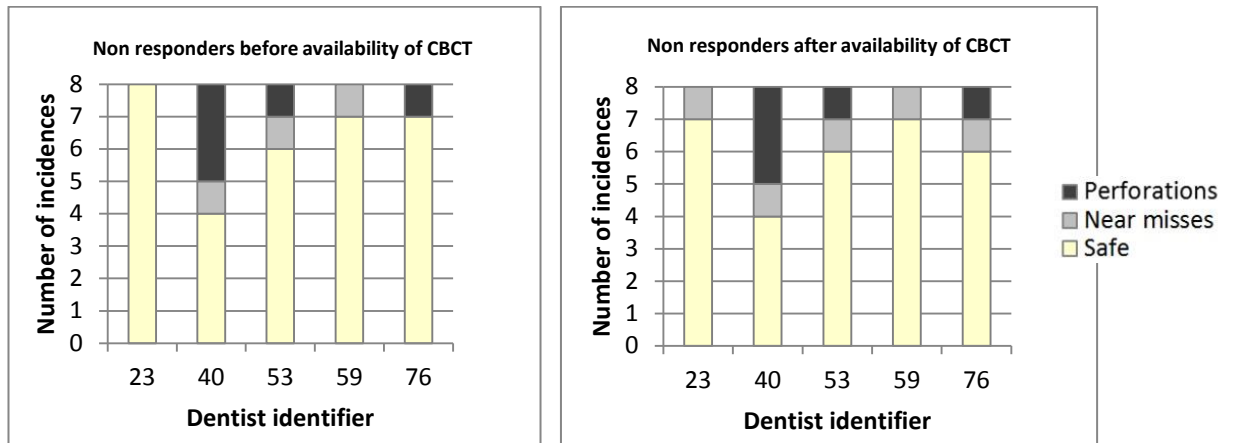


Figure 75 - Perforations and near misses for non-responders before and after availability of CBCT

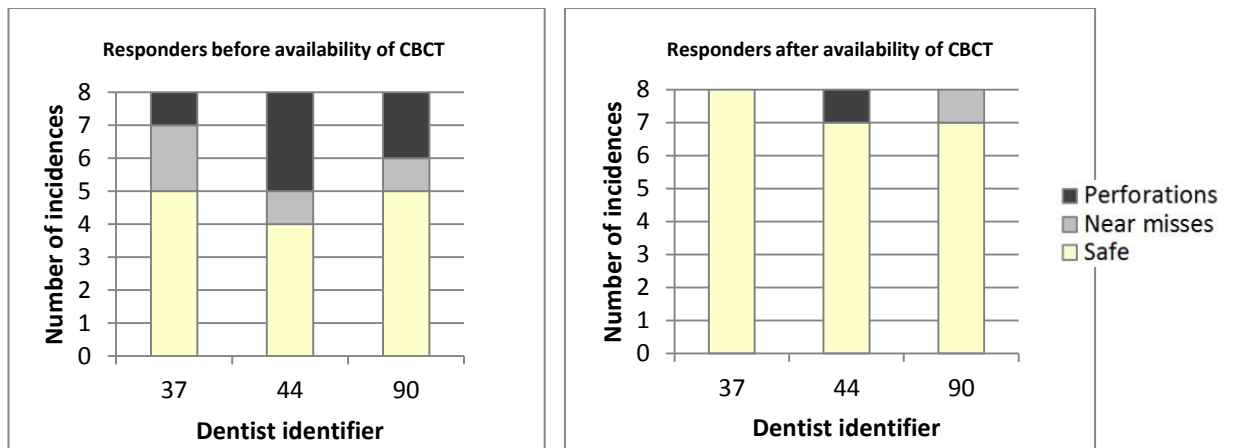


Figure 76 - Perforations and near misses for responders before and after availability of CBCT

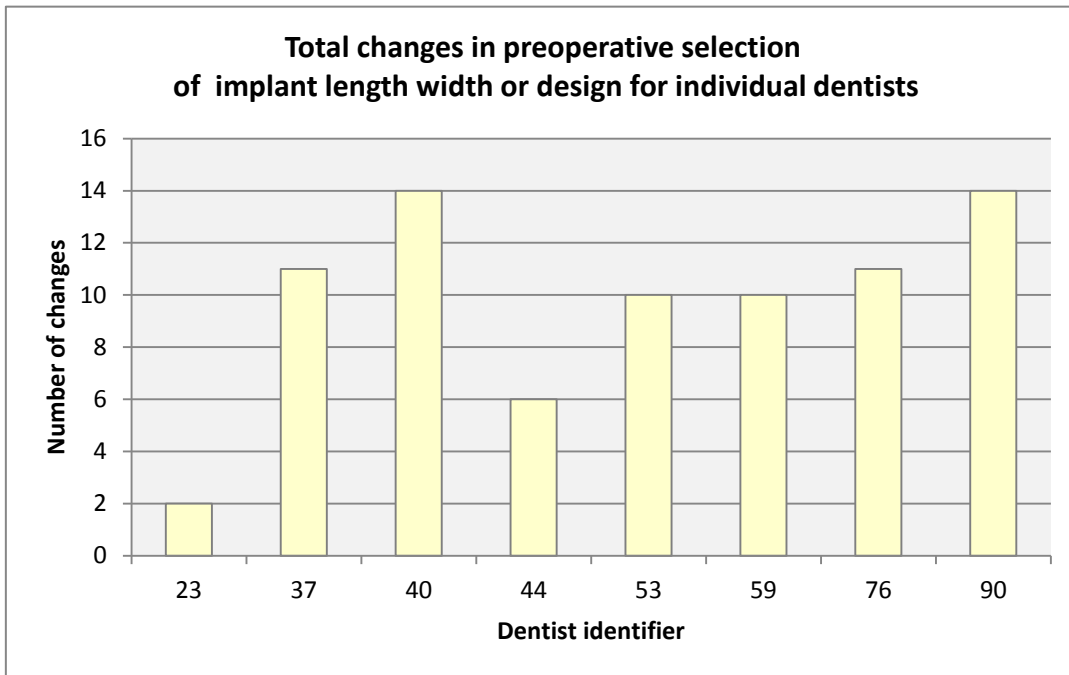
6.3.19 Consistency of selection of implant length, width and design amongst individual dentists

Preoperative selection

The number of changes, for all cases, in preoperative selection of implant length, width and design made by individual dentists, after availability of CBCT, is shown in Table 65 and Figure 77 below.

Mean number of changes	9.75
Standard Deviation	4.03
Range	2 to 14

**Table 65 - Number of changes in implant length, width or design made by individual dentists - preoperative selection**



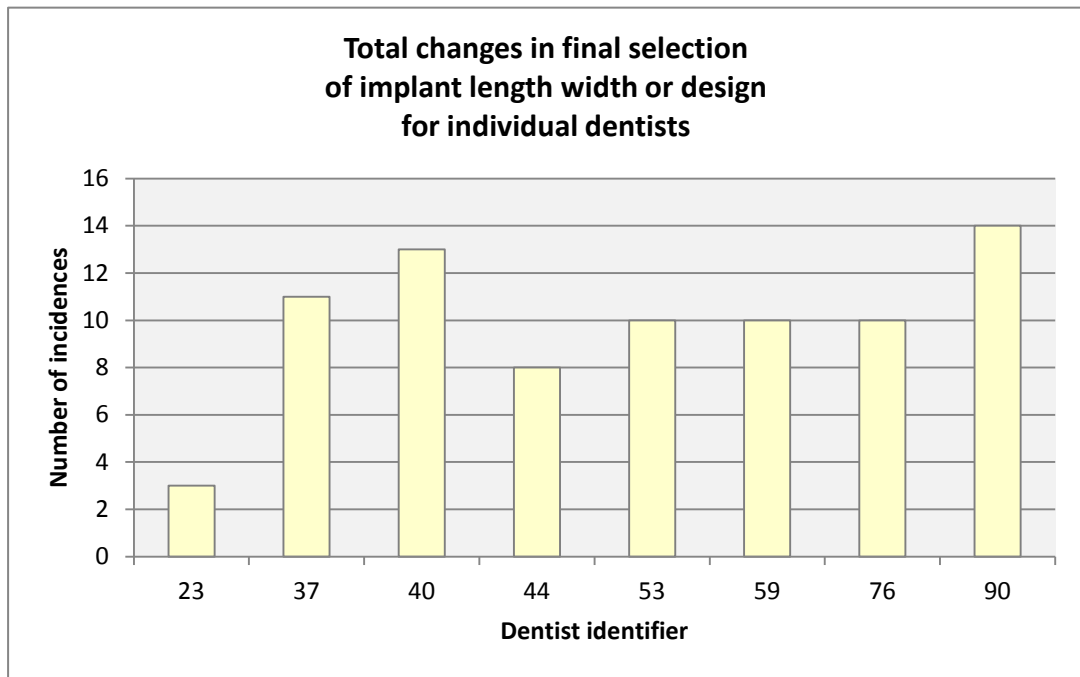
**Figure 77 - Number of changes in implant length, width or design made by individual dentists. Preoperative selection**

Final selection

The number of changes in final selection, for all cases, of implant length, width and design made by individual dentists, after availability of CBCT, is shown in Table 66 and Figure 78 below.

Mean number of changes	9.88
Standard Deviation	4.55
Range	3 to 14

**Table 66 - Number of changes in implant length, width or design made by individual dentists - final selection**



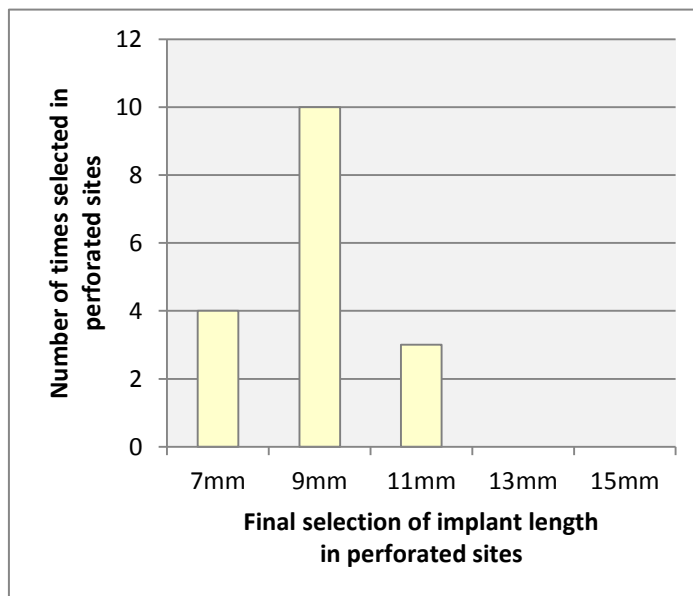
**Figure 78 - Number of changes in implant length, width or design made by individual dentists. Final selection**

### 6.3.20 Use of long implants

Authors have suggested that the use of long implants in the edentulous anterior mandible is associated with perforation of the lingual cortex and discourage this practice. [10, 15, 17] The final selection of length of implants used when participants perforated the lingual cortex in this study is presented in Table 67 and Figure 79 below.

Final selection of implant length	
7mm	4
9mm	10
11mm	3
13mm	0
15mm	0
<b>Total number of perforations</b>	<b>17</b>

**Table 67 - The final selection of implant length in perforated sites**

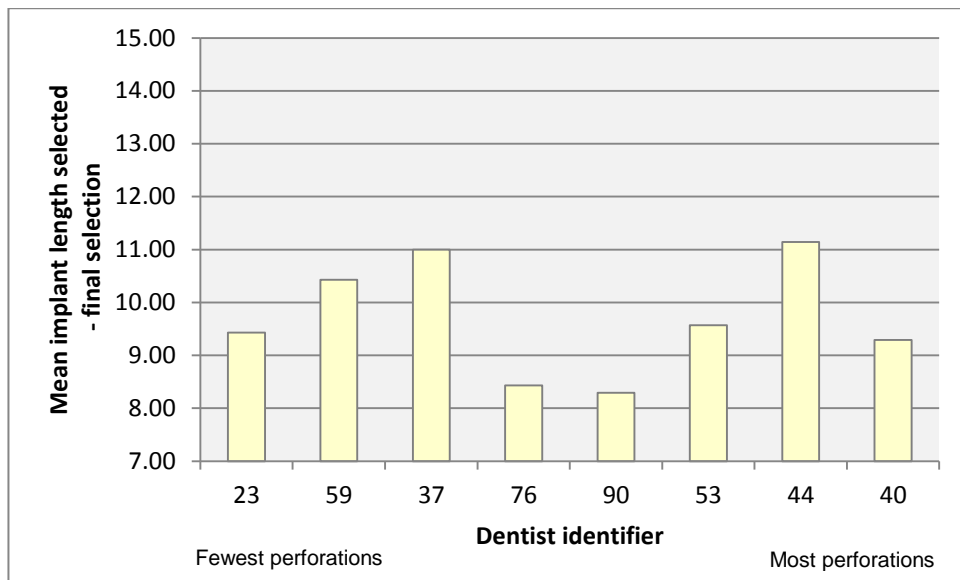


**Figure 79 - The final selection of implant length in perforated sites**

Table 68 and Figure 80 below show the total number of perforations created by each participant during the drilling exercises. The participants are ordered by the total number of perforations created and plotted against the mean length of implant selected in the final selection.

Dentist identifier	Total number of perforations created	Mean implant length selected in final selection
Dentist 23	0	9.43
Dentist 59	0	10.43
Dentist 37	1	11.00
Dentist 76	2	8.43
Dentist 90	2	8.29
Dentist 53	2	9.57
Dentist 44	4	11.14
Dentist 40	6	9.29

**Table 68 - The total number of perforations created by each participant and mean implant length in final selection**



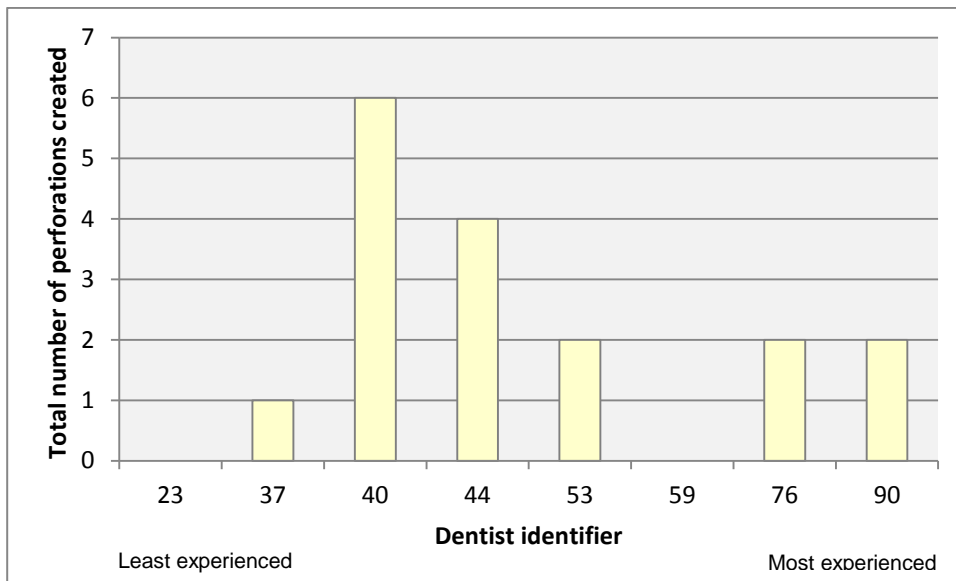
**Figure 80 - Mean implant length in final selection for each participant. Participants ordered by number of perforations created**

6.3.21 Experience in implant placement

Table 69 and Figure 81 below show the total number of perforations created by each participant during the drilling exercises. The participants are ordered by their experience in placing dental implants and plotted against the number of perforations created.

Dentist identifier	Total number of perforations created	Number of implants placed per year
Dentist 23	0	1 to 20
Dentist 37	1	1 to 20
Dentist 40	6	20 to 50
Dentist 44	4	20 to 50
Dentist 53	2	50 to 100
Dentist 59	0	50 to 100
Dentist 76	2	More than 100
Dentist 90	2	More than 100

**Table 69 - The total number of perforations created by each participant and the number of implants placed per year**



**Figure 81 - Total number of perforations created by each participant. Participants ordered by experience**



## 6.4 Discussion

### 6.4.1 Materials and methods

#### 6.4.1.1 Study design

The primary research question for this study was, “What is the impact of cone beam CT imaging on the incidence of perforation of the lingual cortical plate when placing dental implants in the anterior edentulous mandible?”. In the hierarchy of efficacy of diagnostic imaging described by Fryback and Thornbury, this question would be relevant to level five, “Patient outcome efficacy”. [46] Secondary research questions concerned the selection of implant size, implant design and the prescription of special surgical procedures. These questions are relevant to Fryback and Thornbury’s level 4, “Therapeutic efficacy”. A further secondary research question concerned the preoperative assessment of case difficulty. This could be regarded as relevant to Fryback and Thornbury’s level 3, “Diagnostic thinking efficacy”.

The “ideal” study design to answer the primary research question would be a well conducted randomised controlled clinical trial. In such a trial, a large sample of patients might be randomised to receive either conventional images, cross sectional images or perhaps both. Guyatt et al and Feinstein argued that randomised controlled clinical trials are likely to be too cumbersome or impractical for evaluation of diagnostic technologies. [196, 225] Amongst the difficulties would be the ethical dilemma of withholding an established and potentially beneficial diagnostic image, such as CBCT, from those patients randomly assigned to another arm of the study. In the United Kingdom, the National Health Service may not wish to co-operate with such a study. Also, fixed views may pose a problem with recruitment of surgeons and, in order to recruit sufficient patients, a multicentre approach may be required. Training of remotely sited co-workers would be necessary and the expense of such a study would be substantial. Further, the assessment of patient outcome would require an extensive long term follow up period. Guyatt et al drew attention to the potential difficulty of rapid developments in technology which may make the results of a trial obsolete by the time they appear.

Guyatt et al argue that, “Logistical problems and expense of RCTs favor [*sic*] the use of simpler but less powerful designs.” [196] These authors suggest the use of the before-after study design as a pragmatic solution to the difficulties of the randomised

controlled clinical trial when evaluating the impact of diagnostic technologies. Nonetheless, Guyatt et al also draw attention to the limitations of the before-after study. They list four in particular. The first is “limited scope”. In other words, this study design is usually limited to “add-on” technologies. A new test is performed after conventional tests are complete. Secondly, there may be a discrepancy between the stated plans in the study and clinical action in reality. Thirdly, the authors point to the possibility of subconscious bias. For example, participants may be predisposed to new technology and this may affect their treatment decisions. Lastly, Guyatt et al state that before-after studies establish the usefulness of a diagnostic technology only if therapeutic changes lead to beneficial changes in patient outcome. In this research, a number of modifications to the conventional before-after study design were made in an attempt to address these problems.

In the case of the first limitation, limited scope, it was considered that the before-after format already mirrors best practice. Current guideline documents state that conventional radiographs should be prescribed prior to the prescription of CBCT when planning dental implants. [34, 40, 190]. The “before” part of the study presented only conventional images and the “after” part of the study presented both conventional and CBCT images. Therefore, no modifications were considered necessary with regard to this limitation.

Notwithstanding, Guyatt et al’s argument, concerning the limitation to add-on technologies, is not entirely justified. The strategy described in this research could equally be applied to an “either-or” situation as a “before-after” situation. Also, clinically, not all diagnostic tests carry risks such as those of ionising radiation. Therefore, in many instances there may be no ethical issue with the application of multiple, alternative tests on the same patient. One is not necessarily forced into conducting a randomised controlled clinical trial.

The second limitation raised by Guyatt et al is that a participant’s stated plan may be different from that which they might carry out in reality. In this study, the participants were asked to carry out their treatment plan by physically preparing osteotomies for the implants which they had selected. Therefore, although the osteotomies were prepared on a dental simulation, the participants were asked carry out their stated treatment choices.

Guyatt et al's third limitation is that of subconscious bias for or against new technology. In a conventional before-after study, a participant would be presented with conventional images and asked to make a treatment plan. The participant would then be immediately presented with the additional cross sectional images and asked if this new information made any difference to the previous treatment plan decision. Examples of this approach are the studies by Diniz and Frei. [53, 56] This approach seems likely to encourage the manifestation of subconscious bias since the new decision is made immediately and in full knowledge of the previous decision. A related problem might be reluctance to change an initially stated opinion. For example, having selected a size of dental implant with the availability of conventional images, a participant may be reluctant to change their opinion after the availability of CBCT because of a conscious or subconscious need to be seen as consistent. In the present study, participants were presented with four cases. At the first visit there were two cases which had both conventional images and CBCT available and two cases which had conventional images only. In other words, two were "before" cases and two were "after" cases. There was then a washout period of four weeks. At the second visit the same four cases were presented but the two "before" cases were presented as "after" cases and the two "after" cases were presented as "before" cases. The participants were not told that the same four cases had been presented with different images. In this way, the method was concealed with the intention of reducing such bias.

In their fourth limitation of before-after studies, Guyatt et al assert that a diagnostic technology is only useful if it leads to beneficial changes in patient outcome. This study went a step further than previous studies by including a practical drilling exercise. The primary outcome measure was whether the participants created a perforation through the lingual surface of the mandible. The clinical consequences of this are potentially fatal and, therefore, this study was directly related to patient outcome. [10, 11, 17, 18, 29]

#### 6.4.1.2 Preparation of the images

In the questionnaire study, described earlier in this thesis, an imaging method was described in which specimen mandibles were positioned within a realistic, anatomical water phantom containing a section of human cervical spine. (Figure 10 page 61 Figure 11 page 62) This allowed multiple, realistic images to be taken. The same method was used to produce images of the four mandibles used in this study.

This method went further than many previous studies in attempting to produce realistic images. In some previous studies dried bone specimens have been used.[226] Others have used impression compound or polymers in an attempt to reproduce soft tissue. [227-231]. Nevertheless, these do not reproduce soft tissue within the bone itself. Water is a logical choice since human soft tissue itself is largely water. This approach has the advantage that, if left to soak, air inside the bones will be displaced by water thus representing the soft tissue within bone. This method has been used by Schorn et al [232] and Devlin and Horner [233]. Nonetheless, neither of these studies used a water container which was anatomical. Therefore, there would have been varying thicknesses of water, unlike the thicknesses of soft tissue in life. Also, for panoramic tomograms and CBCT, the x-ray beam would pass through the spinal column where attenuation would take place. The effect of this was not reproduced in these phantoms.

In order to reduce the time necessary for completion of the practical exercise, measurements were pre-marked on the images. (Figure 30 page 183 and Figure 31 page 185) In the practice situation, the participants might be expected to make their own measurements. Therefore, this method represented a departure from normal practice. Nevertheless, a pilot study showed that dentists might be expected to complete the practical exercise in some forty to sixty minutes. Had these dentists also been asked to make all of their own measurements on the images, it was felt that this would have been an unreasonable imposition. The time required is an important part of the decision to participate and this is particularly true of busy practitioners. [75, 77, 105] Further, this method meant that measurement was largely controlled. It was less likely, therefore, that variation in the results resulted from varying practices in taking measurements.

#### 6.4.1.3 Presentation of the mandibles in the dental simulation

An attempt was made to reproduce clinical circumstances as far as possible. A pilot study suggested that the dental simulation was as close to clinical circumstances as one might reasonably hope to achieve. (Section 5.2.7 page 196) Nevertheless, one aspect of the simulation which departed from clinical practice was the exposure of the bone in advance of the exercise. This represented the bone that might be exposed after reflection of a typical surgical flap. It would have been possible to completely cover the mandibles with soft tissue analogue material and ask the participants to use surgical instruments to reflect their own surgical flap. Nonetheless, this would have

added considerably to the time required of the participants. Further, this was not a critical consideration because the silicone soft tissue analogue material did not bond to the bone analogue material. This allowed the operator to use a periosteal elevator to lift the soft tissue and explore beyond the boundaries of the exposed bone as required. (Figure 45 page 195) This is very similar to common surgical practice. Also, in a similar way to the pre-measurement of the images, the pre-exposed bone reduced the time asked of the participants and introduced an element of control. It was less likely that variation in the results would be the result of individual's variation in reflection of their surgical flaps. Notwithstanding, a simulation was produced which may be useful in studies with different objectives such as evaluation of surgical technique.

#### 6.4.1.4 Separation of the visits

The two visits to each participant were separated by four weeks. At each visit, the participants were presented with the same cases but with different sets of images. This washout period was intended to be long enough for the participants to forget the details of the cases which they had prepared at the first visit. All details of the cases, such as the history and the photographs were kept exactly the same. The exception was the name of the case. In every instance the initials were reversed. For example, Mrs MG became Mrs GM. The case histories were also written to be deliberately bland. This was an attempt to make the cases forgettable. (Appendix M page 315) No evidence has been identified which would guide researchers on the appropriate length of time for such a washout period. This period of four weeks was therefore based on judgement. Nevertheless, none of the participants commented that they recognised the cases on the second visit.

#### 6.4.1.5 The sample of dentists

In this research, expense and time requirements were high. Expensive drillable models had to be produced and at least two hours was asked of each participant. There was, therefore, a need to keep the sample size within reason. At the same time, it was clearly important to have a sample of sufficient size to detect clinically important differences. No previous research existed to provide data on the anticipated primary outcome which was perforation of the lingual surface of the mandibles. Conventional wisdom suggests a sample size of between twenty four and fifty participants for a pilot study sample size. [234-237] A pilot sample of such a size was, in itself, in excess of a

realistic, final sample size for this research. This would have simply added to the impracticality of the study. Therefore, the final figures used in the sample size calculation were based on an exploration of different sample sizes and a judgment of possible numbers of perforations based on clinical experience. (Table 35 page 216 and Table 36 page 217)

This exploration suggested a minimum sample size of thirty three matched pairs. (Section 6.2.2 page 212) A practical sample size was considered to be sixty four matched pairs, well in excess of the minimum of thirty three. This consisted of eight dentists who were twice asked to prepare two osteotomies in each of four mandibles. This was judged to provide a sufficient margin of error and was adopted as the sample size for the final study.

The demographic characteristics of dentists in the North West of England, who place dental implants, were known from the previous questionnaire study. An attempt was made make the sample representative of this population. The results are shown in Table 37 on page 218. It was considered that this was as close a match as reasonably practicable. Whilst there were some differences in the type of training received and the university of first qualification, there was close similarity on gender, age, experience and postgraduate qualifications.

A randomised controlled clinical trial would require a large sample size to account for random variation between patients and clinical circumstances. For example, in 2012, Roeder et al calculated the sample size required to conduct a study to evaluate panoramic radiography and CBCT prior to lower third molar removal. To compare permanent neurosensory disturbance of the inferior alveolar nerve, these authors calculated a sample size of 649,036. [238] In a 2013 study of the cost effectiveness of computed tomography in a trauma centre, Saltzherr et al randomised a sample of 1,124 patients. [239] One advantage of a before-after study, conducted on a dental simulation, is that many factors can be controlled. These cannot be controlled in a randomised controlled clinical trial. For example, every participant had the same implant equipment, instruments and supporting materials available and these were presented in the same phantom head. Each case could be reproduced exactly so that a number of dentists could prepare osteotomies on the same mandible. This would not be possible in a randomised controlled clinical study. Therefore, the small sample size for this study is not directly comparable with that required for a randomised controlled clinical trial.

#### 6.4.1.6 Analyses

The primary outcome measure for this study was perforation through the lingual plate or “near miss” perforation. There were two osteotomies prepared in each mandible and so 64 pairs of data. The sample size was calculated to evaluate the differences in number of perforations, or near misses, between osteotomies prepared with or without the availability of CBCT. Statistical analysis was appropriate for these data. The supplementary outcomes were the choice of implant width, implant length, implant design, the assessment of case difficulty and the prescription of special surgical procedures with and without the availability of CBCT. In the case of implant length, width and design, there were also 64 pairs of data. Although a different statistical test was used from that intended in the sample size estimation, it was considered that a supplementary statistical analysis could be carried out for these data. In the case of assessment of case difficulty and need for special surgical procedures, only one assessment was made for each mandible. Therefore, there were only 32 pairs of data. Nevertheless, statistical analysis was carried out for these data which was close to the 33 pairs of data suggested by the sample size estimation.

In addition to these primary and supplementary data, there were demographic data on the participants which was known from the questionnaire study. Nonetheless, meaningful conclusions based on demographic data would require a sample size similar to that used in the questionnaire study. Therefore, no statistical analysis was carried out on these results. These data are presented as interesting findings. Notwithstanding, they should be interpreted with caution and general conclusions about the population of dentists in the North West of England cannot be drawn.

## 6.4.2 Discussion of Results

### 6.4.2.1 Total perforations and near misses for all osteotomies.

In total, 128 osteotomies were prepared. Of these, there were 17 perforations (13.28%) and 13 near misses (10.16%). It has been estimated that some 10,000 dental implants are placed in the mandible in the United Kingdom each year. [240] Separate figures for the anterior edentulous mandible are not available. Nevertheless, perforation of the lingual surface of the mandible may occur when placing dental implants in both the anterior and posterior mandible. These results, therefore, suggest that there may be many hundreds of lingual perforations of the mandible each year in the UK when placing dental implants. This raises the question of why there are not more reports of haemorrhages in the floor of the mouth. The reason, at least in part, must be that not every perforation results in trauma to a lingual vessel. This may be because drills miss vessels or that contact with vessels does not always result in trauma. For example, it may be that some contacts with drills displace rather than puncture vessels. Naturally, this is a risk which should not be deliberately taken. Additionally, in this study, some operators were observed raising the lingual soft tissue and protecting the lingual surface of the bone with a periosteal elevator whilst drilling. This protocol may prevent trauma to vessels if perforation occurs. Protection of the lingual surface was not always carried out, however, and some perforations in this study are likely to have been in inaccessible areas. Nonetheless, this may also explain why lingual haemorrhage is not reported more commonly. It should be noted that deep reflection of the lingual tissues, in itself, runs the risk of damage to lingual vessels. Lastly, there is no compulsory reporting system for such incidence and it may be that a number remain unreported.

### 6.4.2.2 Perforations and near misses before and after availability of CBCT

When considering all cases, the results showed that there were fewer perforations and near misses after the availability of CBCT. Nonetheless, the overwhelming majority of osteotomies were prepared safely, with neither perforation nor near miss before or after the availability of CBCT. (Table 40 page 229 and Figure 62 page 229) A cross tabulation was carried out to show the numbers of participants who changed to or from a safe osteotomy after the availability of CBCT. (Table 41 page 230 and Table 42



page 230) When considering perforations and near misses together, there were eleven occasions where participants perforated the same sites before the availability of CBCT but not after. Nevertheless, there were five occasions where participants perforated the same sites after the availability of CBCT but not before. In other words, whilst there were eleven occasions where the osteotomies became safe, there were five occasions where osteotomies became unsafe after the availability of CBCT. When considering perforations alone, there were seven occasions where osteotomies became safe but two where osteotomies became unsafe after the availability of CBCT. This cross tabulation was analysed using McNemar's test. The results were found to favour acceptance of the null hypothesis that there is no significant difference in the proportion of lingual perforations or 'near miss' perforations before or after the availability of CBCT images. ( $P=0.21$  for perforations and near misses,  $P=0.18$  for perforations alone). (Table 41 page 230 and Table 42 page 230)

The cases had been previously categorised as two "regular" cases and two "challenging" cases. (Section 6.2.2 page 212) It was noted that there were no incidences of perforations in the two regular cases and only a single near miss. (Table 43 page 231 and Figure 63 page 231) All perforations, and all but one near miss, were performed on the challenging cases. (Table 44 page 232 and Figure 64 page 232). Nevertheless, the evidence was very weak that the availability of CBCT had an effect on the incidence of perforation or "near miss" perforation. Further, if the Bonferroni correction is applied then it appears still more probable that the differences in numbers of perforations and near misses occurred by chance. Nevertheless, it should be noted that the Bonferroni correction decreases the probability of a type one error whilst simultaneously increasing the possibility of a type two error. (See "multiple comparisons" on page 125)

A number of authors have recommended cross sectional imaging in general, and CBCT in particular, as a preventive strategy to avoid perforation of the lingual plate when preparing osteotomies in the anterior mandible. For example, in 2007, Longoni carried out a study of dried skulls and asserted, "A CT examination should routinely be performed before any surgical approach to the interforaminal region." [30] More recently, in 2013, Sakka reported on a case of sublingual haemorrhage following implant placement in the edentulous anterior mandible. This author went further by recommending two sets of CT scans and declared, "It is advisable to perform pre- and postoperative 3-dimensional CT scans in both dentate and edentulous jaws." [241] Other authors have been more circumspect. For example, in 2004 Kalpidis and

Setayesh suggested that “CT may be advisable in demanding cases” and in 2009 Pigadas et al advise that “CT ... may be an advantage.” [10, 11]

These two, contradictory, positions are reflected in current guidelines. The American Academy of Oral and Maxillofacial Radiology (AAOMR) published their most recent guidelines in 2102 entitled, “Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography”. These guidelines state, “AAOMR recommends that cross-sectional imaging be used for the assessment of all dental implant sites and that CBCT is the imaging method of choice for gaining this information”. [42] In the same year the European Association of Osseointegration published their guidelines, “E.A.O. guidelines for the use of diagnostic imaging in implant dentistry”. These take an opposing position to those of the AAOMR and state, “If the clinical assessment of implant sites indicates that there is sufficient bone width and the conventional radiographic examination reveals the relevant anatomical boundaries and adequate bone height and space, no additional imaging is required for implant placement.” [40] Other guidelines take a similar position to that of the EAO. For example “Selection Criteria in Dental Radiography” is published by the Faculty of General Dental Practice (UK). The latest guidelines were published in 2013 and state that, in the case of the anterior edentulous mandible, cone beam CT examination is recommended in cases of severe resorption or clinical doubt on the shape of the alveolar ridge. [34] Notwithstanding, these guidelines draw attention to limited evidence. The authors state, “Overall, it can be concluded that, at present, there is a limited evidence base on which to formulate guidelines for the use of radiographs in implant dentistry”.

The results of this study do not support the position of the AAOMR. Taking into account all cases, there was no statistically significant difference in perforations or near misses after the availability of CBCT. If the regular cases are looked at in isolation, there were no perforations either with or without the availability of CBCT. This weakens the position of the AAOMR that CBCT should be used for all implant sites. If the challenging cases are looked at in isolation, there were fewer perforations after the availability of CBCT. This might be thought to support the position of the EAO, FGDP(UK) and others that CBCT may be advisable in demanding cases.

Nonetheless, the difference in perforations before and after the availability of CBCT was not statistically significant and it must be acknowledged that this was likely to have been a chance finding. Furthermore, some participants, in some sites, did not

perforate before the availability of CBCT but perforated the same sites after the availability of CBCT. Therefore, at the very least, it can be concluded that the availability of CBCT is no guarantee against perforation.

This study provides very weak evidence for the efficacy of CBCT imaging when planning dental implant placement in the anterior edentulous mandible. Therefore, those who argue that CBCT should be used routinely prior to dental implant placement remain unsupported by evidence. Conversely, however, this raises the question of whether this evidence should lead practitioners to abandon CBCT as an imaging modality when planning dental implant placement in the anterior edentulous mandible. First, this was a relatively small sample of dentists and mandibles. On that basis alone, the results should be interpreted with caution. Secondly, in the FGDP(UK) Selection Criteria in Dental Radiography, the authors comment that the choice of radiographic technique is complicated by a number of factors, including the experience of the practitioner. [34] Although these results do not support this, it remains a common sense position that CBCT is helpful for some dentists and some cases. Based on this evidence, it would be inappropriate to suggest that CBCT should not be used in the preoperative assessment of dental implant sites in the edentulous anterior mandible. In short, these results suggest that there is no case for routine prescription of CBCT for the preoperative assessment of all implant cases. Nevertheless, it would be premature to suggest that CBCT has no place in the assessment of the anterior edentulous mandible when planning dental implant placement.

The question is also raised of whether this evidence is applicable to other sites in the mouth. In the case of the edentulous anterior mandible, the transsymphyseal view is available and was presented as a conventional image in this study. [32] The transsymphyseal view is an approximation of a true cross sectional view taken with a plain film. Some of the same information that would be available from a CBCT image will also be available from the transsymphyseal view. Similar techniques are not available for other sites and, therefore, the requirement for CBCT images will be different in other areas of the mouth. This evidence, therefore, has limited applicability to other implant sites.

In the previous questionnaire study, it was noted that many implant practitioners prescribed panoramic views only, without the additional transsymphyseal view or its equivalent lateral cephalometric view. In addition, some practitioners prescribed no radiographs at all. For the very resorbed case, 27% of respondents prescribed only a

panoramic view and 1.5% prescribed no radiographs. For the well-formed case, 41 % of respondents prescribed only a panoramic view and 2.2% prescribed no radiographs. If the participants in this before-after study had been asked to prepare osteotomies with the guidance of only a panoramic view, or without any radiographs, then the results may have been very different. The possible permutations of prescription of conventional radiographs would be expected to change subtly the relative impact of the availability of CBCT.

#### 6.4.2.3 Post hoc calculation of sample size

As a result of analysing the challenging cases only, the sample size was effectively halved. These analyses, therefore, were carried out on 32 matched pairs of data. In this smaller sample size, visual assessment of the results suggests that differences in perforations may be important. (Figure 64 page 232) A post hoc sample size calculation was carried out. This suggested that, if the same results were repeated in a larger sample size, statistical significance was set at 0.05 and power set at 0.8, then that sample size would be 88 matched pairs. In this study, where both challenging cases and regular cases were included, this would suggest a sample size of 176 matched pairs of data. Using four mandibles, each with two osteotomies, would lead to a sample of 22 dentists. If the Bonferroni correction is taken into account, setting statistical significance at 0.0125, the same calculation would suggest a sample of 32 dentists. This is four times the size of the present study. Naturally, the repetition of the same results with a bigger sample size is speculation. Nevertheless, this does suggest the order of sample size which might be necessary in a larger, repeat study based on these results.

#### 6.4.2.4 Selection of implant length, width and design

The selection of implant length, width and design was recorded both before and after drilling of the osteotomies. The choice of implant design was either straight or tapered. In the cases of length and implant design, the number of changes before and after the availability of CBCT was always within one or two of the number of changes in the opposite direction. Larger differences were noted for the selection of implant width and these were subject to statistical analysis. It was also noted from the data that differences arose largely from the challenging cases. (Table 49 and Figure 66 page

236, Table 52 and Figure 69 page 239) For this reason separate analyses were carried out for the challenging cases alone.

It is perhaps unsurprising that the availability of CBCT made no statistically significant difference to the selection of implant width when considering regular and challenging cases together. Implant width only becomes critical when the bone width is limited. Implant width selection for the regular cases is perhaps more a matter of the practitioners' preference. Where bone width is reduced, such as in the challenging cases, then this may begin to dictate the implant width.

These results provide evidence that the availability of CBCT led to the selection of narrower implants for the challenging cases. Nevertheless, if the Bonferroni correction is applied to these four analyses, this leads to a new significance level of  $0.05/4 = 0.0125$ . The preoperative selection of implant width remained statistically significant but the final selection of implant width ceased to be statistically significant. Whilst this should be taken into consideration when interpreting these results, the Bonferroni correction has been criticised for being overly conservative. (Section 3.6.3.6 page 125) The preoperative selection remains statistically significant. Therefore, taking the two sets of results together, one might conclude that, on balance, there is good evidence that the availability of CBCT leads practitioners to select narrower implants in challenging cases. The case, however, is somewhat weakened by the effect of multiple comparisons.

It might be considered logical that implant length is unaffected by the availability of CBCT. Correcting for magnification, a panoramic view can be measured for the height of the mandible at the site of the proposed dental implants. Notwithstanding, the panoramic view does not show lingual concavities which might restrict the height available in which to safely place a dental implant. It may be reasoned, therefore, that the transsymphyseal view is providing much of the information required to make a judgement on implant length. Furthermore, the lengths of the implant system provided are in 2 mm increments. Therefore, there would have to be a substantial difference in judgement made before and after the availability of CBCT for the selection of implant length to change. In contrast, the widths of the implant system provided are in 0.5 mm or 0.25 mm increments. It is, therefore, more likely that the more precise measurements offered by a CBCT image, at exactly the site of the proposed implant placement, would lead to a change in selection of implant width.

The participants were offered a choice of straight or tapered dental implants. In order to reproduce clinical circumstances as far as possible, the implant system was a commercially available one. In common with other implants systems, the shortest and narrowest implants are available only as straight or parallel sided. (Appendix M page 315) This may have dictated the choice of straight implants in the challenging cases. Nevertheless, no difference was demonstrated in the results, with approximately equal numbers of changes to and from straight and tapered implants before and after the availability of CBCT. There were appreciably fewer changes of implant design than changes in length or width. For example, in the preoperative selection of implant length there were 17 changes to a longer implant and 15 changes to a shorter implant. For implant design, there were 8 changes to a straight implant and 10 changes to a tapered implant. This is considered to be because some implant practitioners often have a preference for straight or tapered systems. Some may be expected, therefore, to choose a straight or tapered implant regardless of the radiographic images presented to them.

#### 6.4.2.5 Preoperative assessment of case difficulty

These results show that, for challenging cases, practitioners assess the cases to be more difficult when presented with CBCT images than when presented only with conventional images. This difference in perception of difficulty is most likely to be represented by the difference between the information provided by the transsymphyseal view and that provided by the CBCT view. The transsymphyseal view provides an approximation of a cross sectional image but, in reality, is a superimposition of the mandible from approximately canine to canine region. This obscures some detail and is probably most representative of the cross section at the midline. By contrast, the CBCT view provides a true cross sectional image exactly at the site of the intended implant. For example, lingual concavities at the canine regions, but not at the midline, will be demonstrated on the CBCT view but may be obscured on the transsymphyseal view. Notwithstanding, this finding is relevant to Fryback and Thornbury's level three, diagnostic thinking. [46] Perception of case difficulty is of importance only if it changes the outcome for the patient. This is Fryback and Thornbury's level five. The evidence from this study suggests that, even for the challenging cases, the difference in patient outcome after availability of CBCT is not statistically significant. (See Table 47 page 234)

#### 6.4.2.6 Prescription of special surgical procedures

There were very few instances of prescription of special surgical procedures. In every case where this was prescribed, the practitioners said that they would refer the case for bone grafting by a specialist and all such prescriptions were for the challenging cases. In this study, the participants were asked on a case by case basis whether they would prescribe special surgical procedures. This is most likely to be how a prescription for bone grafting would take place in real clinical circumstances. The effect of this was that there were 32 pairs of data rather than the 64 pairs which arose from consideration of the two osteotomies for each case. When considering challenging cases only the sample size was further reduced to 16. Therefore, the sample size was small for this analysis. Whilst it may appear that the change in prescription of special surgical procedures for the challenging cases was appreciable, the statistical analysis of this small sample size favours the probability of this being a chance finding. Nevertheless, some observations may be made. There were no instances of a participant who prescribed bone grafting before the availability of CBCT but prescribed no bone grafting after the availability of CBCT. This would be in agreement with the findings above where it was perceived that the challenging cases were more difficult after the availability of CBCT. (Section 6.4.2.5 page 270) Also for the purposes of this study, if a participant prescribed bone grafting, they were then asked to continue and prepare osteotomies for the cases regardless of this. Interestingly, there were seven prescriptions of bone grafting including those before and those after availability of CBCT. Fourteen osteotomies were, therefore, prepared at sites for which bone grafting had been prescribed. Of these, only four sites were subsequently perforated (28.6%). For the challenging cases overall, there were 32 osteotomies prepared and 17 perforations (53.1%). This was appreciably in excess of the proportion of perforations created only on those cases for which bone grafting had been prescribed. This raises the question of whether bone grafting was necessary for these cases. It might be speculated that, having prescribed bone grafting but asked to prepare osteotomies anyway, the practitioners proceeded with appropriate caution. They may also have simply risen to the challenge of preparing sites which they had declared themselves as very difficult. Naturally, the consequences of perforation in a model are very different from the potential consequences of perforation on a patient. This enabled the participants to proceed on these cases free of serious risk.

#### 6.4.2.7 Additional results

Demographic information was available for the respondents from the questionnaire survey described earlier in this thesis (Section 3.3.2 page 86). The sample size of eight dentists was small and so meaningful conclusions about the population of implant practitioners on the North West of England cannot be drawn. Accordingly, no statistical analysis was performed. Nonetheless, some observations can be made.

##### Perforations and near misses

Consideration of these results shows that there are appreciable differences between the participants. (Table 63 page 249, Table 64 page 249, Figure 73 page 250 and Figure 74 page 250) One participant, dentist 23, created no perforations and only one near miss. Conversely, another, dentist 40, created six perforations and two near misses in total. It appears clear that practitioners vary in their preparation of osteotomies.

It was further observed that three participants appeared to be responders to CBCT and created fewer perforations when these images were available. Five participants appeared to be non-responders and created similar numbers of perforations and near misses both with and without the availability of CBCT. These data are presented in Figure 75 on page 251 and Figure 76 on page 251.

##### Implant selection

Figures for consistency of implant selection were prepared. The number of changes of width, length or design was recorded for both preoperative and final choices of implant. It is interesting to note that dentist 23, who created the fewest perforations, was also the most consistent in the selection of implant. The dentist who created the most perforations, dentist 40, was one of the least consistent in implant selection.

##### Implant length

A number of authors have identified unnecessarily long implants as a causative factor in perforation of the lingual surface of the mandible and consequent haemorrhage in the floor of the mouth. [15, 17] For example, Givol et al in 2000 recommended, "The



decision to use implants longer than 14mm in the mandibular canine or premolar area deserves careful consideration". Similarly, in 2004, Kalpidis and Setayesh commented that, "Utilization [sic] of <15 mm implants would be advisable, especially in the canine sites". An exploration of the length of implants selected by the participants in this study was, therefore, of interest. Table 67 on page 254 and Figure 79 on page 254 show the length of implants used when osteotomies perforated the lingual surface. The most commonly used implant was 9mm and there were no implants used which were longer than 11mm. As a second exploration of these data, the mean implant length selected by each participant was plotted against the number of perforations that the participant created. (Table 68 on page 255 and Figure 80 on page 255) This does not suggest any relationship between perforations and the participant's preference for long or short implants. In the early days of dental implantology, it was recommended that implants should be placed as long as possible and with bicortical fixation. [242] These results may suggest that such practices are no longer conventional wisdom. Further, some dentists who chose longer implants, for example dentists 59 and 37, created the fewest perforations. It may be speculated that, up to a reasonable limit on implant length, avoidance of perforations is less attributable to the length of the implants selected than to the skill of the dentist who places them. In a 2011 study, Dimitrijevic et al investigated the depth and distance perception of dentists and dental students and commented, "Ability to perform perceptual tasks varied enormously". They conclude, "Some dentists ... have great difficulty in accurately gauging depths and distances". [243]

#### Experience in implant placement

It cannot be said from these results that the more experienced implant practitioners created the fewest perforations. For example, dentist 23, created no perforations and places fewer than 20 implants per year. Similarly, dentist 30, who also places fewer than 20 implants per year created only one perforation. It is tempting to conclude from the shape of Figure 81 on page 256 that beginners in dental implantology proceed with caution appropriate to their experience. This is followed by a period of over-confidence after which they return to a more measured approach based on their familiarity with dental implantology. This is, of course, simply imaginative speculation and such conclusions cannot be drawn from this very small sample of implant practitioners.

### 6.4.3 Limitations of this study

#### Reproduction of clinical circumstances

Every effort was made to reproduce realistic clinical circumstances as far as possible. Nevertheless, dentistry carried out on a dental simulation can never be the same as dentistry carried out on a patient. For example, the drilling exercise was carried out without the presence of bleeding or saline coolant. There were no difficulties with local anaesthesia, patient co-operation or movement during the procedures. There were limitations on the time available to carry out the exercise although this may well also apply in clinical circumstances. Also, dentists may have taken longer to consider the images and plan their osteotomies in advance if these had been real patients. Notwithstanding, these same circumstances existed for both the 'before' and 'after' parts of the study and for all participants. The study design therefore controlled for these factors.

One important factor may be that the procedures were risk free. The participants did not have the real concern of causing a perforation and possible haemorrhage on the dental simulation. This may well have affected the preparation of the osteotomies. On the other hand, however, the exercise was observed by the investigator and the participants would naturally have wished to prepare the best osteotomies they could in front of another dentist.

The bone was exposed by a simulated surgical flap in advance. This was done in an effort to keep the time required for the exercise to a reasonable level. The same was true for the measurements which were pre-prepared on the images. Whilst both of these pre-preparations are departures from real clinical circumstances, they were very valuable in restricting the time required. Whilst the pilot study suggested that the exercise would take 40-60 minutes to complete, one participant took some two hours in the main study. With the additional burden of taking image measurements and raising a surgical flap, this appointment would have been impractical. An attempt was made to mitigate the departure from reality by using a panel of implant practitioners to advise on typical bone exposure and image measurements in advance.

One difficulty with the exercise in raising surgical flaps in advance is that the participants in this preliminary study were given a full set of images to guide them in raising their flaps. If the participants in the final study had been asked to raise their own flaps in the “before” part of the final study, they would have done this without the availability of the CBCT images. Nevertheless, the variation in flap reflection was considerable. (Figure 48 page 200) The silicone soft tissue analogue could also be separated from the bone model in a similar way to life. This, in effect, meant that the participants could expose further bone themselves if they so wished. This was observed many times during osteotomy preparation.

The bone analogue material was judged, in the pilot study, to be a realistic reproduction of real bone. Notwithstanding, it was different from real bone. Although the surface of the bone models was intact, there was no cortex as one might find in life. (Figure 33 page 187) Typically, an implant practitioner would feel a distinct difference between the cortical and cancellous parts of the bone. Further, the consistency of the bone analogue material was even throughout the model. In reality, one would expect more variation with areas of dense and sparse bone or even sudden voids. Similarly, the silicone soft tissue analogue material was different from real mucoperiosteum although it could be separated from the bone model in a similar way.

Some participants were observed to protect the lingual soft tissues with a periosteal elevator. The effect of this was not taken into consideration. Further, we cannot know which of the perforations would have caused a haemorrhage and which would have remained relatively harmless.

#### The sample

The sample size was restricted by the expense of manufacturing the models, the time required of the participants and of the single investigator. It is possible that a larger sample size may have revealed clinically important differences. Nevertheless, this would have to be a very much larger sample size, at least four times the size of the present study. (See section 6.4.2.3 page 268) Whilst the sample of eight dentists was chosen to represent the population of implant practitioners in the North West of England, this was still only eight dentists out of a population of some 200. We cannot know whether another sample of eight dentists would have produced different results. This also restricted the conclusions that could be drawn about the results of the exercise in relation to demographic factors.

## 6.5 Conclusions

A method has been established to test the practical effect of the availability of different image types on the placement of dental implants in the edentulous anterior mandible. This study goes further than any previous investigations by encompassing Fryback and Thornbury's hierarchy of efficacy of diagnostic imaging levels three, four and five. [46] The investigation of assessment of case difficulty was appropriate to level three, diagnostic thinking efficacy. The investigation of selection of implant length, width and design was appropriate to level four, therapeutic efficacy. The investigation of perforations of the lingual surface of the mandible, and thus potentially fatal haemorrhage, was appropriate to level five, patient outcome efficacy.

A previous systematic review (Section 4.1.1 page 133) revealed that only five previous studies had investigated the impact of image types when placing dental implants in sites including the anterior mandible. [53, 56, 59, 61, 62] These studies had a number of limitations. All of these studies investigated the selection of dental implants and so were relevant only to Fryback and Thornbury's level four. In these studies, the maximum number of participants was four although the number of cases was up to 121. This was considered to be the reverse of the ideal method for this type of study. Some of these five studies had only one participant and it was considered that a small number could easily represent idiosyncratic practices. The intention of this study, therefore, was to investigate a wider range of implant practitioners presented with a smaller number of reproducible cases in a customised dental simulation. In addition, none of these five studies investigated the impact of cone beam CT. This has largely replaced the conventional tomography or multi slice medical CT used in these studies.

This investigation, therefore, was unique in investigating the impact of cone beam CT on dental implant placement up to Fryback and Thornbury's level five using a relatively wide range of participants and reproducible cases. The dental simulation was also novel in a number of respects. The realistic radiographic phantom allowed multiple images to be taken of the four edentulous mandibles used in the investigation. The mandibles were reproduced using a method and bone analogue material that was developed especially for the investigation. The development and production of the models in a silicone soft tissue analogue were also developed exclusively for this study.

In this study, 13.28% of the sites were perforated. It has previously been reported that some 10,000 implants per year are placed in the mandible in the UK annually. Therefore, these results suggest that, when preparing osteotomies in the anterior edentulous mandible, perforations may be reasonably common. It seems clear that not all perforations lead to a haemorrhage in the floor of the mouth. This may be partly due to the surgical practice of protecting the lingual tissues with a periosteal elevator or that perforations do not always perforate arteries.

For the two regular cases in this study, there were no perforations either before or after the availability of CBCT. From these results, therefore, it must be concluded that the availability of CBCT has no impact on the outcome of the preparation of osteotomies in the edentulous anterior mandible in regular cases. This contradicts the position of the AAOMR who recommend that, "cross-sectional imaging be used for the assessment of all dental implant sites and that CBCT is the imaging method of choice for gaining this information".[42]

For the challenging cases, there were fewer perforations after the availability of CBCT. Nevertheless, there is very weak evidence of an effect ( $P=0.18$ ). Furthermore, it is clear that some participants, who did not perforate before the availability of CBCT, did perforate after the availability of CBCT. In other words, their performance was worse when they had CBCT images. At the very least, therefore, it can be concluded that the availability of CBCT is no guarantee of the avoidance of perforation.

These results are not directly applicable to other regions of the mouth. The transsymphyseal technique, or alternatively the lateral cephalogram, is a conventional view which gives an approximation of a cross sectional image at the sites of implant placement in the edentulous anterior mandible. They provide at least some of the information which is provided by CBCT. Equivalent, conventional views are not available for sites elsewhere in the mouth and therefore these results should not be considered applicable to sites other than the edentulous anterior mandible.

The EAO guidelines and the FGDP(UK) guidelines are similar and recommend that cross sectional imaging may be appropriate in some situations. [34, 40] The FGDP guidelines further comment that the choice of radiographic technique is complicated by a number of factors including the experience of the operator. The results of this investigation show that implant practitioners do vary in the number of perforations they create and in the consistency of their implant selection. Further, some participants

were identified as responders to the availability of CBCT and some as non-responders. This finding is consistent with the position of the EAO and FGDP(UK). Notwithstanding, consideration of the demographic information for the participants did not suggest any relationship between demographic factors and perforations. For example, the experience of the implant practitioner was no predictor of safety in this group of implant practitioners. These results are, therefore, unhelpful in identifying the cases and practitioners for which CBCT is most useful.

Some authors have suggested that the use of long implants is associated with perforations of the lingual surface of the anterior mandible.[10, 15, 17] Whilst this is, of course, a common sense position, it may be concluded that the perforations created by this sample of implant practitioners were not associated with the use of long implants.

The results of this study suggest that CBCT images may lead implant practitioners to choose narrower implants for challenging cases in their preoperative selection. ( $P=0.007$ ) The case for selecting a narrower implant in the final choice, after osteotomy preparation, is weakened by the effect of multiple comparisons which would set statistical significance at  $P= 0.0125$ . ( $P=0.021$  for final choice) Nevertheless, on balance, there is moderately strong evidence that implant practitioners choose narrower implants for challenging cases when CBCT is available. There was no impact, however, of CBCT on the selection of implant length or design. It was also found that implant practitioners perceive challenging cases as more difficult after the availability of CBCT. ( $P=0.006$ ) This would seem to be consistent with the finding that they choose narrower implants when CBCT is available for these cases.

The practitioners in this study did prescribe special surgical procedures for the challenging cases more often when CBCT was available. The special surgical procedure was always bone grafting. There were no instances of a participant prescribing bone grafting before the availability of CBCT but not after. This again would seem consistent with the finding that the participants perceived the challenging cases to be more difficult and that they required narrower implants after the availability of CBCT. Nonetheless, this was based on a very small sample of 16 cases and the results provide very weak evidence of an effect. ( $P=0.25$ )

In summary, a novel method of conducting a before-after study is described which presents reproducible simulated cases in a dental simulation. When placing dental implants in the edentulous anterior mandible, the results suggest that the availability of

CBCT has no overall impact on the incidence of perforations of the lingual surface of bone. There is very weak evidence that CBCT may be helpful in the more challenging cases for some dentists. The availability of CBCT leads implant practitioners to perceive challenging cases as more difficult and to select narrower implants for these cases. Nonetheless, the availability of CBCT images is no guarantee of safety and the experience of implant practitioners is no predictor of perforation. These results are not directly applicable to other sites in the mouth. The findings of this investigation contradict the recommendations of the AAOMR but are consistent with the recommendations of the EAO and FGDP(UK). [34, 40, 42]

The use of the dental simulation developed for this study may be useful for teaching and assessment in dental implant training.





## 7 Conclusions for this thesis

- ▶ The placement of dental implants in the anterior edentulous mandible to support a complete overdenture is a common procedure. It is recommended by some authorities as the minimum standard of care for edentulous patients.
- ▶ The motivation for this research arises from a concern over the risks of lingual perforation during osteotomy preparation and a wish to reduce these as far as possible with dissemination of evidence based research information.
- ▶ Beyond risk benefit considerations, there are also economic aspects. Resources are always limited and choices must be made concerning their deployment. This issue has begun to be addressed for dental CBCT. [244] [245]
- ▶ Published guidelines on preoperative imaging prior to dental implant placement have been published. In some instances guidelines are conflicting. It is hoped that these results will contribute to future guideline development.
- ▶ Whilst there is ample evidence about the technical and dimensional accuracy of CBCT, there is very little evidence to evaluate its impact on diagnostic thinking, treatment planning or patient outcome.
- ▶ An important achievement for this research was to carry out investigations using independent dental practitioners where most implantology is conducted.
- ▶ A literature review explored the conduct of questionnaire studies in dental radiology. Many are conducted poorly and this arises from a lack of attention to potential survey errors.
- ▶ A questionnaire study of implant practitioners in the North West of England showed no agreement on radiographic prescription when planning dental implant placement in the edentulous anterior mandible.
- ▶ A systematic review identified very little evidence with which to evaluate the impact of cross sectional imaging prior to dental implant placement in the anterior mandible. The evidence which was identified was conflicting.

- ▶ A unique dental simulation was developed in which reproducible cases, including a range of different images, could be presented to implant practitioners
- ▶ A before-after study was implemented using a dental simulation. Very weak evidence was found that the availability of CBCT led to fewer perforations in challenging cases. For regular cases, CBCT was found to have no effect on the incidence of perforations.
- ▶ This research is unique in addressing patient outcome efficacy and by investigating the impact of the availability of CBCT prior to dental implant placement in the edentulous anterior mandible.
- ▶ Fryback and Thornbury listed typical measures of analysis of patient outcome efficacy. [46] One example is “Morbidity avoided after having image information”. This research recorded perforation of the lingual plate of bone which has the potential cause significant morbidity. Therefore the results are relevant to this measure of patient outcome efficacy. Nevertheless, patient outcome efficacy is a broad issue and other aspects remain unaddressed by research. For example, Fryback and Thornbury list “Percentage of patients improved ‘with test’ compared with ‘without test’.” This might include long term measures such as the function of prostheses or patient satisfaction. This research, therefore, addressed only one aspect of patient outcome efficacy.
- ▶ The challenges of conducting a randomised controlled clinical trial to investigate patient outcome efficacy of diagnostic imaging are considerable. The materials and methodology developed for this simulation may be helpful for future researchers.
- ▶ The work presented in this thesis used achievable and pragmatic study methodology to provide significant information of use to implant practitioners and those developing evidence based guidelines.

## 7.1 Recommendations for further research

This research suggests further topics for investigation as follows:

### **Practitioners' awareness and interpretation of existing radiographic guidelines.**

This results of the questionnaire study raised the issue of whether practitioners were aware of guidelines, perhaps ignored them or whether the guidelines were too vague to apply to specific, individual, clinical situations. Further research to investigate these issues would be valuable in the development of future guidelines.

### **The effect of implant training on radiographic prescription.**

A question asked in the questionnaire survey was, "What was your main training in dental implantology?" This was very likely to have concealed multiple sources of training and so the effect of the type of training was not clear. Further investigation of the effect of the type of training would be of interest and would inform future training programmes.

### **Other geographical areas**

This research was carried out in the North West of England. Repeat investigations in other geographical areas would be useful to confirm these results or highlight any regional or national differences.

### **Other clinical situations for dental implants**

This research specifically investigated radiographic assessment prior to placement of dental implants to support a complete lower overdenture. Radiographic prescription for other dental implant situations is of interest. For example, the missing upper anterior tooth is another common use of dental implants. The survey methods developed in this research would be applicable to such investigations.

### **An economic evaluation of imaging strategies prior to dental implant placement**

The economic implications of imaging methods were beyond the scope of this research. Nevertheless, this is a vital consideration. Resources for health care are always limited. An economic evaluation of the choice of imaging strategies prior to dental implant placement, which examined both costs and consequences, would also be valuable to assist in the development of guidelines.

**When is CBCT useful?**

The before-after study raises the question of how to identify those dentists, or those cases, for whom, or for which, CBCT is of benefit. A research project to determine these questions is likely to require a large sample size and multi centre approach with appreciable funding. The method developed in this research may be useful in such an investigation.

**Other implant systems**

This survey was carried out using the Neoss Dental Implant System.<sup>lvii</sup> Whilst this system provided a wide range of dental implants, both parallel sided and tapered, there is variation amongst other systems and investigation of these would be of interest. For example, there is available a wide range of, so-called, mini implants which are very different from the more conventional implants used in this study.

**Dentists in other branches of the dental profession**

This investigation was carried out with dentists in private practice who surgically place dental implants. This was done deliberately because the vast majority of implants in the UK are provided by these independent practitioners. In contrast, most research into dental implantology is carried out in the hospital environment. Nevertheless, a repetition of this study with hospital based dentists, and a comparison of results, would be of interest.

**Other radiographic views**

The questionnaire study revealed many permutations of image prescription prior to implant placement. This research compared only two. These were conventional panoramic radiography and a transsymphyseal view, with or without the added availability of CBCT. There is, therefore, much scope for investigations of other prescriptions. For example, many dentists prescribed only panoramic views. A similar before-after study which compared panoramic radiography alone with the added availability of CBCT would be of interest. Another interesting permutation would be to compare panoramic radiography alone with the added availability of a transsymphyseal view.

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<sup>lvii</sup> Neoss Ltd, Harrogate, Yorkshire. UK.

**Other research areas**

The dental simulation developed for this study may well be helpful in other study areas such as a comparison of different surgical techniques in oral surgery. For example, different drilling protocols for dental implants or the use of different implant designs could be compared. It would also be possible to incorporate replica teeth into mandibular, or maxillary, replicas. The effect of image prescription on the damage to adjacent teeth when preparing osteotomies, for example, could then be investigated.



## 8 List of definitions and abbreviations

3D imaging	Computed tomography techniques
CBCT	Cone beam computed tomography
Conventional radiography	Radiography other than computed tomography techniques
Cross sectional imaging	Computed tomography techniques
Dental simulation	An artificial reproduction of clinical circumstances incorporating a phantom head. A phantom head is sometimes known as a “dental simulator”. Therefore, for clarity, the term “Dental simulator” has not been used in order to avoid confusion between a phantom head and a dental simulation which incorporates a phantom head.
DPB	Dental Practice Board, the UK Government body responsible for remuneration of general dental practitioners working in the National Health Service in England and Wales.
EMTREE	Controlled vocabulary and thesaurus of Elsevier Life Science
EPOC	Cochrane Effective Practice and Organisation of Care Group
FGDP(UK)	The Faculty of General Dental Practice of the Royal College of Surgeons of England
HD	Identification code for a mandible used in the before-after study (became DH in the after part of the study)
HIPS	High impact polystyrene
Independent dental practitioner	In the UK, the word “private practice” implies that a dentist has no contract with the UK National Health Service and thus the term “independent” has been used. In the practice situation, all dental implants are placed on a private basis. UK dental practitioners will often provide other treatment under the terms of the UK National Health service.

Independently run course	A course directed by private individuals independently of Universities or other Institutions.
Jpeg	Joint photographic experts group
Medical CT	Conventional medical (multi slice) computed tomography
MeSH	Medical Subject Headings
MG	Identification code for a mandible used in the before-after study (became GM in the after part of the study)
MRI	Magnetic resonance imaging
PASW	Predictive Analytics Software, formerly SPSS.
PMMA	Poly methyl methacrylate
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	Prospective Register of Systematic Reviews
QUADAS	Quality Assessment of Diagnostic Accuracy Studies
RL	Identification code for a mandible used in the before-after study (became LR in the after part of the study)
RS	Identification code for a mandible used in the before-after study (became SR in the after part of the study)
SD	Standard deviation
SPSS	Statistical package for the social sciences
WHO	World Health Organisation



## 9 Appendices



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**Appendix A Definitions of response rates**


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**Kviz 1977 [125]**

Response rate  $\frac{\text{Number of completed interviews/questionnaires}}{\text{Number of eligible sample members}}$

Completion rate  $\frac{\text{Number of completed interviews/questionnaires}}{\text{Sample size}}$

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**Shosteck 1979 [126]**

Gross response rate  $\frac{\text{Questionnaires completed or otherwise accounted for}}{\text{Surveys distributed}}$

Gross completion rate  $\frac{\text{Questionnaires either wholly or partially completed}}{\text{Surveys distributed}}$

Final completion rate  $\frac{\text{Number who eventually answer the questionnaire}}{\text{Surveys distributed minus the ineligible}}$

---

**Groves 1989 [86]**

Response rate  $\frac{\text{Completed cases}}{\text{CC+PC+NC+R+NI}}$

CC Completed cases  
 PC Partially completed cases  
 NC Eligible cases not contacted  
 R Eligible cases who refused to participate  
 NI Other cases not interviewed, status unknown

---

**Asch 1997 [83]**

Response rate  $\frac{\text{Number of surveys returned}}{\text{Number of surveys distributed}}$

---

**Locker 2000 [127]**

Completion rate  $\frac{\text{Number of cases completed}}{\text{Number of cases sampled}}$

Co-operation rate  $\frac{\text{Number of cases completed}}{\text{Number of cases contacted}}$

Response rate  $\frac{\text{Number of cases completed}}{\text{Number of eligible cases in sample}}$

---

**The American Association for Public Opinion Research (AAPOR) 2009 [128]**

RR = Response rate  
 COOP= Cooperation rate  
 REF = Refusal rate  
 CON = Contact rate  
 I = Complete interview  
 P = Partial interview  
 R = Refusal and break-off

NC = Non-contact  
 O = Other  
 UH = Unknown if household/occupied HU  
 UO = Unknown, other  
 e = Estimated proportion of cases of  
 unknown eligibility that are eligible

## Response Rates

1	$\frac{I}{(I + P) + (R + NC + O) + (UH + UO)}$
2	$\frac{(I + P)}{(I + P) + (R + NC + O) + (UH + UO)}$
3	$\frac{I}{(I + P) + (R + NC + O) + e(UH + UO)}$
4	$\frac{(I + P)}{(I + P) + (R + NC + O) + e(UH + UO)}$
5	$\frac{I}{(I + P) + (R + NC + O)}$
6	$\frac{(I + P)}{(I + P) + (R + NC + O)}$

## Cooperation Rates

1	$\frac{I}{(I + P) + R + O}$
2	$\frac{(I + P)}{(I + P) + R + O}$
3	$\frac{I}{(I + P) + R}$
4	$\frac{(I + P)}{(I + P) + R}$

## Refusal Rates

$$1 \quad \frac{R}{(I + P) + (R + NC + O) + (UH + UO)}$$

$$2 \quad \frac{R}{(I + P) + (R + NC + O) + e(UH + UO)}$$

$$3 \quad \frac{R}{(I + P) + (R + NC + O)}$$

## Contact Rates

$$1 \quad \frac{(I + P) + R + O}{(I + P) + R + O + NC + (UH + UO)}$$

$$2 \quad \frac{(I + P) + R + O}{(I + P) + R + O + NC + e(UH + UO)}$$

$$3 \quad \frac{(I + P) + R + O}{(I + P) + R + O + NC}$$

## Appendix B Ethical approval

The screenshot shows the 'Ethics Approval Applications' page on the Leeds Dental Institute website. The page header includes the Leeds Dental Institute logo and the University of Leeds logo. The navigation bar shows 'DREC' and 'Welcome Andrew Shelley'. The main content area displays a table of applications with the following data:

A1. Application number	A2. Title of the research	Created	B1 a. Chief investigator surname	B1 d. E-mail address	Decision (for office use only)
160511/AS/29	Imaging of the symphyseal region of the mandible prior to dental implant placement	13/06/2011 21:17	Shelley	andrew@andrewshelley.com	Accepted
060813/AS/107	Impact of imaging of the anterior mandible when placing dental implants to support an overdenture	28/08/2013 13:41	Shelley	andrew@andrewshelley.com	Approved

Copy of web page to confirm ethical approvals from Leeds University Dental Research Ethics Committee.

## Appendix C Consent form for use of photographs in questionnaire study



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### Use of Photographs for Research - Consent Form

**Title of Research Project:**

A questionnaire study to investigate custom and practice of imaging methods for the anterior region of the mandible prior to dental implant placement.

**Name of Researcher:**

Andrew Shelley

**Research information:**

The aim of this project is to find out which x-rays dentists take when planning dental implants for patients who need complete dentures. We will present the dentists with some cases with patient photographs and ask them which x-rays they would take. In order to make the cases realistic there will be some patient details but they will be fictitious and will not be your details. The photographs will be only of the mouth and patients will not be identified in any way. The survey will be an internet based one but only selected dentists will be asked to complete it. As soon as the survey is completed, it will be removed from the internet. We would be most grateful if we may use your photographs for this important research.

*Please initial the box if you agree with the statement to the left*

- ▶ I confirm that I have read and understand the information given in this document explaining the above research project and I have had the opportunity to ask questions about the project
- ▶ I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences
- ▶ I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research
- ▶ I agree for the images taken of me to be used in future research and teaching
- ▶ I have been given a copy of this consent form including the research information

\_\_\_\_\_  
Name of participant                      Date                      Signature

\_\_\_\_\_  
Lead researcher                      Date                      Signature

*Signed and dated in presence of the participant*

## Appendix D Implementation letters to participants in the questionnaire study



**UNIVERSITY OF LEEDS**

23<sup>rd</sup> April 2011

Mr Hamish McPhee  
McPhee Dental Practice  
1 Acacia Avenue  
Manchester  
M1 1AB

Dear Hamish,

### University of Leeds Dental Implant Project

I am writing to ask for your help with our research project. We are trying to find out which x-ray views dentists use when assessing patients for dental implants. This information will be used in the development of future guidelines. The research is supervised by Professor Paul Brunton of the University of Leeds and Professor Keith Horner of the University of Manchester. You are one of a small number of dentists who have been randomly selected to help in this study.

We have made enquiries using the internet and other resources such as yellow pages. These suggest that you surgically place dental implants. If you have placed only one implant then we are still interested in your views. However, if you have never placed an implant then it would be very helpful if you could let us know so that we can remove your name from our list and of course we will not contact you about this again. Please be reassured that all our data will be kept confidentially. We only need to know who has replied and who has not. Once this research is complete your responses will be permanently anonymised. For all queries about this research do please get in touch on 0161 320 4230 or email me at [andrew@andrewshelley.com](mailto:andrew@andrewshelley.com).

This questionnaire is internet based. This allows us to show you some clinical cases and copies of x-ray views which you select. We hope you will find this interesting. Please enter this web page address in your internet browser and type in your access code to begin the survey.

[www.leedsuniversityresearch.com](http://www.leedsuniversityresearch.com)

Your access code 1234

We have conducted a pilot study of this questionnaire which tells us that it should take you only around 7 minutes to complete. Nevertheless, we appreciate that your time is valuable. By taking a few minutes to complete this questionnaire you will be helping us out a great deal and a small token of appreciation is enclosed as a way of saying thank you.

I hope you enjoy completing the questionnaire and look forward to receiving your responses.

With many thanks

Andrew Shelley BDS-MSc MFGDP(UK) DPDS MGDS RCSEd FDS RCSEd FFGDP(UK) Dip Rest Dent RCS Eng  
Lead researcher



**Email 1**

SUBJECT LINE: Leeds University Dental Implant Research

Dear Hamish,

Recently we sent you a letter asking you to respond to a very brief internet questionnaire about x-rays to assess dental implant patients. The questionnaire is short and should take less than 7 minutes to complete.

If you have already completed the survey we would like to thank you for your time as your responses are very important to our research. If you have not yet answered the questionnaire, we'd like to urge you to take a few minutes to do so. By sending this email with your access code and a link to the website, we thought it might be easier to respond.

[www.leedsuniversityresearch.com](http://www.leedsuniversityresearch.com)

Your access code 1234

Thank you for your help. This questionnaire is important. It is one of the few ways available to get the opinions of implant dentists in the real word of dental practice.

Yours sincerely,

Andrew Shelley  
Dental Practitioner, Denton, Manchester.  
Lead researcher, University of Leeds Dental Implant Project

**Email 2**

SUBJECT LINE: Leeds University Dental Implant Research – Please help

Dear Hamish,

Recently we sent you an email asking you to respond to a very brief internet questionnaire about x-rays to assess dental implant patients. If you have already completed the survey we would like to thank you for your time as your responses are very important to our research.

Many surveys in the dental literature have poor response rates. However, with the enthusiastic group of implant practitioners we have in the North West, we would really like to prove that a 100% response rate can be achieved. We are nearly there now. We are just waiting for the last few responses so if you could help us with this we would be really grateful.

Please click on the link below and then enter your access code

[www.leedsuniversityresearch.com](http://www.leedsuniversityresearch.com)

Your access code 1234

With thanks,

Yours sincerely,

Andrew Shelley  
Dental Practitioner, Denton, Manchester.  
Lead researcher, University of Leeds Dental Implant Project

Letter 2

**UNIVERSITY OF LEEDS**

Mr Hamish McPhee  
McPhee Dental Practice  
1 Acacia Avenue  
Manchester  
M1 1AB

Dear Hamish,

University of Leeds Dental Implant Project

Recently we sent you a letter asking you to respond to a very brief internet questionnaire about x-rays to assess dental implant patients. The questionnaire is short and should take around 6 minutes to complete.

If you have already completed the survey we would like to thank you for your time as your responses are very important to our research. If you have not yet answered the questionnaire, we'd like to urge you to take a few minutes to do so. The website address and your personal access code are below.

[www.implantresearch.co.uk](http://www.implantresearch.co.uk)

Your access code 1234

Thank you for your help. This questionnaire is important. It is one of the few ways available to get the opinions of implant dentists in the real world of dental practice.

With many thanks

A handwritten signature in blue ink, appearing to read 'Andrew Shelley', written over a faint circular stamp or watermark.

Andrew Shelley BDS MSc MFGDP(UK) DPDS MGDS RCSEd FDS RCSEd FFGDP(UK) Dip Rest Dent RCS Eng  
Lead researcher

**Contact details**

[andrew@andrewshelley.com](mailto:andrew@andrewshelley.com)

practice no. - 0161 320 4230

[www.andrewshelley.com](http://www.andrewshelley.com)

## Appendix E Confidentiality policy

# Imaging of the anterior mandible prior to dental implant placement – a questionnaire study

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## Anonymisation and confidentiality policy

### Lead researcher

Andrew Shelley BDS MSc

All our data will be kept confidentially. We ask for your name or your identification number only so that we know who has replied and who has not. To do this we will use a process known as pseudonymisation.

### Pseudonymisation

In pseudonymisation you will be assigned an identification number or pseudonym. There will be a single separate “link file”. This computer data file will link your name with your identification number. This file will be held securely on the University of Leeds computer server until the research is complete. During the period of research we will be able to use the link file to see who has replied and who has not. When the research is complete, the file will be deleted. In this way your data will be permanently anonymised.

### Data protection

The lead researcher is registered with the Data Protection Agency and complies with the requirements of the data protection Act of 1998

### Confidentiality

The lead researcher, one research assistant and the software developer will have access to the link file. All are bound by a confidentiality policy which is reproduced in the Appendix to this document.

### Contact details

For any queries about our anonymisation and confidentiality policy please contact the lead researcher, Andrew Shelley

Andrew Shelley Dental Practitioner  
117 Stockport Road, Denton, Manchester. M34 6DH

andrew@andrewshelley.com

## Confidentiality Policy for Researchers

### Imaging of the anterior mandible prior to dental implant placement – a questionnaire study

*This policy will apply equally to all staff and researchers working in any capacity with or for this research project.*

*The lead researcher requires that all project related personnel ensure that any information they handle regarding research participants remains secure and confidential at all times. It is the responsibility of project research and support staff to be familiar with the requirements of the Data Protection Act 1998. Any unauthorised disclosure of information may constitute a breach of the Data Protection Act and may lead to criminal or civil penalties.*

*No information or data item that might identify a research participant may be divulged to a non-authorised recipient. Authorised recipients will be identified by the Lead Investigator.*

*Access to confidential data held in the main project database is restricted to authorised users. Authorised users are responsible for safeguarding the data and ensuring that passwords remain secret and are not divulged to third parties for any reason whatever.*

*When viewing or accessing confidential data researchers must take care to ensure that computer monitors or screens cannot be overlooked by unauthorised personnel.*

*Before leaving the computer at which confidential data may be displayed researchers must close down the application and log off. Do not leave computers unattended when entering or viewing confidential data.*

*E-mail communications are not to be considered secure and no information of a confidential nature may be disclosed in the body of an e-mail.*

Signed

.....

Date

.....

## Appendix F Instructions to web developers

# Instructions to web developers

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The key thing for questionnaires is to keep them as simple as possible, no gratuitous design features to distract the respondent from the task at hand. The respondents will be busy dentists who will want to spend as little time as possible on this so it needs to feel clean, efficient and fast. It needs to be clear that the whole thing is sponsored by the University of Leeds because that gives it authority and they are more likely to respond. However we just tell them that and then don't clutter up the questionnaire with logos etc. any more than necessary. There are only going to be two cases for the respondents to look at and to prescribe radiographs for.

The pages that the respondents see will depend on their responses to the questions so I guess we'll need some "IF" statements in the code somewhere or a similar mechanism. I don't know how that happens but I'm sure you'll advise.

### **Corporate image**

The University have guidelines on what you can and what you can't do with their logo. They are at:

<http://www.leeds.ac.uk/identitymanagement/guidelines/index.htm>

[http://www.leeds.ac.uk/comms/website\\_regulations/index.html](http://www.leeds.ac.uk/comms/website_regulations/index.html)

## Appendix G Brief to research assistant for compiling sample frame

# Dental Implant Study

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## Brief -Compiling the sample frame

### Introduction

---

The sample frame is the most comprehensive, accurate and up to date list which we can compile of dental practitioners\* who place dental implants\* in the North West of England\*. (\* - defined below) The objective is to make this as close as we possibly can to the real population of these dentists. From the sample frame we will then select a sample to take part in a questionnaire study.

### Definitions

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#### **“Dental Practitioners”**

The dentists can be in general or specialist dental practice but not in the hospital or community dental service. The practices can be wholly or partly private. Dentists working in corporate practices such as Oasis should be included.

#### **“place dental implants”**

Those who carry out oral surgery to place implants. There is no minimum number. If they have placed an implant then they should be included.

#### **“North West of England”**

This is defined as the three counties of

- ▶ Lancashire
- ▶ Cumbria
- ▶ Cheshire

and the metropolitan counties of

- ▶ Greater Manchester
- ▶ Merseyside

### Aims

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To assemble a list of all the dental practitioners in the North West of England who surgically place implants. The most important thing is to identify the names of the dentists and record where they work. Some, or possibly all of them, will be selected for the working sample. At that stage will need their full details such as email address and telephone number. Therefore, if full details are easily available, it will save a job later on if these are recorded. Nevertheless, don't spend too much time at this stage trying to find their email address, for example, if it is not easily found.

### Method

---

We are going to compile the list using a multiple source search strategy. In other words, we are going to use as many different sources of information as we can think of. The more sources we use, the less likely it is that anyone will be left out of the sample frame. For example, this means that we might start by looking in the Yellow Pages directory for dentists who place implants. Then we might look at the website for a specialist implant society; ask an implant manufacturer who they supply in the North West and so on. Of course, this strategy will produce many duplicates. Therefore, at each stage, it is only necessary to add in the new dentists which have been found.

It may not be immediately obvious which dentists place implants and which dentists just restore implants. If they only restore implants then we don't want them on the list. This means that you may have to make some telephone calls to find out. You should simply say that you are carrying out research for the University of Leeds, trying to find out who places implants in their area. If they ask for further credentials, use my name and say that you are a research assistant working for Andrew Shelley who is carrying out PhD research under the supervision of Professor Paul Brunton at the University of Leeds and Professor Keith Horner at the University of Manchester. In most cases you needn't get further than the dental receptionist. They will usually know if someone places dental implants in their practice or not. Also, dentists are busy people and we want to retain their co-operation for later stages of the study so let's not disturb them too much at this stage.

In some cases the practices will have a visiting surgeon who places the implants for them in their own practice. That person's name may crop up several times for different practices. If this is the case, then you just need to record the name once with details of where they can be contacted most easily. They may have their own main practice for example.

Please keep a careful record of what you find out at each stage of the process as the research method may be subject to scrutiny later on.

#### Recording the list

---

I have given you a Microsoft Excel file with the first few dentists included. Please continue to complete this list, filling in details as appropriate. Also please back up the file regularly. There are no graphics on the file which means that it will be quite small in size, even if it ended up with a few hundred dentists on it. That means that a convenient method of backing up is to simply attach the file to an email and send it to yourself. That way the file is sitting on an external server and can be accessed from another computer if you have a hardware crash. As a secondary back-up you could use a pen drive for example.

#### Search strategy – sources of information

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##### **ADI**

ADI (Association of Dental Implantology)

This society has a find a dentist page which is very useful.. You can search by county, name, postcode etc.

<http://www.adi.org.uk/public/findconsult.php>

Many dentists who are involved with implants are members of this society and it might make a good start to the list. In a preliminary search I identified 187 members in the North West. However, the list includes:

- ▶ Technicians
- ▶ Hospital based dentists
- ▶ Dentists who do implant prosthetics only

These should not be on our sample frame. I may recognise some of them and so be able to eliminate them very quickly. It would be a good idea for us to look at this list together so that I can do this. The search on this site also has links to practice websites where these are available. This may give us the information we need.

##### **Directories**

- ▶ Yellow pages – internet version will allow searches
- ▶ Thompson local directory

##### **Advertisements in newspapers and periodicals**

- ▶ Local newspapers
- ▶ Cheshire life
- ▶ Lancashire life

### Internet search engines

Searches on Google, for example, are likely to reveal many dentists who provide an implant service in our region of interest. Care will be needed to eliminate those who only restore implants. A further look at individual practice websites may well elicit the information we need.

### Implant companies

Some implant suppliers have “find a dentist” areas on their websites.

- ▶ <http://www.dentists4implants.com/why-choose-ankylos.php>
- ▶ <http://www.straumann.co.uk/gb-index/patients/gb-doc-finder/gb-doc-finder-north-west.htm>
- ▶ [http://www.nobel smile.co.uk/en\\_gb/](http://www.nobel smile.co.uk/en_gb/)

We have a closer relationship with some other companies and a telephone call to the representative may be the best way to find out who buys implants from them in the North West. For example, the representatives from Neoss and Southern might be expected to be very co-operative. Astra might also be helpful.

### Specialist societies

Some specialist societies have web based “find a dentist” facilities. For example:

- ▶ BSP (British Society of Periodontology)
- ▶ BSRD (British Society for Restorative Dentistry)
- ▶ BSSPD (British Society for the study of Prosthetic Dentistry)
- ▶ BAOMS (British Society of Oral and Maxillofacial surgery)

These societies may include members in practice who place implants but are likely to be largely hospital based. BAOMS will be pretty well all hospital based although it is possible that some of them might be visiting surgeons to practices. It may not be productive to spend very much time following up these unless it is clear from the websites that they are practice based.

### Training courses

There are a number of training courses both in the North West and beyond where dentists are trained to place implants. I have taught on some of them and so it should be fairly easy to get the information for those courses.

These are the courses I know about. It is probably best if I approach them myself and pass the information on to you.

- ▶ Genix – It is the first year of the course which is based in Leeds. There are 6 students – I don't think any of them are based in the North West but this can be easily checked.
- ▶ Perio implant Europe – Good relationship with course director, this shouldn't be a problem
- ▶ There is a large course run by Prof Cemal Ucer who I know personally
- ▶ There is a course run at Manchester University where I have good contacts
- ▶ FGDP(UK) Dip Imp Dent Course. I know some of the local tutors personally

### Dental Laboratories

Dental laboratories will know which of their clients place implants. Especially where we know them personally, it is worth asking who they know amongst their clients.

### Who do “non-placing dentists” refer their implant cases to?

Ask key dentists in each area who they refer to or who they know. If you telephone a practice to get clarification and find that they only restore implants, then it is worth asking them who they refer to for their implant placement or who else they know in the area who places implants. Again it is probably not necessary to go any further than the receptionist.

I will also ring some dentists I know personally around the region and ask them the same questions.



## Appendix H Record of randomisation

Random sample of 169 from sample frame for sample size pilot.

---

Each member of sample frame numbered 1 to 208. Random number generator asked to generate a random sequence of 1 to 208. First 169 selected for sample.

# RANDOM.ORG

Search RANDOM.ORG  
 Google Custom Search

True Random Number Service

### Random Sequence Generator

Here is your sequence:

18	74	90	126	203	177	164	128	130
55	67	157	120	111	34	199	194	169
32	14	155	99	42	39	91	198	36
134	144	89	35	114	206	51	41	101
85	162	154	196	75	208	94	132	123
49	98	31	56	53	29	179	3	160
107	191	187	78	117	204	161	141	140
59	201	205	186	159	105	127	87	136
17	129	176	112	182	163	33	7	
72	38	92	79	192	166	145	23	
27	150	175	11	135	197	9	102	
64	178	66	47	121	152	95	173	
138	184	193	44	1	21	54	156	
153	119	93	60	172	84	19	207	
115	62	43	108	147	142	12	125	
109	113	82	2	118	76	131	69	
158	48	20	71	40	174	104	37	
106	25	57	88	183	181	151	86	
190	167	30	8	103	81	110	46	
52	45	200	13	96	68	22	70	
73	24	122	65	137	77	61	26	
139	16	124	202	83	97	146	188	
189	28	168	15	116	165	6	4	
80	143	50	149	5	195	180	185	
100	133	63	171	170	58	148	10	

Timestamp: 2011-11-05 12:57:16 UTC

**Appendix I Script for telephone reminders**

Hello, this is XXXXX, research assistant for the University of Leeds Dental Implant Project. We wrote to Dr XXXXX recently asking him/her to take part in our online survey about x-rays for dental implants. I wonder if you could please remind Dr XXXXX for us? It's a recognised University project, not a commercial survey, and his/her response is really important to the research. Would you please thank him/her in advance. We really appreciate it.

Further details if requested:

Web address

[www.implantresearch.co.uk](http://www.implantresearch.co.uk)

Access code

XXXX

Our pilot study shows that it only takes 6 minutes

## Appendix J Script for post survey analysis

# First call

---

Hello this is non-responding dental practice of Carlisle, Jane speaking, how may I help you?

(Make a note of his/her name)

**Good morning, this is XXXXXXXXX from the University of Leeds Dental Implant Research Project.**

**We've been running an important dental implant survey which you might know about. The survey is now closed so we're not asking Dr..... to respond. We are just asking one question by telephone so that we have a little bit of information about those who didn't have time to respond to the survey. Is Dr....available now or can I leave a message with you?**

No he's with a patient but I can take a message.

**Okay, thank you. Have you got a pen and paper ready? This is the message. It's only short.**

**"Please consider an edentulous patient with good ridges. You are planning an implant supported lower complete denture with a dental implant in each of the lower canine regions. Which x-ray views would you prescribe?"**

**.....and the message is from the University of Leeds.**

**Could I ring you back tomorrow please to get the reply?**

He's not in until Thursday

**Okay thanks Jane, we appreciate your help with this. I'll ring you back on Friday.**

(ie. use her name and tell her that you will ring her back personally)

**Thank you very much, goodbye.**

(On the off chance that the dentist is available just ask him the question and write down the reply in the order in which it is given).

# Follow up call

---

Ask to speak to Jane personally

**Hello Jane, It's Lauren again from the University of Leeds Dental Implant Project. I said I'd ring today to get the reply to our message.**

When we get a reply, write down the dentists x-ray prescription in the order in which it is given.

If we do not get a reply after the return phone call then, unless they give you a good reason to ring back, that is the end of the matter.

# In general

---

- ▶ Be prepared to improvise
- ▶ Please monitor the script. If after the first few 'phone calls you think that the script isn't working well then we can discuss it and change it.
- ▶ Be prepared for rudeness on behalf of the staff and or dentist. They can be a funny lot, especially the ones that have refused to reply to the survey. Please try to be philosophical and confident that you are undertaking serious and important research for one of the UK's leading Universities. The research is supervised by Prof Horner of the University of Manchester and Prof Brunton of the University of Leeds.

**Appendix K Pearson's chi-square tests – tables of full results.**

Same prescription for both cases	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female	.566	.452		
Non UK qualified			1	1.000
<b>Experience</b>				
Qualified 0-10 years	.000	.986		
Place > 100 implants per year	9.878	.002		
<b>Training</b>				
Independently run course	.771	.380		
University course	.957	.328		
FGDP course	4.325	.038		
Manufacturer's course			2	.701
<b>Equipment available</b>				
Intra oral set	2.426	.119		
Panoramic set	.219	.640		
CBCT	6.021	.014		
Medical CT			2	.501
Lateral cephalogram			2	.184
<b>Qualifications</b>				
Has postgraduate qualification	3.750	.053		

**Full results of chi-square analysis, same prescription for both cases**

Used 3D imaging Case 1	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female	2.490	.115		
Non UK qualified			1	.111
<b>Experience</b>				
Qualified 0-10 years	8.244	.004		
Place > 100 implants per year	.482	.487		
<b>Training</b>				
Independently run course	9.763	.002		
University course	2.160	.142		
FGDP course	2.017	.156		
Manufacturer's course			2	.462
<b>Equipment available</b>				
Intra oral set	.036	.849		
Panoramic set	.378	.539		
CBCT	5.754	.016		
Medical CT			2	1.00
Lateral cephalogram			1	.185
<b>Qualifications</b>				
Has postgraduate qualification	5.910	.015		

Full results of chi-square analysis, use of 3D imaging for case 1

Used 3D imaging Case 2	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female	.748	.387		
Non UK qualified			1	.554
<b>Experience</b>				
Qualified 0-10 years	6.524	.011		
Place > 100 implants per year	1.866	.172		
<b>Training</b>				
Independently run course	9.519	.002		
University course	.016	.901		
FGDP course			1	.012
Manufacturer's course			2	.432
<b>Equipment available</b>				
Intra oral set	3.035	.082		
Panoramic set	.490	.484		
CBCT	10.123	.001		
Medical CT			2	1.000
Lateral cephalogram			1	1.000
<b>Qualifications</b>				
Has postgraduate qualification	4.222	0.040		

Full results of chi-square analysis, use of 3D imaging for case 2

Used conventional radiography before 3D imaging Case 1	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female			1	1.000
Non UK qualified			1	.376
<b>Experience</b>				
Qualified 0-10 years			1	.516
Place > 100 implants per year			1	.161
<b>Training</b>				
Independently run course	.734	.392		
University course	.254	.614		
FGDP course			1	1.000
Manufacturer's course			1	.298
<b>Equipment available</b>				
Intra oral set			1	.565
Panoramic set	.711	.399		
CBCT			1	.126
Medical CT			2	1.000
Lateral cephalogram			1	.354
<b>Qualifications</b>				
Has postgraduate qualification	.361	.548		

Full results of chi-square analysis, conventional radiography before 3D imaging case 1

Used conventional radiography before 3D imaging Case 2	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female			1	.544
Non UK qualified			1	1.000
<b>Experience</b>				
Qualified 0-10 years			1	1.000
Place > 100 implants per year			1	.348
<b>Training</b>				
Independently run course			2	.836
University course			2	.424
FGDP course			1	.119
Manufacturer's course			1	1.000
<b>Equipment available</b>				
Intra oral set			1	.634
Panoramic set			1	1.000
CBCT			1	1.000
Medical CT			2	1.000
Lateral cephalogram			1	1.000
<b>Qualifications</b>				
Has postgraduate qualification			2	.710

Full results of chi-square analysis, conventional radiography before 3D imaging case 2

Used radiographic guide Case 1	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female			1	1.000
Non UK qualified			1	.290
<b>Experience</b>				
Qualified 0-10 years	.000	.984		
Place > 100 implants per year	9.446	<b>.002</b>		
<b>Training</b>				
Independently run course	1.298	.255		
University course	.020	.889		
FGDP course			1	1.000
Manufacturer's course			1	.368
<b>Equipment available</b>				
Intra oral set	.001	.980		
Panoramic set	1.622	.203		
CBCT			1	.341
Medical CT			2	1.000
Lateral cephalogram			1	.691
<b>Qualifications</b>				
Has postgraduate qualification	1.133		.313	

Full results of chi-square analysis, use of radiographic guide case 1

Used radiographic guide Case 2	$\chi^2$ (1)	significance	Cells with count less than 5	Fishers exact test
<b>Descriptive</b>				
Male or female			1	.757
Non UK qualified			1	1.000
<b>Experience</b>				
Qualified 0-10 years	.903	.342		
Place > 100 implants per year	5.934	<b>.015</b>		
<b>Training</b>				
Independently run course	2.556	.110		
University course	.162	.687		
FGDP course			1	1.000
Manufacturer's course			2	.412
<b>Equipment available</b>				
Intra oral set	.260	.610		
Panoramic set	.837	.360		
CBCT			1	.545
Medical CT			2	1.000
Lateral cephalogram			1	.717
<b>Qualifications</b>				
Has postgraduate qualification	3.054	.081		

Full results of chi-square analysis, use of radiographic guide case 2



**Appendix L Exposure factors for images**3D Accuitomo CBCT<sup>lviii</sup> - Manchester University Dental Hospital

## 3D Accuitomo

Voltage	90kV
Current	4.0mA
Time	17.5 sec

Soredex Panoramic<sup>lix</sup> - Manchester University Dental Hospital

## Soredex Cranex 3 Ceph

Voltage	64kV
Current	4mA
Time	11.0 s

Trophy Atlantis Transsymphyseal View<sup>lx</sup> - A Shelley Dental Practice, Manchester.

X-ray machine	Trophy Atlantis
Focus to film distance	20cm
Voltage	60kV
Current	7mA
Time	0.739s
Film	Agfa Dentus M2 film, E/F speed, size 2. <sup>lxi</sup>
Processor	Durr Periomat Plus Automatic film processor. <sup>lxii</sup>

Scanora Spiral Tomography<sup>lix</sup> - Leeds Dental Institute

## Soredex Scanora

Voltage	57kV
Current	1.6mA
Time	84s

---

<sup>lviii</sup> J Morita Mfg. Corp. Kyoto, Japan

<sup>lix</sup> Soredex, Tuusula, Finland

<sup>lx</sup> Trophy Radiologie, Marne-la-Vallée, France.

<sup>lxi</sup> Agfa-Gevaert N.V. Mortsels, Belgium

<sup>lxii</sup> Dürr Dental AG Bietigheim-Bissingen, Germany

Trophy Atlantis Periapical View<sup>lxiii</sup> - A Shelley Dental Practice, Manchester.

X-ray machine	Trophy Atlantis
Focus to film distance	20cm
Voltage	60kV
Current	7mA
Time	0.273s
Film	Agfa Dentus M2 film, E/F speed, size 2. <sup>lxiv</sup>
Processor	Durr Perimat Plus Automatic film processor. <sup>lxv</sup>

GE Medical CT<sup>lxvi</sup> - LifeScan, Manchester

## GE Lightspeed

Voltage	120kV
Current	80mA
Time	15s

Soredex Lateral Cephalogram<sup>lxvii</sup> - Manchester University Dental Hospital

## Soredex Cranex 3 Ceph

Voltage	75kV
Current	10mA
Time	0.5s

---

<sup>lxiii</sup> Trophy Radiologie, Marne-la-Vallée, France.

<sup>lxiv</sup> Agfa-Gevaert N.V. Mortsels, Belgium

<sup>lxv</sup> Dürr Dental AG Bietigheim-Bissingen, Germany

<sup>lxvi</sup> GE Healthcare, Waukesha, USA.

<sup>lxvii</sup> Soredex, Tuusula, Finland

**Appendix M Case history and questionnaire for one of the four cases prepared  
for the before-after study**

## Case MG

Confidential participant number .....

### Mrs MG

Mrs MG is 62 years. She became fully edentulous in her twenties and has had a number of conventional dentures since then. Whilst she coped well when she was younger, she now feels that the looseness of the lower denture sometimes causes her embarrassment when she is speaking. There are no medical complications. After discussion, you have agreed that you will plan an implant retained lower overdenture with two implants placed in the lower canine regions.



Please consider this case, look at the supplied images and answer the following two questions about implant planning for this case. Please then select the implants which you would use for this case.

#### Question 1

Thinking about complete overdenture cases where implants are placed in the lower canine regions, please indicate your opinion of the difficulty of implant placement in this case by circling one of the numbers below

Very easy

Very difficult

1    2    3    4    5    6    7    8    9    10.

#### Question 2

I would carry out special surgical procedures in this case such as bone grafting  
YES NO  
(Please circle YES or NO)

If YES, please briefly specify

Thank you. Please now use the models of this case in the phantom head to drill osteotomies in preparation for placement of the implants which you have selected. You may refer to the available images and other information as you wish. During preparation you may change your selection of implant size and/or design. If you do change your mind, please mark your final selection of implant below.

Implant selection 3

Please make your selection of implant for the lower right canine region by ticking one only of the options below

Parallel sided implants	Tapered implants
<p>Width 3.25mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	
<p>Width 3.5mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 3.5mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.0mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.0mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.5mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.5mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.0mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	<p>Width 5.0mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.5mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>	<p>Width 5.5mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>

Implant selection 3

Please make your selection of implant for the lower left canine region by ticking one only of the options below

Parallel sided implants	Tapered implants
<p>Width 3.25mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	
<p>Width 3.5mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 3.5mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.0mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.0mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.5mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.5mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.0mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	<p>Width 5.0mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.5mm Length</p> <p>7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>	<p>Width 5.5mm Length</p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>

Using the information available, please choose one implant for each of the lower canine sites from those below. No other types or sizes of implants are available for selection.

Implant selection 3

Please make your selection of implant for the lower right canine region by ticking one only of the options below

Parallel sided implants	Tapered implants
<p>Width 3.25mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	
<p>Width 3.5mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 3.5mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.0mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.0mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.5mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.5mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.0mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	<p>Width 5.0mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.5mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>	<p>Width 5.5mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>

Implant selection 3

Please make your selection of implant for the lower left canine region by ticking one only of the options below

Parallel sided implants	Tapered implants
<p>Width 3.25mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	
<p>Width 3.5mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 3.5mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.0mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.0mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 4.5mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p> <p>17mm <input type="checkbox"/></p>	<p>Width 4.5mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.0mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>	<p>Width 5.0mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p> <p>15mm <input type="checkbox"/></p>
<p>Width 5.5mm Length</p> <p> 7mm <input type="checkbox"/></p> <p>9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>	<p>Width 5.5mm Length</p> <p> 9mm <input type="checkbox"/></p> <p>11mm <input type="checkbox"/></p> <p>13mm <input type="checkbox"/></p>

## Instruction leaflet given to study participants at the first visit

**University of Leeds Dental Implant Project**

Many thanks indeed for agreeing to help us with our research project. We are investigating the placement of dental implants in the anterior mandible to support an overdenture. The results will be used in the development of future guidelines. The research is supervised by Professor Keith Horner of the University of Manchester and Professor Paul Brunton of the University of Leeds.

We will ask you to assess four case scenarios from the information supplied. For each case scenario there will be:

- ▶ A clinical history
- ▶ A clinical photograph
- ▶ A number of radiographs
- ▶ A "drilling model" in a phantom head


We will ask you to assess each case and answer some questions about them. We will present you with a wide choice of implants and ask you to make a selection for each case. We will then ask you to drill the appropriate osteotomies in the "drilling models". We will supply you with the drills, a handpiece and implant motor. Alternatively, you may use your own implant handpiece and motor where this is more convenient. In four weeks' time we will ask you to repeat the exercise with four new cases.

We have carried out a pilot study which suggests that this exercise should take up some 40 to 60 minutes of your time. We know that your time is valuable and your help is very much appreciated.

Please be reassured that the results of this research will be confidential and your name will not be associated with the results in any way. To this end we will use a process called pseudonymisation. We have enclosed a copy of our confidentiality policy which explains this in more detail.

We have also enclosed some further information about the radiographs and the drilling models.

With many thanks,



Andrew Shelley  
BDS MSc MFGDP(UK) DPDS MGDS RCSEd FDS RCSEd FFGDP(UK) Dip Rest Dent RCS Eng  
Lead researcher

I give consent for my anonymised data to be used for the above research project. I have been given a copy of this form and the project's confidentiality policy.

Name .....

Signature ..... Date .....

### The radiographs

Different types of radiographs may be available for the different cases. Please make your assessment from the radiographs which are supplied. No others are available. One view, with which you may not be familiar, is the transsymphyseal view. This periapical view is taken with a radiopaque paste around the midline of the patient's denture. It is illustrated below. An article about the transsymphyseal view is also provided should you wish further information.



The radiographic views are available with and without measurements. All the measurements are those suggested by a panel of implant practitioners. Where cone beam CT images are available, you may also use the supplied software to take your own measurements if you wish. For conventional views, measurements were made using a 5mm ball bearing as a reference diameter.

### The drilling model

Each "drilling model" is a model of a mandible surrounded by soft tissue. In each case the radiographs represent the form of the mandible in the "drilling model". We carried out a preliminary study to determine the typical flap which an implant practitioner would reflect for each case. These are represented on the models. The models will also allow you to explore beyond the reflection of the flap with a periosteal elevator as you might do on a patient. This is shown below.



On each model there are two lines which run through the mandible where the implants should be placed. This can be seen on the picture above. On the panoramic images, this is the position of the 5mm ball bearing markers. Where a cone beam CT image is available, this line also marks the position of the slices which have been pre-prepared.

## Appendix N Instruction leaflet given to study participants at the second visit

### University of Leeds Dental Implant Project – 2<sup>nd</sup> visit

Many thanks once again for agreeing to help us with our research project.

We will ask you to assess another four case scenarios from the information supplied. For each case scenario there will be:

- ▶ A clinical history
- ▶ A clinical photograph
- ▶ A number of radiographs
- ▶ A "drilling model" in a phantom head

As before, we will ask you to assess each case and answer some questions about them. We will present you with a wide choice of implants and ask you to make a selection for each case. We will then ask you to drill the appropriate osteotomies in the "drilling models". We will supply you with the drills, a handpiece and implant motor. Alternatively, you may use your own implant handpiece and motor where this is more convenient. We know that your time is valuable and your help is very much appreciated.

Please be reassured that the results of this research will be confidential and your name will not be associated with the results in any way. You have kindly already signed a copy of our confidentiality policy. A further copy is available if you would like one.

To remind you, we have enclosed the information about the radiographs and the drilling models again.

With many thanks,



Andrew Shelley  
BDS MSc MFGDP(UK) DPDS MGDS RCSEd FDS RCSEd FFGDP(UK) Dip Rest Dent RCS Eng  
Lead researcher

### The radiographs

Different types of radiographs may be available for the different cases. Please make your assessment from the radiographs which are supplied. No others are available. One view, with which you may not be familiar, is the transsymphyseal view. This periapical view is taken with a radiopaque paste around the midline of the patient's denture. It is illustrated below. An article about the transsymphyseal view is also provided should you wish further information.



The radiographic views are available with and without measurements. All the measurements are those suggested by a panel of implant practitioners. Where cone beam CT images are available, you may also use the supplied software to take your own measurements if you wish. For conventional views, measurements were made using a 5mm ball bearing as a reference diameter.

### The drilling model

Each "drilling model" is a model of a mandible surrounded by soft tissue. In each case the radiographs represent the form of the mandible in the "drilling model". We carried out a preliminary study to determine the typical flap which an implant practitioner would reflect for each case. These are represented on the models. The models will also allow you to explore beyond the reflection of the flap with a periosteal elevator as you might do on a patient. This is shown below.

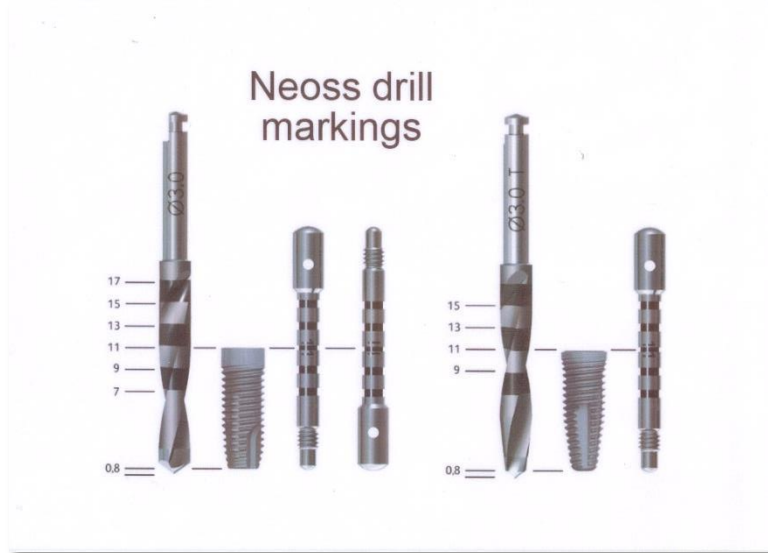


On each model there are two lines which run through the mandible where the implants should be placed. This can be seen on the picture above. On the panoramic images, this is the position of the 5mm ball bearing markers. Where a cone beam CT image is available, this line also marks the position of the slices which have been pre-prepared.



## Appendix O Neoss drilling guides

(provided to participants as full A4 sheets)



### Drilling Guide, Neoss ProActive® implants

**1.4. Treatment**

	ProActive Implant Ø3.25 mm	ProActive Implant Ø3.5 mm	ProActive Implant Ø4.0 mm	ProActive Implant Ø4.5 mm	ProActive Implant Ø5.0 mm	ProActive Implant Ø5.5 mm	Drill Stop
Ø2.2							
Ø2.85							
Ø3.0							
Ø3.2							
Ø3.4							
Ø3.6							
Ø3.9							
Ø4.1							
Ø4.4							
Ø4.6							
Ø4.9							
Ø5.1							
Countersink	Ø3.25	Ø3.5	Ø4.0	Ø4.5	Ø5.0	Ø5.5	
Screw Tap	Ø3.25	Ø3.5	Ø4.0	Ø4.5	Ø5.0	Ø5.5	

**Guidelines**  
 Drill step for Regular bone recommended before drill step for Dense bone.

**Additional notes**  
 The Neoss drill assortment allows for individualised drill protocol in Soft bone.  
 Screw taps available but not required.

Neoss Implant System Surgical Guidelines 1.15

### Drilling Guide, Neoss Tapered Implants

	Tapered Implant Ø3.5 mm	Tapered Implant Ø4.0 mm	Tapered Implant Ø4.5 mm	Tapered Implant Ø5.0 mm	Tapered Implant Ø5.5 mm	Drill Stop
Ø2.2						
Ø3.0 T						
Ø3.2						
Ø3.6 T						
Ø3.9 T						
Ø4.1						
Ø4.4 T						
Ø4.6						
Ø4.9 T						
Ø5.1						
Countersink	Ø3.5 T	Ø4.0 T	Ø4.5 T	Ø5.0 T	Ø5.5 T	
Screw Tap	Ø3.5	Ø4.0	Ø4.5	Ø5.0	Ø5.5	

**Guidelines**  
 Drill step for Soft bone not intended for Regular and Dense bone.  
 Drill step for Regular bone required before drill step for Dense bone.  
 Drill step for Dense bone does not require drilling to full depth.

**Additional notes**  
 The Tapered implant allows for further under-preparation in Soft bone.  
 Screw taps available but not required.  
 Twist drill Ø2.2, Dense bone drills and screw taps in the Neoss Tapered implant drill protocol are the same bone cutting instruments as used for Neoss ProActive® implant drill protocol.

Neoss Implant System Surgical Guidelines 1.16



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