Development of a radiographic dental implant guide for forensic identification using current dental implants

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Thesis submitted in fulfilment of the requirements for the degree

Master of Science: Radiography

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Bellville
August 2018

DECLARATION

I, Lisa Vermeulen, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed **Date**

15 August 2018

ACKNOWLEDGEMENTS

I wish to thank the following people whom I acknowledge for their support and motivation. Without them, this research study would not have been possible:

- Both my supervisors: Mr Aladdin Speelman and Mrs Valdiela Daries. Your guidance, input and knowledge have been of great value to me.
- Prof. Vincent Phillips for being my external supervisor. Your contribution to the field of forensic odontology is inspiring.
- Dr Pieter Wolfaardt for being my mentor during this research study.
- The staff members at the research sites for always accommodating me during the data collection.
- My parents, Roux and Marisa, for supporting me in many ways throughout my studies.
- My sister, Euodia, for her positive attitude and inspiration during this research study.
- The University Research Fund of the Cape Peninsula University of Technology.

ABSTRACT

Introduction: Forensic dentistry plays a key role in identifying human remains that cannot be identified visually or by other means. Studies have shown that in cases of single or multiple deaths, scientific identification of human remains utilising forensic dentistry is often the most successful source of identification. Dental identification of human remains consists of a very complex procedure that makes it necessary during the investigation process to use and compare unique dental identifiers. A reliable and accurate method of identifying human remains is a positive radiological identification between ante-mortem and post-mortem images of dental radiographic images. Even if ante-mortem radiographic images may not be present during the identification process, post-mortem images may include details of dental restorations such as dental implants which cannot be seen during visual examination. The different types of dental implants vary in morphology and in conjunction with the unique appearance of dental anatomy and the placement of custom restorations such as dental implants, it has been found to accurately assist in the identification of human remains.

Objectives: To establish a radiographic dental implant guide for ten commonly used dental implant types in the Western Cape, South Africa; and to identify and describe the morphological characteristics of these dental implant types as observed on pantomographs.

Methods: The ten commonly used dental implant types were imaged radiographically to create a reference instrument which served as a tool for identifying and comparing different types of dental implants. The morphologies of the different dental implants, specifically the apex, thread and neck, were observed on ante-mortem pantomographs and compared to the appearance of the dental implants on the reference instrument to make a positive match. The straight tube image of all ten dental implant types in the reference instrument was used as the point of reference to positively identify the morphological characteristics of each dental implant type on the pantomographs. The morphological characteristics of the ten commonly used dental implant types used in the Western Cape were described and based on this a radiographic dental implant guide was developed.

Results: A total of 384 dental implants were observed on the pantomographs. Of these, 380 dental implants could be positively identified on the pantomographs while 4 dental implants could not. A total of 350 dental implants (91%) were identified as dental implant types listed in the reference instrument while 30 dental implants were identified as a dental implant type not listed in the reference instrument. A total of 208 dental implants (54.2%) could be positively identified using the morphological characteristics namely the apex, thread and neck on the straight tube images of the dental implant type in the reference instrument. The radiographic dental implant guide was developed based on positive identification of the morphological characteristics of the dental implant types.

Conclusion: This research study has illustrated that the morphology of dental implants can be used to differentiate between different dental implant types on pantomographs. Each dental implant type had unique morphological characteristics as well as similarities which enabled distinction between the different dental implant types, which facilitated dental implant identification and the development of a radiographic dental implant guide. The radiographic dental implant guide developed as part of this research study, may be useful in the field of forensic dentistry and forensic radiology.

Keywords: Forensic dentistry, radiological identification, morphological characteristics dental implants, pantomographs, reference instrument, radiographic dental implant guide.

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GLOSSARY

Abutment:	Attachment for final prosthesis.
Ante-mortem:	Period before death.
Dental implant:	Titanium screw that is placed within the alveolar bone of the maxilla or mandible to replace a missing tooth or teeth.
Dental restoration:	Custom restoration, including dental fillings, crowns and bridges, root canals and dental implants.
Healing cap:	Protects the screw hole before the final prosthesis is placed.
Horisontal offset:	Narrowing between neck and abutment of dental implant to promote bone growth for a secure fit.
Intra-oral:	Radiographic dental image taken with digital sensor or film positioned directly inside the patient's mouth.
Morphology:	Within the context of this research study, this term refers to the shape, size, and structure of the apex, thread, and neck of each dental implant type.
Pantomograph:	Panoramic radiograph of the maxilla and mandible.
Post-mortem:	Period after death.
Radiographic dental implant guide:	Document describing the morphological characteristics of the ten different dental implant types.
Reference instrument:	A compilation of radiographic images of the ten dental implant types used for comparison and identification purposes within this research study.

ABBREVIATIONS AND ACRONYMS

ACP	American College of Prosthodontists
AD	Anno Domini
AP	Antero-posterior
CPUT	Cape Peninsula University of Technology
DNA	Deoxyribonucleic acid
DVI	Disaster Victim Identification
Interpol	International Criminal Police Organization
IRS	Implant Recognition System
kV	Kilovolt
mA	Milliamperage
mAs	Milliamperage-second
MPa	Megapascal
OC	Off centre
RC	Regular CrossFit
RN	Regular Neck
SAMRC	South African Medical Research Council
SID	Source-image-distance
SOC	Severe off centre
ST	Straight tube
UWC	University of the Western Cape
WMA	World Medical Association

CHAPTER ONE

INTRODUCTION

Forensic dentistry plays a key role in identifying human remains that cannot be identified visually or by other means; these remains include the victims of violent crime, fires (charred bodies), motor vehicle accidents and accidents on duty. Such bodies or human remains can be disfigured, decomposed, skeletonised and unidentifiable to a certain extent that identification by relatives is neither reliable nor desirable. Victims who have been deceased for some time prior to discovery may be decomposed and those found in water may also appear shrivelled, leading to difficulty in visual identification. A major advantage of dental evidence is that it is often preserved after death (Pretty & Sweet, 2001; Verma et al., 2014).

Dental identification of human remains consists of a very complex procedure that makes it necessary during the investigation process to use and compare unique dental identifiers. Implantology, the science referring to dental implants, has become more popular, accessible and of great value globally. Clinical and radiographic records of dental implant procedures are becoming widely and increasingly available and used during forensic identification of human remains (Silva et al., 2014).

A dental implant is known as a titanium screw that is placed within the alveolar bone of the maxilla or mandible to replace a missing tooth or teeth. It supports the dental prosthesis through the biological process called osseointegration and fuses with the surrounding bone in the jaw to secure a permanent fit (Deepalakshmi & Prabhakar, 2014).

Osseointegration of dental implants is a very complex biological process that involves the interactions between immune-inflammatory responses, angiogenesis and osteogenesis. The physical and chemical characteristics of the dental implant surface influence this process. The titanium material, when placed in a prepared site in the bone of the mandible and/or maxilla, promotes new bone formation due to the close contact of the dental implant with the surrounding healthy bone. This process leads to faster and more extensive osseointegration to ensure and secure a permanent fit in the occlusion (Hobkirk et al., 2003; Feller et al., 2014).

There are numerous manufacturers of dental implants globally. The different types of dental implants vary in length and girth depending on the load they are required to bear in the occlusion. The unique appearance of dental anatomy and the placement of custom restorations ensure accurate identification of bodies or human remains when radiographic techniques are correctly applied. The radiographic morphology of a dental implant placed in the maxilla or mandible can be unique and used for forensic dental identification if a radiographic image of the implant is available after placement (Pretty & Sweet, 2001).

The identification of dental implants on radiographs can be complex for the untrained eye. A certain degree of expertise is required to identify and distinguish between the various dental implant types available on the market.

This research study employed a descriptive research methodology where the morphological characteristics of different implant types, found on ante-mortem radiographic images, were systematically analysed and documented. The purpose of this analysis, and ultimately the research project, was to create a radiographic dental implant guide describing the radiographic appearance of the most commonly used dental implants. This radiographic dental implant guide was developed to assist health science professionals not experienced in the identification of dental implants on dental images. This radiographic implant guide may also serve as a supplementary reference tool for the identification of dental implant types and may support current forensic identification methods for unidentified human remains in South Africa.

1.1 Context

1.1.1 History of dental forensic radiology and dental implants

The identification of human remains is one of the most essential aspects of forensic medicine and odontology (Kahana & Hiss, 2010). In view of this, forensic science requires a multi-disciplinary approach to find evidence and information for human identification. These multi-disciplines include: forensic radiology, forensic odontology, and forensic dentistry (Pallagatti et al., 2011).

The first intra-oral dental radiographs were taken in 1896 and have led the way for science in forensic odontology ever since. Two popular examples of human remains identification using radiographic imaging include the cases of Adolf Hitler and Dr Joseph Mengele. On 19 September 1944, three routine radiographs of Hitler's skull were obtained. When burnt human remains were found, a group of Russian experts used post-mortem radiographs for comparison to the three routine radiographs and made a positive identification using dental anatomy to positively identify the human remains as the body of Adolf Hitler (Brogdon, 1998).

The case of Mengele was also solved after human remains were found in Brazil in 1985. Mengele died in 1979 and a team of forensic scientists, representing multiple disciplines, was employed to assist in this complex identification process. A positive identification was made after the comparison of ante-mortem and post-mortem dental records indicated endodontic filled root canals (Eckert & Teixeira, 1985; Brogdon, 1998).

The history of early dental implants can be traced back several centuries to ancient Egypt, South and North America, and regions of Middle Asia and the Mediterranean, where carved pieces of seashells and/or stones were placed into human jawbones to replace a missing tooth or teeth (Gaviria et al., 2014).

The first evidence of these early dental implants dates back to as early as 600 AD, when archaeologists from the Honduras revealed in the 1930s that in the

Mayan civilization pieces of shell and stone had been found in a mandible. These pieces of shell, as noted by Gaviria et al. (2014) were used to replace missing teeth and compact bone formation was clearly seen around the implant (Abraham, 2014; DiGiallorenzo, 2018).

Gaviria et al. (2014) state that the history of modern dental implants dates from World War II, when in his years of service in the army, Dr Norman Goldberg thought about dental restorations using the same metal materials that were used to replace bone in other parts of the body. In 1948, in association with Dr Aaron Gershkoff, Goldberg produced the first successful sub-periosteal dental implant. This success formed the foundation of implant dentistry in which Goldberg and Gershkoff became well known pioneers in teaching techniques in dental schools and dental societies.

One of the most important advances in the field of dental implantology occurred in 1952, when the Swedish orthopaedic surgeon, Peringvar Brånemark, started studying bone healing and regeneration. He found that bone could grow in proximity to titanium, resulting in the process of osseointegration, and that it could effectively adhere to the metal without being rejected (Gaviria et al., 2014). Brånemark became a pioneer in research at the Nobel Biocare Implant Company in Switzerland. The first titanium dental implant was placed in 1965, and since this first design, modern dental implants have varied in shape and size depending on anterior or posterior placement (DiGiallorenzo, 2018; Nobel Biocare, 2018).

1.1.2 Research rationale

As stated previously, the identification of dental implants on radiographic images can be complicated for inexperienced health science professionals or health science students in training. In South Africa, there appears to be a lack of research on implantology, and particularly on how dental implants can be identified on radiographic images. As far as could be ascertained, there is no literature in the field of forensic dentistry or radiography that indicates the availability or the use of a radiographic dental implant guide during forensic dental identification processes in South Africa.

This therefore implies that there is a need for academic references or dental implant guides which can assist with the delineation of dental implants.

An online search conducted on the Cape Peninsula University of Technology (CPUT) library database, using the following keywords, dental reference guide, dental implant reference guide, dental forensic radiography, dental implants, dental implant morphologies, dental implant identification in South Africa, forensic radiography in South Africa, and dental implant database South Africa, revealed no previous studies related to the development of a radiographic dental implant guide. The databases consulted for the above search were: Science Direct, Scopus, SpringerLink, Ebscohost, Pubmed and Wiley Online Library.

Furthermore, a thorough literature search during February 2017 of the databases below indicated that no master's or doctoral thesis has been completed at or submitted to any South African university on this particular topic:

- Navtech
- Union Catalogue of Theses and Dissertations of South African Universities
- Dissertation Abstracts International of the USA using the Proquest database.

This radiographic dental implant guide, as far as could be established, is the first of its kind to be developed in South Africa. The identification of dental implant types based on their morphologies is not included in the syllabus of radiography or dental students and for future reference this radiographic dental implant guide can be used to enhance pattern recognition skills.

1.2 Research question

The research question for this study was: "Can commonly used dental implants, be used to develop a radiographic dental implant guide for identifying types of dental implants based on morphological characteristics?"

1.3 Research objectives

The research objectives of this study were:

- To establish a reference instrument for ten commonly used dental implant types in South Africa
- To identify dental implant types on pre-existing pantomographs of archived patient records
- To describe the radiographic appearance of dental implants based on the morphological characteristics, including the apex, thread and neck of each dental implant type observed
- To develop a radiographic dental implant guide consisting of the morphological characteristics, as mentioned in the objective above, of ten commonly used dental implant types currently used in South Africa

1.4 Significance of research study

The researcher is of the opinion that the morphologies of dental implants play an important role during the identification process of unidentified persons. Identification of dental implant types can be a complex process for inexperienced health science professionals. Dental implants can have subtle differences in their morphology, which make it difficult to distinguish them from one another. Since no such radiographic dental implant guide could be found in literature, it was postulated that this guide developed as part of the study, may be used as an academic and clinical reference tool for forensic specialists as well as for students in dentistry, radiography or medicine.

This guide can be used to compare morphological characteristics (apex, thread, and neck) and to identify different types of dental implants on pantomographs. This radiographic dental implant guide therefore provides a means of comparing different dental implant types in order to assist with positive identification of unidentified human remains.

In addition to the current acceptable protocols of dental record identification, it is anticipated that this radiographic dental implant guide will benefit the field of radiography and forensic dentistry by serving as an easy-to-navigate reference tool for identifying commonly used dental implant types on radiographs solely by their morphological characteristics.

This radiographic dental implant guide may be used in post-mortem forensic identification for comparing dental implants found on ante-mortem dental radiographs/records for the identification of human remains in South Africa.

The next chapter describes the importance of dental radiography in forensic identification; the morphological characteristics of commonly used dental implant types in South Africa, as well as the use of dental implants in forensic radiography and forensic dentistry.

CHAPTER TWO

LITERATURE REVIEW

2.1 Originality of this research study

As stated in Chapter One, as far as could be ascertained, no publications exist relating to implantology and its use in dentistry, radiography or forensic dentistry within the South African context. Furthermore, no similar master's or doctoral research study has been conducted to develop a radiographic dental implant guide of the different types of dental implants used in South Africa. To validate this research, a search of the following electronic databases, namely Pubmed, SpringerLink, Ebscohost, Scopus, Science Direct, Wiley Online Library, and the CPUT online electronic journals was done using the following keywords: dental forensic radiography, dental implants, dental implant morphologies, dental implant identification South Africa, and dental implant guide South Africa.

This search revealed that no relevant or similar publications or research projects had been conducted previously. Twenty-six related articles were identified, but no specific studies related to dental implants in South Africa or elsewhere were found. This chapter highlights the value of the morphological characteristics that each individual dental implant has in its identification. The literature review that follows gives a broad overview of various constructions and morphologies of dental implants and the importance of dental implants during the identification of human remains.

2.2 The importance of dental radiography in forensic identification

Mason and Bourne (1998) noted that radiological images are a source of objective data supporting the opinions of a forensic team. The most common primary methods used during human remains identification may include: visual identification, fingerprint identification, Deoxyribonuecleic acid (DNA) identification, unique skeletal markings, identification of medical devices including pacemakers and cochlear implants, and dental identification.

Radiography is an important diagnostic tool to identify a variety of dental conditions. Ante-mortem radiographic images are frequently accessible to assist in a positive identification (Kahana & Hiss, 2010). More specifically, dental radiography is an extremely important aspect for any forensic odontologist and forensic pathologist, as well as for any other discipline involved in the identification of human remains.

According to Viner and Robsen (2017), the comparison of ante-mortem and post-mortem images may provide a number of concordant points from which human remains can be positively identified.

Byraki et al. (2010) state that dental evidences, such as dental records and previous radiographic images, are the most widely used tools in human remains identification. Dental evidence has some advantages, for example: low cost, human teeth are the best preserved body part, human teeth are mostly intact after accidents, past dental records are mainly available, and dental characteristics (including dental restorations) are unique to each human being.

Mason and Bourne (1998) concur with Byraki et al. (2010) by indicating a few more advantages of dental records, namely that they are reliable, less time consuming to apply, and straightforward to use when ante-mortem images are available. The use of diagnostic images for identification purposes allows for forensic dentists and forensic pathologists to use points of agreement between ante-mortem and post-mortem images. There is no set number of points needed to make a positive identification of human remains. Useful points of identification may include:

- Specific teeth present
- Unique features (shape of crown and roots)
- Presence of restorations (including endodontic fillings and dental implants) (Mason & Bourne, 1998).

One of the most reliable methods of dental identification involves the documentation of certain anatomical characteristics, including dental restorations that present on dental records. Another reliable and accurate method of identifying human remains is a positive radiological identification between ante-mortem and post-mortem images of dental radiographic images (Brogdon, 1998). Manigandan et al. (2015) also state that by comparing ante-mortem and post-mortem radiographs, similarities can be noted such as the number of/and arrangement of teeth, dental anatomy and hidden restorations, including dental implants. The Disaster Victim Identification (DVI) Guide (Interpol, 2013) further notes that methods of identification used for forensic purposes may include fingerprint analysis, comparative dental analysis, and DNA analysis.

Viner and Robsen (2017) state that even if ante-mortem radiographic images are not present, post-mortem images may include details of dental restorations which cannot be seen during visual examinations. These may include endodontic filled root canals, dental implants, and retained roots.

Ante-mortem panoramic images are a vastly useful tool during the process of identification, as a single image will often illustrate the full dentition. According to Viner and Robsen (2017), this may provide identifiable detail of all teeth. Even small post-mortem fragments may be matched to the detail on such ante-mortem radiographs. Kahana and Hiss (2010) concur, and state that odontologists routinely rely on the result of comparing ante-mortem and post-mortem radiographic images to make a positive identification of human remains. Shanbhag (2016) agrees that accurate, positive identification may be possible when the post-mortem and ante-mortem radiographic dental records obtained are from the same person.

2.3 Dental implants

The next section describes the morphological and physical characteristics of the most commonly used dental implants in South Africa.

2.3.1 Morphological and physical characteristics

Radiographic identification is one method used to identify the type of dental implant through morphological characteristics such as its connection (including body and neck of the dental implant), length and width. The use of dental implants has facilitated the comparison and identification of different shapes, types and lengths for personal identification (Michelinakis et al., 2006). Brown and Davenport (2012) concur that the morphology of dental implants and their differences can be extremely useful when dental comparisons must be made.

Dental implants, considering their morphological characteristics, give an additional layer of evidence during odontological identification, increasing the possibility for a positive proof of identity. It is possible that a victim's dentition could be totally replaced with dental implants with no natural teeth remaining in the occlusion. During the process of post-mortem detection of an implant, ante-mortem dental records would normally be on the system of a treating dentist and may be located with other ante-mortem data (Berketa et al., 2010a).

However, it is important that care should be exercised when using dental radiographs for direct comparison against post-mortem radiographs as there may be distortion and angulation factors that need to be considered and radiographic images are technique sensitive. All these mentioned factors (distortion and technique errors) are disadvantageous, because if these factors are not considered, a positive identification of both dental implants and human remains cannot be made (Berketa et al., 2010b; Byraki et al., 2010).

According to Berketa et al. (2010b), dental implants are a popular choice to replace missing (single or multiple) teeth in the entire dentition. Dental implants have several physical properties such as high corrosion resistance, a high melting point and high structural strength which can resist most physical and chemical assaults. In many cases of single and multiple deaths, scientific identification of human remains utilising forensic odontology is often the most successful source of identification. The increasing use of dental implants means that ante-mortem dental records are in most cases readily available for comparison with post-mortem implant imaging.

2.3.2 Dental implant components

The term 'dental implant body' describes the component placed in the mandible and/or maxilla. Dental implants are axisymmetric, because the majority are designed to be placed in the tapered holes drilled into the bone. The apex forms part of the dental implant body and many are screw-shaped to aid in primary stability when inserted into the tapered holes. Some implants are designed with a tapered effect. The dental implant provides the anchor or foundation for a restoration (crown) and provides a fixed platform on which an abutment can be screwed (Hobkirk et al., 2003; Nobel Biocare, 2018).

The abutment provides support for the crown. It is also the connection between the crown and the implant. The abutment connection varies in length, and different types include: cylindrical, shouldered, angled, and customisable (Animated-Teeth.com, 2017; Nobel Biocare, 2018).

2.4 Dental implant identification in forensics globally

According to a recent study in Sweden by Johansson et al. (2016), radiological images can be a valuable source for identification where dental implants feature on post-mortem dental records. The results of the aforementioned study indicate that intra-oral radiographs taken on different occasions of edentulous mandibles can be matched if treated with the same dental implant system or type of dental implant/s. This study also states that owing to the increasing number of people having reconstructive dental work, including dental implants, it is inevitable that any future human disaster identification process will contain human remains where dental implants are a feature of the recovered jaws.

Michelinakis et al. (2006) indicate that the identification of different types of dental implants is possible if dental radiographic images are available after dental implants have been placed in either the mandible and/or maxilla during dental rehabilitation.

De Angelis and Cattaneo (2015) describe a case where a burnt oral implant was recovered and suspected of belonging to a victim of homicide. Dental implants were present and the site of bone integration played a critical role in identifying the human remains. Owing to the unique morphology of the dental implants, this was used as evidence where DNA analysis failed to do so. Nuzzolese et al. (2008) further elaborate on this statement by De Angelis and Cattaneo (2015) and indicate that dental implants are widely used to identify human remains by radiographic image recognition.

During a study at the University of Adelaide, South Australia, a cremated mandible and maxilla containing dental implants were examined. Following cremation, the brand of dental implants was identified utilising web-based search engines and a prosthodontist was able to identify the deceased (Berketa et al., 2014). A group of scientists, also from the University of Adelaide, published an article indicating that the presence of dental implants in radiographic material may provide a means during the process of identifying human remains where natural teeth, DNA or fingerprints are not present. Owing to a dental implant's high melting point, this can be a positive source of identification. Identifiable features include the grooves, holes, and threads on the surface of an implant. Research has shown that after heating a dental implant up to 1 125° C, the only visible change to the implant was the colour which changed to dark charcoal (European Association of Osseointegration, 2012).

Examination of European tourists after the 2004 tsunami disaster in South-East Asia has shown accurate identification of human remains using radiographs of dental implants. Implant systems used were popular European and Scandinavian designs, resulting in the suggestion that the human remains might have been foreign nationals (Rai & Anand, 2013).

Sarode et al. (2009) note that during the identification process of the 2004 tsunami disaster, 97.4% of the bodies found included a skull, and it was therefore possible to gather dental evidence.

Silva et al. (2014) state that "implantology became an emerging branch of dentistry" and "unique dental evidence, such as morphological traits and signs of treatment interventions, play a key role during the human identification process". In 2013, Silva et al. (2014) noted the following case: An unknown male's charred body was found after a horrific car accident. The investigation focused on dental identification and cause of death. During the dental autopsy, a broken and charred mandible and maxilla were found, but most of the teeth present had fractured crowns due to the high temperature to which they had been exposed. Fortunately, two dental implants were collected with metal-ceramic prosthetic restorations, and all of the evidence was referred for post-mortem radiographs. After investigation officers had obtained medical information from the likely relatives, they were able to compare the ante-mortem dental images with the post-mortem images. Both dental implants recovered from the human remains presented the same morphology and screw pattern compared with the dental implants on the ante-mortem images. Based on these findings, a positive identification could be made.

Chandrasekhar and Vennila (2011) also state that morphological comparison between ante-mortem and post-mortem images can identify human remains. Anatomical details like supernumerary teeth, the shape and morphology of teeth, missing and present teeth, and dental implants are of great value during the identification process. Furthermore, Chandrasekhar and Vennila (2011) state:

> Morphological features of dental implants depicted on radiographs may be used to develop a dental profile of the individual, and this can narrow the search to a smaller number of individuals, or eliminate certain candidates by taking into account the dental system employed.

It can therefore be argued that a radiographic dental implant guide will serve as a useful tool in establishing the radiographic appearance of the most commonly used dental implants in order to assist persons in training with regard to the identification of such implants. Such a guide will also serve as a supplementary layer of identification methods to identify human remains. This dental guide may even find applications beyond South Africa's borders in view of the fact that dental implants are used and distributed worldwide due to the international location of manufacturing companies and/or their distributors.

2.5 Dental implant identification

In South Africa, Dr Paul Botha, a periodontist based in the Western Cape, has created a dental implant global register that allows the dental surgeon or periodontist to place all relevant dental implant data and information on a web-based system, with the patient's permission, for retrieval at any time in the future. The system indicates the type of dental implant placed as well as the date of placement, which is important for forensic purposes (Botha, 2016).

According to the American College of Prosthodontists (ACP) (ACP, 2017), every dental implant is unique in shape, taper, thread, and appearance on any radiographic image. Once a dental implant is placed in a patient's mouth, it will be unidentifiable without information from the dentist, oral surgeon or periodontist who placed it, or by intra-oral recognition. The website "What Implant Is That?" (www.whatimplantisthat.com) was created by Drs Howell and Farley of the ACP to help identify types of dental implants. This website contains a database which provides radiographic images of various dental implant types from all over the world. The process of elimination can be used to narrow the search for the type of dental implant in order to make a correct identification of the dental implant type.

In a study done by Michelinakis et al. (2006), a computer software programme was developed as an aid to identify different types of dental implants. Relevant information includes details for 87 implant manufacturers, with 231 different implant designs based in 21 countries. This program has been successfully tested and is being used in both general dental practices and for forensic identification. This programme also provides valuable information to identify dental implants.

A group of Australian researchers have published results of a study that indicated that dental implant identification on radiographic images does not always have positive outcomes. The accuracy of positively identifying 200 implants during their study only reached 48.4%. A limiting factor during the Australian study was the use of non-standardised radiographic images that distorted the image significantly. The authors also examined the potential improvement in accuracy associated with the use of the computer software, Implant Recognition System (IRS) that has compiled a large database of implants from 87 implant manufacturers. The software program (created and tested by Michelinakis et al. (2006) as mentioned earlier) requests the known features of the dental implant through a series of drop-down menus which allows the user to enter information about implants under the headings: implant type, implant description, thread, neck, surface, diameter, and length. Initiating the program's search function reveals a list of possible dental implants with the manufacturer and dental implant name (Soukoulis, 2016).

Despite the assistance of the computer software system, the accuracy rate only increased marginally to 51.3%. The authors of the Australian study suggest that both rates of successful recognition are poor for forensic identification casework (Soukoulis, 2016).

2.6 Dental implant systems

The next section gives an introduction to the dental implant companies (in alphabetical order) that manufacture some of the most commonly used dental implant types that were included for this research study.

2.6.1 Bicon Dental Implant System

The Bicon Dental Implant System was introduced in 1985 after several years of research. Situated in Boston, Massachusetts, USA, this implant company is known for its short dental implants. In 1998, the first Bicon dental implants were distributed to South Africa and are now widely distributed to more than 75 countries. These dental implants have the following characteristics: flat apex, short implant length, and thin neck (Bicon Dental Implants, 2018).

In 2015, the company introduced the Universal Abutment System which allows for Bicon abutments to be used in combination with any other type of dental implant system (Bicon Dental Implants, 2018).

2.6.2 Biomet 3i and Zimmer Dental

Zimmer Dental and Biomet 3i have merged forces in oral healthcare and operate as the Zimmer Biomet dental division. Headquartered in Palm Beach Gardens, Florida, USA, the Zimmer Biomet dental division has close to 2 000 employees worldwide, with four manufacturing facilities and has 62 years of experience in the dental implant industry. Zimmer Dental and Biomet 3i collectively have over 315 combined issued patents worldwide with another 116 pending. Continuous research and development is a high priority in developing new techniques, technologies, and materials that will help advance all aspects of implant dentistry (Implant Practice US, 2018).

Developed with advanced technology is the 3i T3 Implant, which is designed to deliver aesthetic results through tissue preservation. The implant combines a contemporary hybrid surface, a tight implant and abutment interface, and integrated platform switching. Another advanced product to be added to the company's portfolio will be the introduction of the Zimmer Dental 3.1 mmD Eztetic™ Implant, which has a conical prosthetic connection designed to reduce micromovement and microleakage (Implant Practice US, 2018).

2.6.3 Champion

Little information was available on this dental implant company. Champion Implants was founded in Germany, has about 30 years' experience in the industry and has implemented the Minimally Invasive Method of Implantation MIMI®-Flapless implantation method. This surgical method causes minimal bleeding, is performed without incisions, and without sutures. This technique also allows for dental implants to be placed efficiently and rapidly (Champion Implants, 2016).

2.6.4 Megagen

The Megagen Implant Company was founded in 2002 in South Korea by a group of experienced dental surgeons who had an interest in offering dental implant solutions for patients as well as solutions for difficult surgical cases. Megagen has added a short implant range to their portfolio: Rescue Short & Wide implants (Megagen, 2018).

In 2016, the company launched the AnyRidge Implant System. Morphological characteristics include:

- locking morse tape
- innovative thread shape
- universality of the abutment
  (Megagen, 2018).

2.6.5 MIS

Established in 1995 and headquartered in Israel, MIS Implants Technologies Ltd. is active in the development and production of products and solutions aimed at simplifying implant dentistry.

MIS offers a complete range of dental implants (including MIS7) and superstructures and is distributed in over 65 countries worldwide (MIS, 2018).

Scientists and engineers form the backbone of MIS and conduct continuous research and development in respect of their products and technologies to service the needs of dental implant professionals (MIS, 2018).

2.6.6 Neodent

Founded in 1991, Neodent is a Brazilian manufacturer of dental implants that has been part of the Straumann Group since 2012. This company has over 20 years of experience in the design, development, and manufacture of dental implants. Its variety of dental implant designs are specially designed to address most clinical needs and bone types (Straumann Group, 2018).

Two connection types, morse taper and external hex, and two surface types, NeoPoros and Acqua (hydrophilic), were developed to enhance success rates and treatment outcomes. The implants are complemented by a variety of standard abutments. The Neodent implant systems provide the ability to maintain and preserve bone around the implant placed in the mandible/maxilla (Straumann Group, 2018).

2.6.7 Nobel Biocare

Nobel Biocare was founded in 1952 in Switzerland, and its success was built on over 60 years of experience from Peringvan Brånemark's ground-breaking work with osseointegration. As a young researcher in the 1950s, Peringvar Brånemark was intrigued by the anatomy of blood flow. As part of his work, he placed a titanium-housed optical component in a rabbit's leg, which made it possible to observe microcirculation in the bone tissue through specially modified microscopes. At the time when he had to remove this titanium-housed optical component, he discovered that the bone and titanium had become attached. Not long afterwards, Brånemark claimed that they had "changed the direction of dental work to investigate the body's ability to tolerate titanium" (Nobel Biocare, 2018).

In 2008 the NobelActive® implant was introduced. It is designed for high primary stability and soft and hard tissue preservation. This design allows for the implant to be inserted into soft bone, immediately after tooth extraction (Nobel Biocare, 2018).

2.6.8 Southern Implants

Southern Implants was established in 1987 and is headquartered in South Africa. With this company's product range being continually expanded, it offers a wide variety of dental implant types. Southern implants are made from Grade 4 pure titanium, ASTM-F67-95, with a tensile strength of 550 MPa. The surface of the dental implants is enhanced with abrasion and chemical conditioning and has been proved in clinical trials (Southern Implants, 2018).

2.6.9 Straumann

Straumann's core business is restorative and regenerative dentistry and it forms part of the Straumann Group. Straumann conducts research and develops and manufactures dental implants as well as a variety of dental materials and instruments. This company also focuses on bone regeneration biomaterials for use in restoration and tooth replacement, or to prevent tooth loss. Founded in 1954 and headquartered in Switzerland, the first dental implant was produced in 1974 and today they have six production sites and have distributed over 15 million dental implants worldwide (Straumann, 2018).

During this literature review, no publication was found related to the radiographic dental implant guide, which is an indication of a lack of research and justifies the need for such a guide.

Contrary to the identification methods used by the ACP and Michelinakis et al. (2006), the radiographic dental implant guide that has been developed will provide a summary of the morphological characteristics of each dental implant. It will not be expected of the user of the radiographic dental implant guide to enter certain information as it will serve as an aid to identify the type of dental implant. The user will be able to use this guide as a supplementary method in identifying dental implant types in combination with other methods, such as dental records, facial radiographic images, and other dental radiographic images.

The next chapter describes the research methodology.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research study design

The methodology considered for this research study was a positivist approach through a quantitative, exploratory, non-experimental research design. This design is used when there are no or only a few studies to refer to in the existing literature (Manerikar & Manerikar, 2014). In other words, in view of the fact that no study on dental implantology has been done in South Africa, and in view of the researcher's quest to establish a radiographic dental implant guide, the above-mentioned scientific research design is within this context, ideally placed to achieve the research objectives.

This research study employed a descriptive research methodology. This research study consisted of four components:

- The first component consisted of the radiographic imaging of ten commonly used dental implant types to establish a reference instrument.
- The second component sought to identify the radiographic appearance of the most commonly used dental implants among a sample of ante-mortem pantomograms.
- The third component sought to describe the morphological characteristics of dental implants to create a radiographic dental implant guide.
- The fourth component consisted of the development of the radiographic dental implant guide based on the description of the morphological characteristics of each dental implant type.

The above process enabled the researcher to draw comparisons between ten commonly used dental implant types and those found on the pantomographs in order to develop the radiographic dental implant guide describing the different morphological characteristics of these dental implant types.

3.2 Research study sites

With permission, the dental practice (including all resources needed, especially dental implants) of Dr P Wolfaardt (periodontist based in Bellville, Cape Town) was used to image radiographically ten commonly used dental implant types.

Secondly, the pantomograph images collected (with permission) from the Department of Oral Pathology and Radiology, Faculty of Dentistry, University of the Western Cape (UWC) were retrieved from the digital system at the Radiology Department of UWC. All pantomographs used for this research were gathered on location at the aforementioned department. Physical address: Francie van Zijl Drive, Parow, South Africa, 7500.

3.3 Sampling method

The data, in the form of pantomographs, was gathered by the researcher from the archival patient records of the Department of Oral Pathology and Radiology of the Faculty of Dentistry, UWC, which is located adjacent to the Tygerberg Academic Hospital.

For this study, 384 dental implants were identified on 105 archived ante-mortem pantomographs retrieved from the electronic database of the above-mentioned department. This method of convenience sampling was considered since not all pantomographs viewed presented with dental implants.

The ten dental implant types were selected using a nonprobability sampling method, known as convenience or availability sampling (Daniel, 2012:81-82). This sampling method was preferred owing to the availability of the ten dental implant types at the practice of Dr Wolfaardt. In addition, the number of dental implant types selected aims to be a broad selection commonly used by periodontists in the Western Cape. As stated earlier, Southern Implants is the sole manufacturer of dental implants in South Africa. The nine other chosen dental implants are from global manufacturing companies, including those in Switzerland, Sweden, the United States of America, Israel, and South

Korea. These dental implants are widely available and used throughout South Africa.

3.3.1 Sample size

To determine the proportion or sample size of dental implants to be used in this study, the following formula was used (Kumar, 2010).

$$N = \frac{Z^2pq}{e^2}$$

The possibility of being able to identify as well as not identify dental implants was set at 50%.

N = Number of dental implants to be used

P = 50% ability to identify dental implants

Q = 50% ability not to identify dental implants

Z = constant (1.96) from the normal distribution

E = precision (0.05)

$$N = \frac{1{,}96^2 .\ 0.5 .\ 0.5}{0.05^2}$$

N = 384

3.3.2 Inclusion criteria

Only pantomographs, acquired between January 2013 and August 2017 presenting with dental implants, were selected for this study. Age, gender, and race were irrelevant to this study.

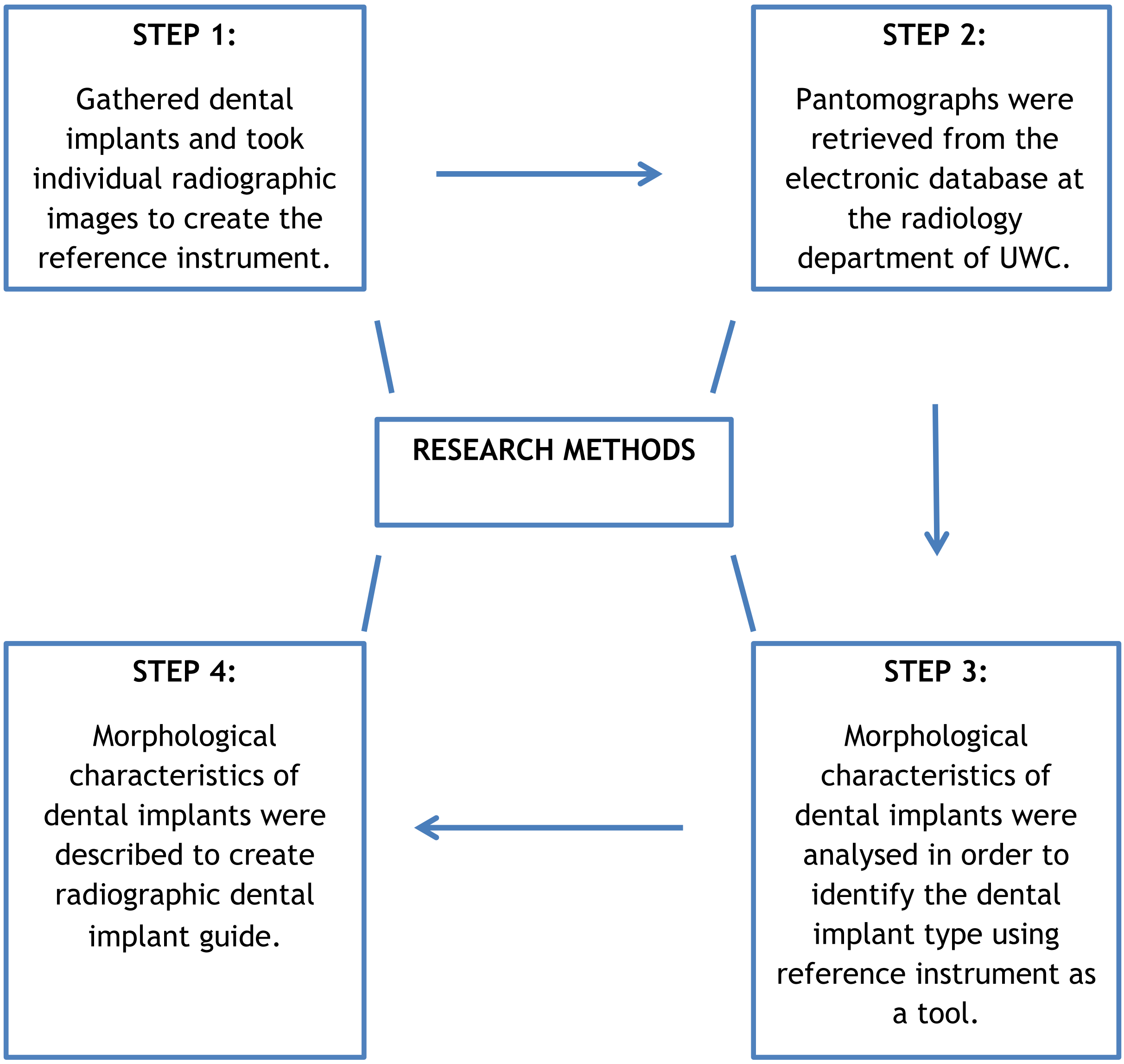
3.3.3 Exclusion criteria

Pantomographs that did not present with dental implants were not included in this study. Pantomographs acquired before the pre-set time interval, as well as pantomographs of paediatric patients and pantomographs where facial or dental abnormalities were present, were excluded.

3.4 Methods

The flowchart below gives a broad overview of the steps conducted in this research study.

3.4.1 Flowchart



A detailed description of each step in the flowchart above is explained next.

3.4.2 Radiographic imaging of the dental implants: Component 1: (Step 1)

Thirteen (ten plus 3 subtypes) dental implants commonly used in South Africa from ten dental implant types were gathered by the researcher and individually radiographed under non-clinical conditions. This was done with consent from the practice of Dr P Wolfaardt, a periodontist based in Bellville, Western Cape. The following dental implants from the ten dental implant types were radiographed:

- Bicon: example dental implant
- Biomet: Full Osseotite® 3.25mm x 11.5mm
- Champion: example dental implant
- Megagen: AnyRidge 4mm x 10mm
- MIS: MIS7 internal hex 6mm x 10mm
- Neodent: example dental implant
- Nobel Biocare: NobelActive®
- Southern: IB 3.75mm x 12mm
- Straumann: three example dental implants (the same type, just different lengths)
- Zimmer: two SwissPlus dental implants (the same type, just different lengths)

Prior to the individual imaging of the ten dental implant types, the name of each dental implant type was registered on Carestream (software) on an Asus Pro Windows laptop with i7 processor that was connected to a digital detector with dimensions: 27.6mm x 37.7mm; resolution: 24 lp/mm. Before the dental implant was placed on the detector, the name of the dental implant type was selected on the laptop computer. This ensured that the dental implant being radiographed corresponded with the dental implant type selected on the computer program in order to correctly label the dental implant on the computer system.

The radiographic exposure was set at 70kV (dental x-ray units usually operate between 50kV and 90kV), 8 mA and 0.4s (3.2mAs). Dental implants were removed from the plastic enclosure and were then individually placed flat on the clean digital detector and were radiographed in three positions: straight tube (ST: which was positioned perpendicular to the dental implant), off centre (OC at 5 degrees angulation), and severe off centre (SOC at 30 degrees angulation in the opposite direction). This method of exposing the dental implants in three different positions was to create radiographic images of the dental implants that would correspond with the dental implants on the pantomographs which may appear in an off-centre (or oblique) position owing to technique errors during actual acquisition of the pantomographs or depending on surgical placement.

The x-ray tube was positioned for the first exposure using a ST, with a vertical central ray perpendicular to the digital sensor with a source-to-image distance (SID) of 18cm and object detector distance of 0cm (Figure 3.1). The SID and object film distance were constant during all exposures to ensure standardisation of image quality.

Figure 3.1: ST presentation

Before each exposure, the blue button (Figure 3.1) was pressed and the x-ray system allowed for a ten-second delay that acted as a safety feature to ensure no exposure could be made and that all persons could exit the clinical room. The blue light became green (Figure 3.2) that indicated that an exposure could be made. After the first exposure, the tube was angulated in two different directions (Figures 3.2 and 3.3) to acquire the off-centre and severe off-centre images.

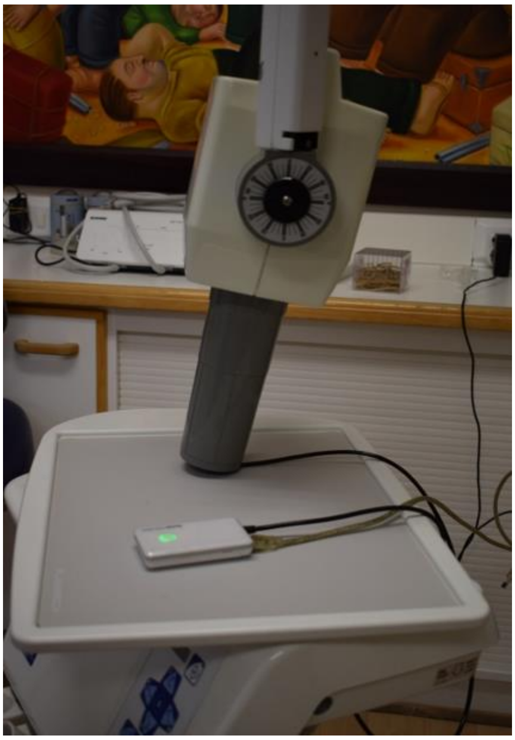


Figure 3.2: OC presentation

Figure 3.3: SOC presentation

After each individual type of dental implant was exposed in three different positions with different angles, the images automatically appeared on the laptop computer screen and were saved on the laptop hard drive, recording the type of dental implant and angle of exposure (straight tube: ST; off centre: OC; severe off centre: SOC) for each image.

The radiographic imaging of the dental implants was performed to resemble closely the position of the dental implants on pantomographs to be reviewed, but the OC and SOC images were taken to determine whether a positive identification of the dental implant type could still be made with the angulation of dental implants. In other words, these acquisitions were obtained to determine whether the position of the dental implant, because of the angle at which it was placed in the patient’s mandible or maxilla during surgery, or tilting of the x-ray tube during radiographic acquisition, would influence the morphology of the dental implant and, furthermore, to determine whether a positive identification could be made for malposition of the dental implant.

A total number of 35 images (three images of each dental implant type, ST images of the Straumann subtypes with crowns attached and three images (ST, OC and SOC of the Zimmer subtype) were taken and saved. Afterwards all the images were sent via email to the researcher's personal computer [(Mecer Xpression, Model: W251HP, HDMI (High-Definition Multimedia Interface)] and saved in a folder named 'Dental implant data'.

All 35 images were backed up on a personal external hard drive, saved with the corresponding folder name 'Dental implant data'. In order to safeguard the data, a password for the folder on the researcher's personal computer was created.

3.4.3 Identification of dental implants on pantomographs: Component 2: (Step 2)

This component consisted of the retrieval of pantomograms from the Department of Oral Pathology and Radiology, Faculty of Dentistry, UWC. The pantomographs were retrieved by the researcher from the computer monitor of the Panorex x-ray unit at one of the workstations within the above mentioned department. The software used on the computer monitor linked to the Panorex x-ray unit is Sidexis XG. After Sidexis XG was opened on the computer screen, the 'select image' icon was selected on the vertical toolbar on the left of the computer screen. A pop-up screen appeared with the list of patients' surnames and initials; these were automatically arranged according to year of birth (oldest to youngest) and in alphabetical order according to the patient's surnames.

According to the year of birth (starting at the oldest), each patient's surname was captured in a separate book in alphabetical order. After each 50 patient's surnames were captured, the surnames were individually typed into the 'search criteria' and the patient's details appeared. If there was more than one patient on the system with a similar surname, the patient was selected according to the year of birth. After double clicking on the correct patient, a preview pantomograph of the patient appeared on the screen. If no dental implants were viewed on the preview pantomograph, the image was closed and the next surname was typed in the ‘search criteria’. If dental implants were present on the preview pantomograph, the image was enlarged by double clicking on it.

Each pantomograph which presented with dental implants was saved in the folder on the computer monitor named ‘Ante-mortem pantomographs’. To save the image, the ‘Image’ icon was selected at the horizontal top toolbar and a drop-down list appeared. ‘Export’ was selected which opened a list to the right of the computer screen where ‘Export’ was again selected. A pop-up screen appeared with a list of folders and the ‘Ante-mortem pantomographs’ folder was selected for the image to be saved in. A total of 223 pantomographs were collected and included a large number of dental implants that exceeded the sample size of 384 calculated for this research study.

Each surname was changed to a reference name labelled ‘pan001 to pan223’ to ensure anonomysation of data. The ‘Ante-mortem pantomographs’ folder was copied from the computer monitor onto a compact disk (CD) after which the ‘Ante-mortem pantomographs’ folder was deleted from the facility’s computer. The CD (Melody CD-R: 52x speed, 80min/700MB) was kept securely in a lockable cupboard at the researcher’s home.

No external hard drives were allowed to be inserted into the computers of the above-mentioned facility and therefore data were copied to the CD. The researcher was the only person who collected the data from the computer monitor of the Panorex x-ray unit where the pantomographs were archived. No research assistant was employed during the course of this study.

Of the 223 pantomographs that presented with dental implants, 105 pantomographs were regarded as suitable for analysis. A total of 118 pantomographs with dental implants were excluded. This will be discussed further in Chapter Four and Chapter Five.

3.4.4 Description of morphological characteristics of dental implants on pantomographs: Component 3:(Step 3)

The CD with the folder containing the pantomographs was inserted into the researcher's computer. The folder 'Ante-mortem pantomographs' was selected on the pop-up screen and was copied onto the researcher's computer which was password protected. The folder was opened and each pantomograph was viewed individually on the computer screen.

The reference instrument of the ten different dental implant types was created by opening the folder named 'Dental implant data' (as discussed under 3.4.2) on a separate screen connected to the researcher's computer monitor. The 35 images of the individual dental implants were viewed as 'extra-large icons'. This method ensured that each individual image could be enlarged by double clicking on the specific image for more accurate viewing if necessary. The split-screen option was used to ensure separate viewing of the reference instrument and pantomographs. Comparisons were made between the dental implants found on the pantomographs and the dental implants used for the reference instrument in order to find a match and identify the type of dental implant/s.

As part of the third component of this research study, each positively identified dental implant on the pantomographs was identified using morphological characteristics, namely the shape of the neck, appearance of the thread, and shape of the apex as seen on the reference instrument. These results were recorded in a data collection sheet (refer to Appendix A). The dental implant types were listed in alphabetical order with the number of pantomograph (pan001 to pan105) listed next to the corresponding dental implant type identified. Each morphological characteristic used to make a positive identification was marked with 'X' in the corresponding column. An 'other' column was added to indicate additional characteristics (such as abutments) that aided in the identification process.

3.4.5 Development of the radiographic dental implant guide: Component 4: (Step 4)

For the radiographic dental implant guide, the ten dental implant types used in the reference instrument were listed in alphabetical order. Each dental implant type was described according to the apex, thread, and neck as seen on the radiographic images. Three radiographic images (ST, OC, and SOC) were included as part of the description. The radiographic dental implant guide also consisted of additional information, including a description of variations of morphological characteristics that aided the researcher in some cases to make a positive identification (Appendix B). A PDF of this radiographic dental implant guide is available as well as an e-format in Appendix C.

3.5 Statistical analysis

The statistician of CPUT was consulted for statistical analysis and interpretation of the research findings. Frequency analysis was used to analyse the data. The researcher did consult with a periodontist in the case/cases where the type of dental implants could not be identified.

Please refer to Chapter Four for a detailed discussion of the research results.

3.6 Delimitations of research

Identifying types of dental implants for this study has certain limitations.

- This study did not evaluate the accurate or successful placement of dental implants.
- This study did not evaluate the quality of pantomographs.
- Only dental implants were analysed during this study. Any other dental restorations were excluded as they were irrelevant to this study.

Further discussions related to limitations are described in Chapter Five.

3.7 Ethical considerations

Permission to conduct this research study was obtained in March 2017 from the Research Ethics Committee of the Faculty of Health and Wellness Sciences of CPUT.

After permission had been granted by the CPUT Research Ethics Committee, permission to conduct the study was obtained from the Dean of the Faculty of Dentistry, UWC.

The ethical principles of the Declaration of Helsinki (WMA, 2018) were upheld during this research study in the following ways:

- No patients were involved in the research study therefore no patient consent was required and no patient was harmed or coerced to participate, or was disadvantaged or directly benefited from this study.
- Patient information (age, gender and date of birth) displayed on pantomographs was kept confidential at all times. All pantomographs were anonymised after saving them on the researcher's personal computer to protect the identity of such patients.
- Furthermore, in order to further enhance confidentiality, any anatomical anomalies or dental pathologies observed on the pantomographs were neither recorded nor disclosed to anyone else.
- The data and results of this research study were saved on the researcher's computer which had a password to maintain the confidentiality of information and results.
- The researcher discussed the research study with the assigned supervisors before embarking on the research.
- The data collection only commenced once ethical approval had been granted by the Research Ethics Committee of CPUT.
- Data will be safeguarded after finalising the thesis and will be destroyed five years after the research study had been concluded.

The ethical principles on human participants in research of the South African Medical Research Council (SAMRC) (SAMRC, 2018) were not applicable to this study.

In the researcher's opinion, it is important to understand the ethical implications of the research study. Unethical behaviour may result in the study being unsuccessfully conducted. In order to justify the funding provided by CPUT for this study, the researcher has a moral responsibility to publish the results in an honest and objective manner, irrespective of whether a positive or negative outcome was achieved.

The results were therefore under no circumstances manipulated or adjusted to correspond with any preconceived outcome.

The next chapter discusses the results of this research study.

CHAPTER FOUR

RESULTS

4.1 Introduction

For this research study, a total of 4 682 pantomographs were viewed and of these, 223 pantomographs presented with dental implants. Of the 223 pantomographs, 105 presented with 384 dental implants and were regarded as suitable for analysis. A total of 118 pantomographs with dental implants were excluded owing to poor radiographic technique resulting in suboptimal radiographic image quality which hampered the analysis of the in situ dental implants. This specific aspect is discussed in Chapter Five as part of reject analysis.

A total of 384 dental implants were present on the 105 pantomographs finally included in this research study. Of the ten different dental implant types that were radiographed for the reference instrument, only 9 types of dental implants were observed among the dental implants identified on the pantomographs. An additional 5 types of dental implants were identified on the pantomographs that were not x-rayed (as part of the 10 dental implant types radiographed) and 4 dental implants seen on the pantomographs could not be identified and were recorded as: “could not identify implant” (CNII) on the data collection sheet (Appendix A).

4.2 Description of dental implant morphologies

Previously mentioned research studies (Pretty & Sweet, 2001; Michelinakis et al., 2006; Berketa et al., 2010a; Byraki et al., 2010; Brown & Davenport, 2012) have indicated that dental implant types can be identified by their unique morphological characteristics. The next section describes the different morphological characteristics of each dental implant type and how each morphological characteristic were used to identify dental implants on the pantomographs in this research study. The ST image was used as the point of reference to identify dental implant types, with each positively identified dental implant type compared to the OC and SOC images thereafter. Throughout this chapter there is reference to the reference instrument (Appendix D) and radiographic dental implant guide (Appendix B). Also refer to section 3.4.2 for explanation on how dental implants were radiographed to create the reference instrument.

Each dental implant type listed in the reference instrument is discussed in detail with regard to the 3 morphologies namely the apex, thread, and neck.

4.2.1 Bicon

For this research study, an example Bicon dental implant was imaged radiographically and presented with the abutment and healing cap already attached to the neck of the implant (Figure 4.1).

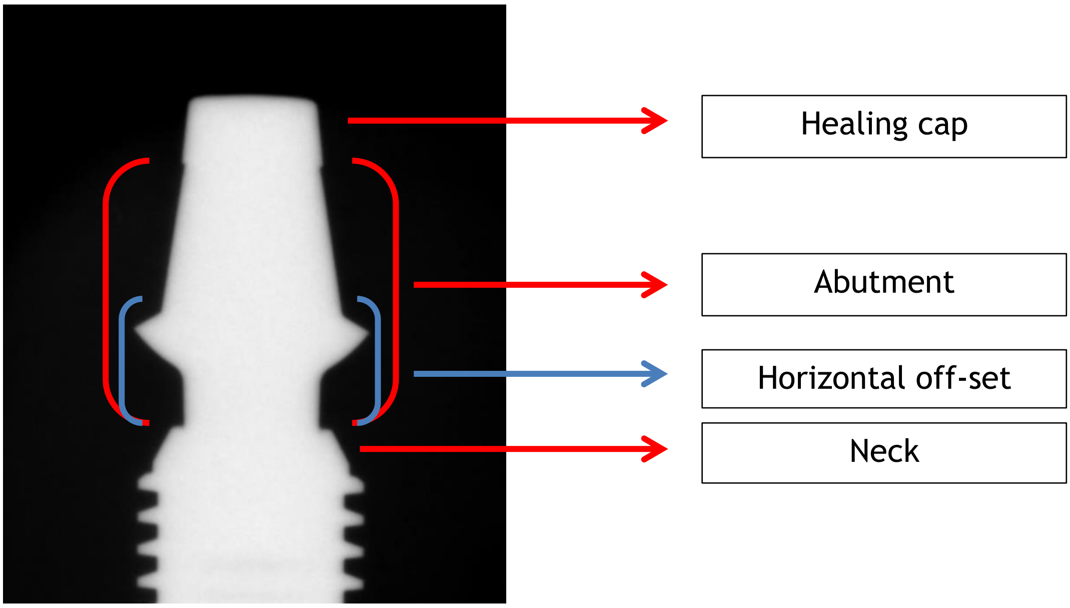


Figure 4.1: Bicon dental implant (ST presentation) indicating part of the body (thread), neck, horizontal off-set, abutment, and healing cap.

This dental implant presented with 13 individual, sharp-edged threads, covering the body of the dental implant in horizontal twirls. The apex of the dental implant is flat and the apical end presents with four spiral channels separating 11 threads towards the neck. The two final threads continue around the body of the implant. The neck of the dental implant is short and smooth, with an inward curve allowing for a horizontal off-set where the abutment connects to the neck (Figure 4.2a-c).

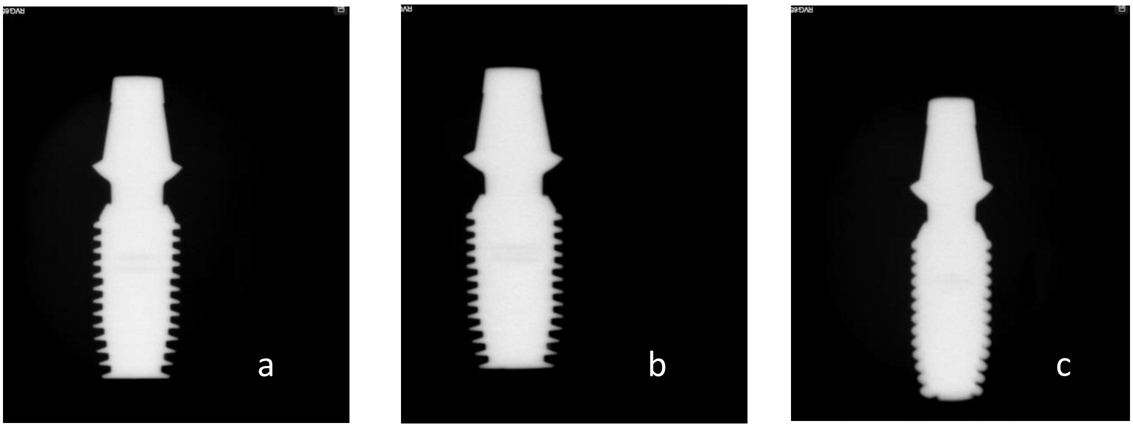


Figure 4.2a-c: Bicon dental implant example used in the reference instrument:
a - ST, b - OC and c - SOC.

A total of 13 Bicon dental implants were identified on the pantomographs using all three morphological characteristics as seen on the reference instrument.

Bicon dental implants are known to be a short dental implant type and have an accentuated horizontal off-set which can also be used as an additional identification morphology (Figure 4.1). The threads and apex appear to be round on the SOC image (Figure 4.2c). Despite this, all 13 dental implants were identified with the OC and SOC images.

As seen in Figure 4.3, the dental implant in the 45 anatomical region (dental implant on the left) is slightly distorted. This could be due to the patient's dentition or the angle of placement. The accentuated horizontal off-set was an additional tool that enabled the researcher to make a positive identification of the Bicon dental implant.

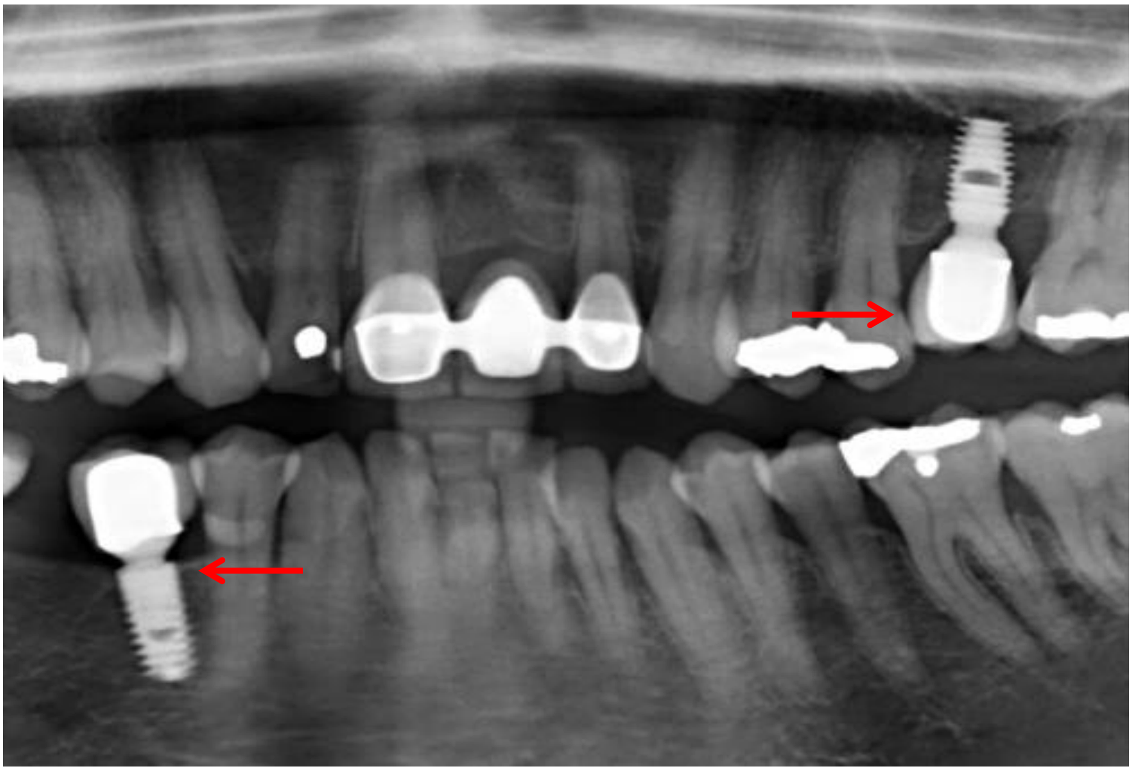


Figure 4.3: Magnified pantomograph (archival records: UWC) presenting with two Bicon dental implants. Both dental implants have crowns already attached (see arrow).

4.2.2 Biomet

For this research study, the Full Osseotite® 3.25mm x 11.5mm dental implant was imaged radiographically. It is a relatively long dental implant. The dental implant presents with a semi-round apex with the thread starting just above the apex, continuing around the body with 12 twirls. The neck of the dental implant is short, smooth and straight with no curves around the edge. No abutment or healing cap was present (Figure 4.4a-c).

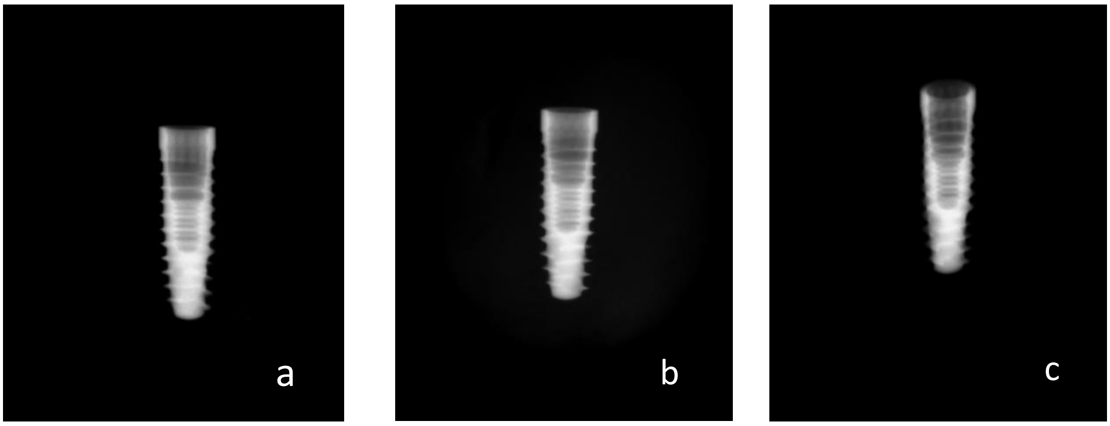


Figure 4.4a-c: Biomet dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

A total of 12 Biomet dental implants were observed on the pantomographs and the researcher identified these using all three morphological characteristics (apex, thread and neck). In addition, all 12 dental implants could be identified from the OC and SOC images as well. As seen on the SOC image (Figure 4.4c), the thread appears to be smooth and not sharp as presented on the ST and OC images. The 12 dental implants identified with the SOC image were identified according to the apex and neck.

The two dental implants in the pantomograph (Figure 4.5) indicate that the apex is semi-round with the thread starting just above the apex. The neck of both dental implants appears to be longer, but it has the smooth surface characteristic that is comparable with the example in the reference instrument. Referring to Figure 4.5 again, the dental implant in the 36 anatomical region (dental implant on the right) presents with eight twirls around the body and the dental implant in the 34 anatomical region (dental implant on the left) presents with seven twirls around the body. This is an indication that both dental implants, compared to the dental implant imaged radiographically for the reference instrument with 11 twirls, are shorter than the example used in the reference instrument. The length of each dental implant used is dependent on the anatomical region of placement.

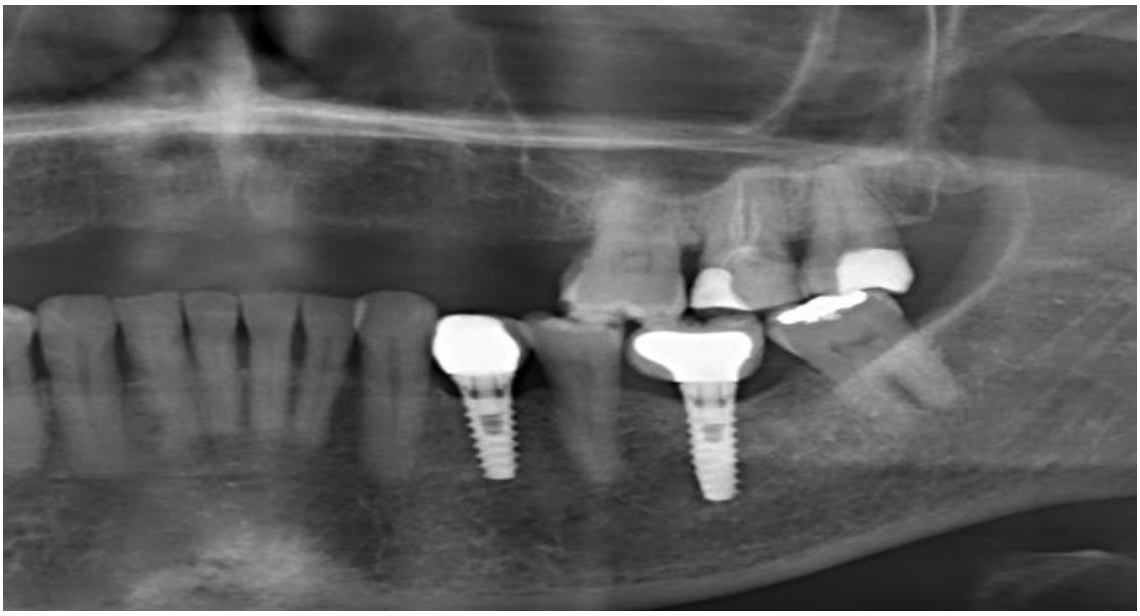


Figure 4.5: Magnified pantomograph (archival records: UWC) presenting with two Biomet dental implants. Both dental implants have crowns already attached.

4.2.3 Champion

For this research study, an example Champion dental implant was imaged radiographically and presented with the abutment already attached to the neck of the dental implant (Figure 4.6).

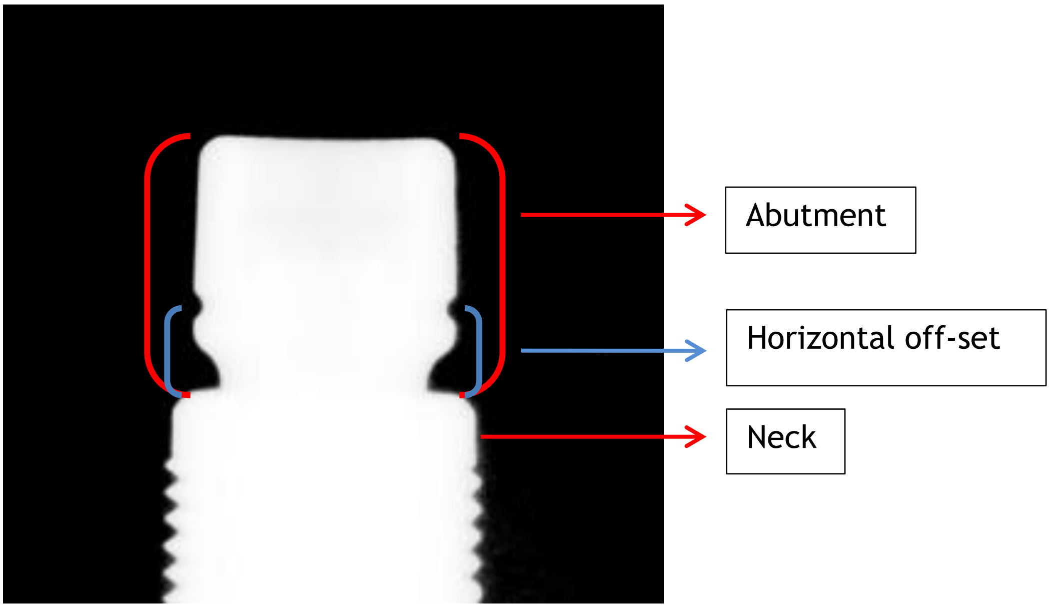


Figure 4.6: Part of the Champion dental implant (ST presentation) indicating the body, neck, horizontal off-set and abutment.

The Champion dental implant presented with a sharp, screw-like apex. The thread is quite prominent with large spaces between each twirl in comparison with the smaller threading at the neck of the dental implant. At the edges of the neck, the dental implant curves inward (this can be clearly seen in Figure 4.6). There are five twirls on the body and six smaller twirls on the neck (Figure 4.7a-c).

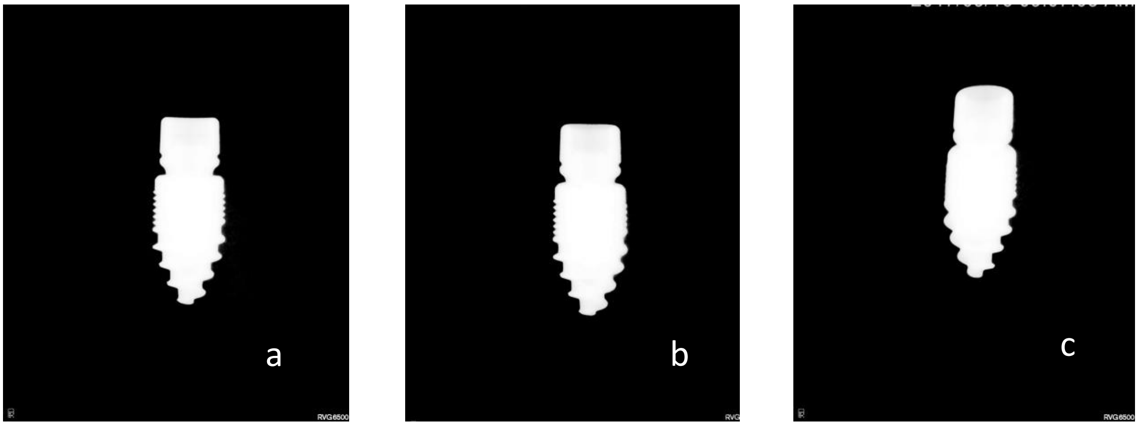


Figure 4.7a-c: Champion dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

A total of seven Champion dental implants were identified on the pantomographs using all three morphological characteristics as seen on the reference instrument. This dental implant type was unique, especially with the sharp, screw-like apex. In addition, all seven dental implants could be identified from the OC and SOC images as well.

In Figure 4.8, distortion can be seen. This feature did not influence the identification process since all six dental implants have the same characteristics.

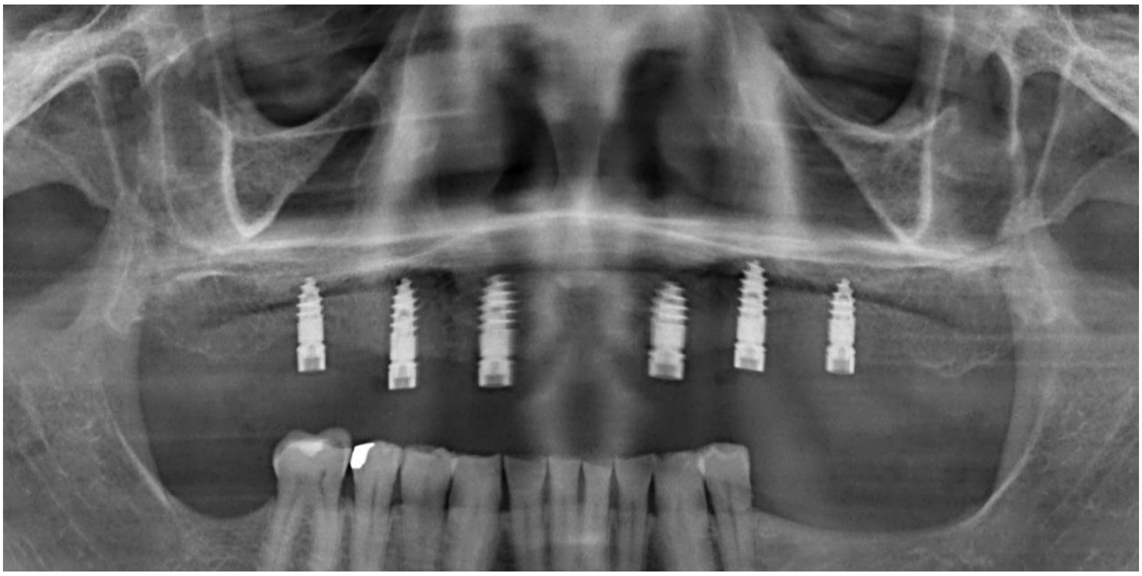


Figure 4.8: Magnified pantomograph (archival records: UWC) presenting with 6 Champion dental implants. All 6 dental implants have abutments already connected.

4.2.4 Megagen

For this research study, the AnyRidge 4mm x 10mm dental implant was imaged radiographically. This dental implant type is relatively new to the field of implantology. The Megagen dental implant is quite similar in morphological characteristics to the Biomet dental implant (as indicated in Figure 4.9). It can be distinguished primarily by the length and edge of the neck. The neck of the Biomet dental implant is slightly longer and rounder at the edge in comparison with the shorter neck of the Megagen, presenting with an inward curve at the edge. The thread of the Megagen is also sharper at the edges, more prominent and the dental implant is wider.

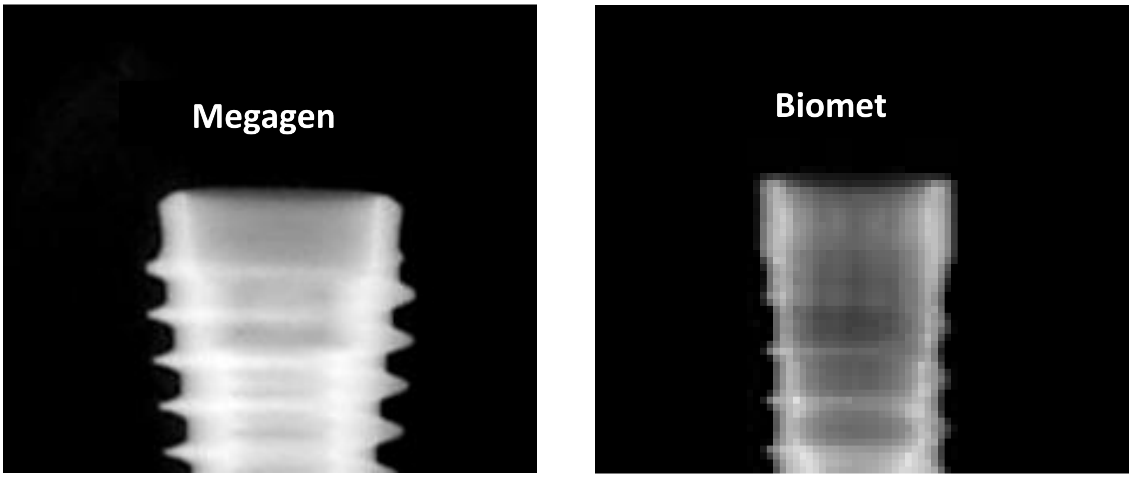


Figure 4.9: Comparison between Megagen and Biomet indicating the neck and part of the body.

The apex of the Megagen dental implant is semi-round with threading starting just above the apex, continuing around the body with nine twirls. The neck of the Megagen dental implant is short and smooth, and presents with an inward curve at the edge. Referring to Figure 4.10c, as seen on the SOC image, the thread appears to be smooth around the edges in contrast to the other two images.

During this research study, no Megagen dental implants were observed in the sample of pantomographs that were selected for inclusion.

Figure 4.10a-c: Megagen dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

4.2.5 MIS

For this research study, the MIS7 internal hex 6mm x 10mm dental implant was imaged radiographically. This dental implant is relatively short, with six twirls around the body and micro-rings around the neck. The apex appears semi-round, with three spiral channels at the apical end of the dental implant separating three threads to support the self-tapping properties. The three final threads continue around the body (Figure 4.11a-c).

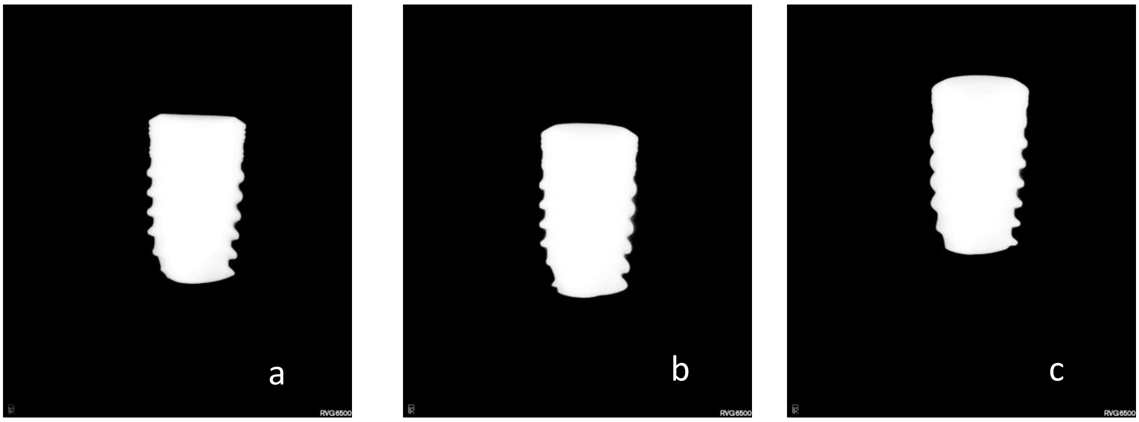


Figure 4.11a-c: MIS7 dental implant example used in the reference instrument:
a - ST, b - OC and c - SOC.

A total of 16 dental implants were identified on the pantomographs as a MIS dental implant type, but not as the MIS7 type seen in the reference instrument. Only five dental implants were identified using the apex and neck. The additional 11 dental implants were identified on the pantomographs using other morphological characteristics, including the abutment (Figure 4.12). Refer to section 4.4 for an explanation on how dental implants that were not part of the reference instrument were identified.

Figure 4.12: Magnified pantomograph (archival records: UWC) presenting with four MIS dental implants in the mandible.

4.2.6 Neodent

For this research study, an example Neodent dental implant was imaged radiographically with a width and length of 4.3mm x 13mm. This dental implant is relatively long, with a screw-like apex and thick threading which appears double with each twirl. The dental implant has ten twirls around the body and four around the neck. The final twirl at the neck allows for an outward curve around the edge (Figure 4.13a).

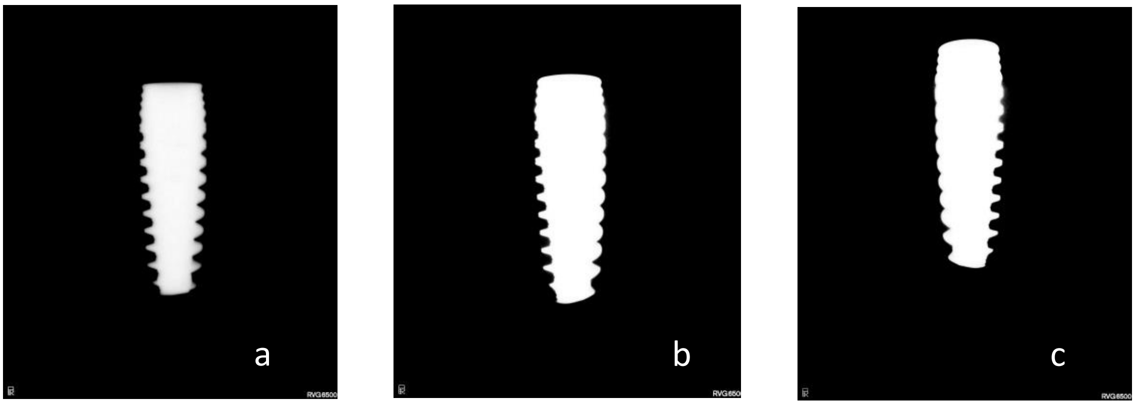


Figure 4.13a-c: Neodent dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

A number of 15 dental implants were identified on the pantomographs as Neodent, using the example in the reference instrument. Of the 15 Neodent dental implants found on pantomographs, 11 were identified using all three morphological characteristics and four were identified according to the thread and neck. It was possible to identify 11 dental implants using the OC image, but only seven dental implants could be identified using the SOC image in the reference instrument.

Owing to the angulation, there is a noticeable difference in the presentation of the thread in both the OC and SOC images which justify the decision to image each dental implant in three different X-ray tube angulations (refer to discussion in section 3.4.2).

In Figure 4.14, distortion can be clearly seen. This did not influence the identification process as all eight dental implants on the pantomographs have the same characteristics. Of the eight dental implants, seven presented with an abutment.

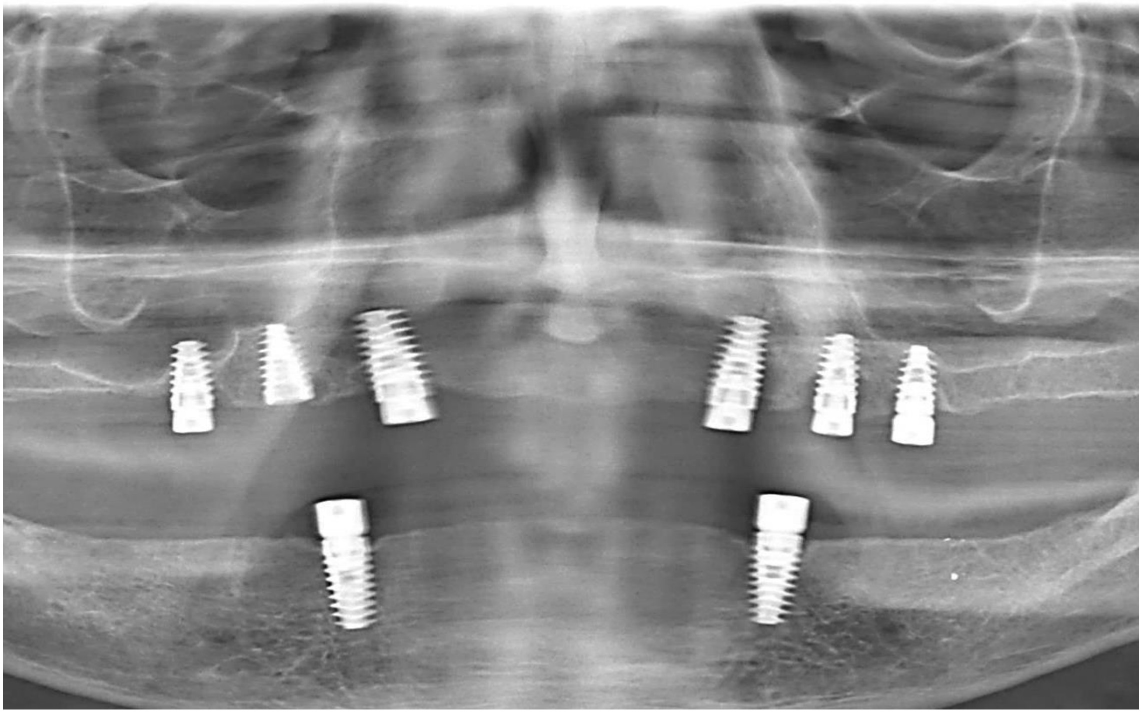


Figure 4.14: Maginified pantomograph (archival records: UWC) presenting with eight Neodent dental implants.

4.2.7 NobelActive®

For this research study, the NobelActive® dental implant was imaged radiographically. The NobelActive® dental implant presented is of shorter length. This dental implant has an expanding tapered body with a double lead design to condense bone gradually. There are six main threads visible on the body that move up vertically on each turn of the implant. The neck is more vertical, in contrast to its tapered body, with three threads surrounding it (Figure 4.15a-c).

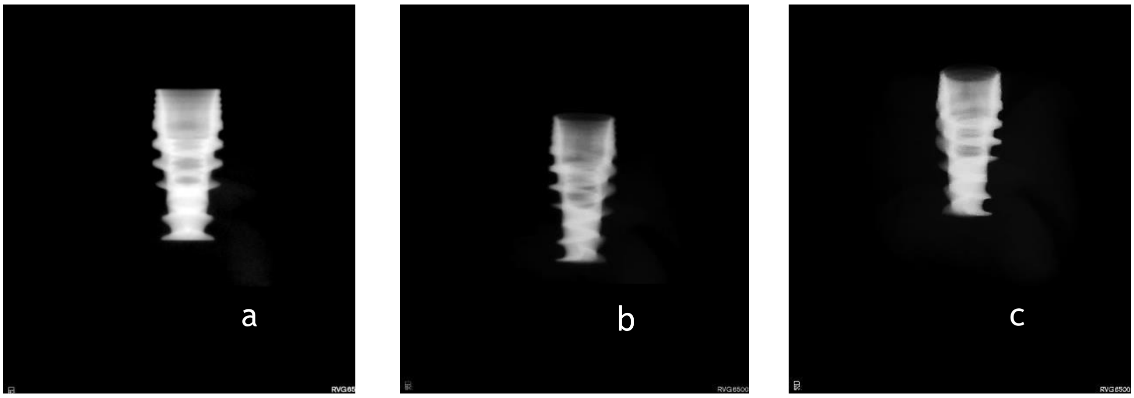


Figure 4.15a-c: NobelActive® dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

The NobelActive® and Bicon dental implants presented with similar apex and thread morphologies (Figure 4.16). Both dental implant types have a flat apex and prominent threading. The primary difference was the shape of the neck with the NobelActive® presenting with a longer neck with twirls. The Bicon dental implant has a short, smooth neck curving inwards, allowing for a horizontal off-set (as mentioned earlier) where the abutment connects to the neck.

Figure 4.16: Comparison between NobelActive® and Bicon indicating the apex and part of the body.

During this research study, 56 dental implants were identified on the pantomographs as NobelActive®. All 56 dental implants were also identified from both the OC and SOC images. All three morphological characteristics as seen in the reference instrument were used to identify the NobelActive® dental implant with the thread being used to identify all 56 dental implants.

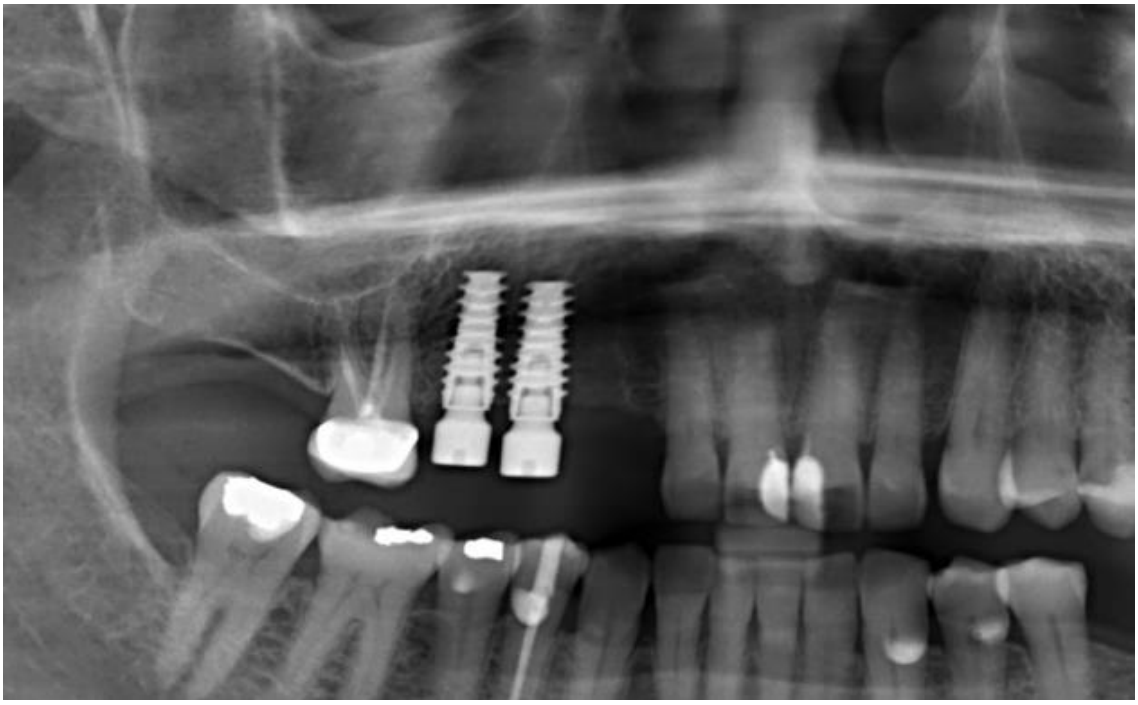


Figure 4.17: Magnified pantomograph (archival records: UWC) presenting with two NobelActive® dental implants.

4.2.8 Southern

The Southern dental implant imaged radiographically for this research study was the IB 3.75mm x 12mm external hex. This dental implant presented with a flat apex, curving slightly outward before threading starts. There are 19 twirls indicating that the thread is very compact and non-prominent. The thread is also sharp at the edge with a small space between each twirl. The neck is short, smooth and curves outward before presenting with a 90-degree inward angle to create an attachment for the abutment (Figure 4.18a). This dental implant has no horizontal off-set.

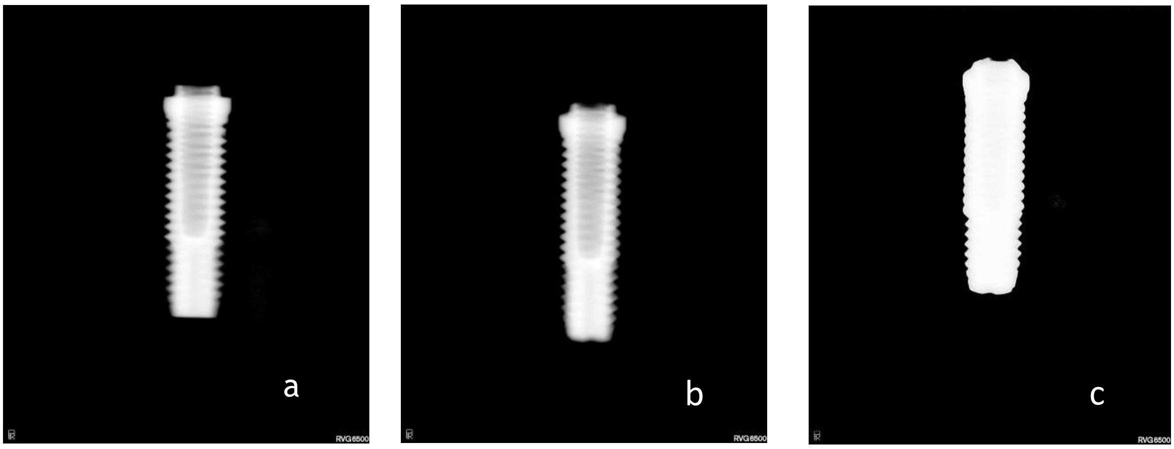


Figure 4.18a-c: Southern dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

A total of 160 Southern dental implants were identified on the pantomographs. Of the 160, only 38 were identified using the example in the reference instrument (Figure 4.19). The additional 122 were identified using variations of the morphological characteristics. The thread of this type of dental implant allowed the correct identification of these implants in 95.6% of the cases. Variations of the morphological characteristics included: round apex, increased width towards the neck, and slightly longer neck. This can be observed in Figure 4.20.

Southern Implants is the only manufacturing company in South Africa, and therefore may explain the high number of dental implants identified on the pantomographs.

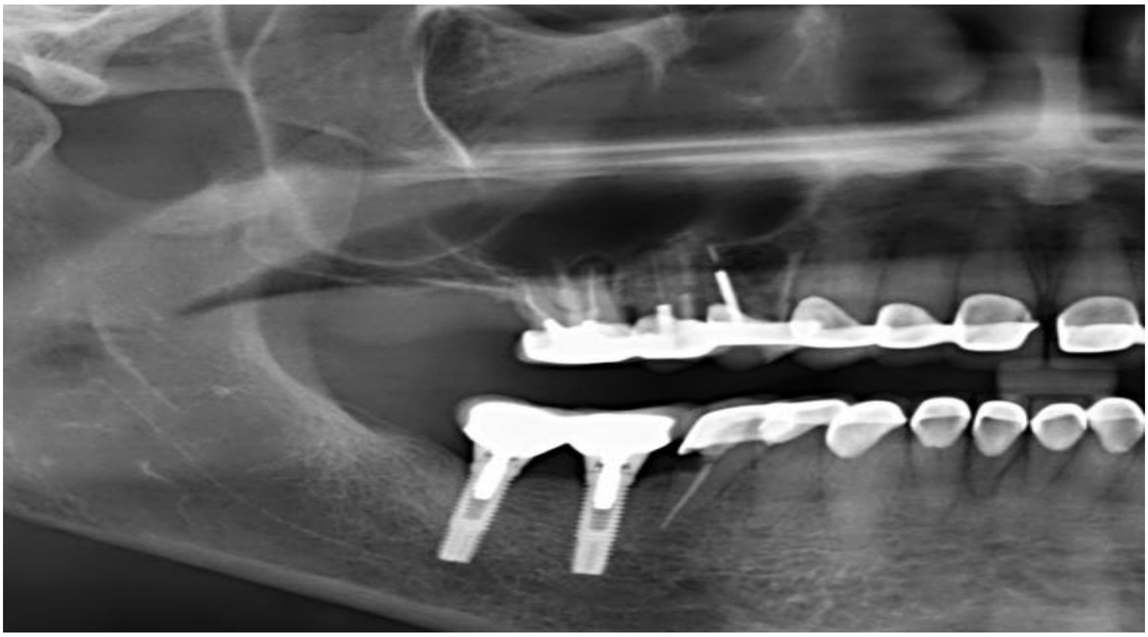


Figure 4.19: Magnified pantomograph (archival records: UWC) presenting with two Southern implants.

As seen in Figure 4.20, the thread is corresponding with the example in the reference instrument however the apex and neck appear to vary with the apex being round and the neck slightly wider and longer.

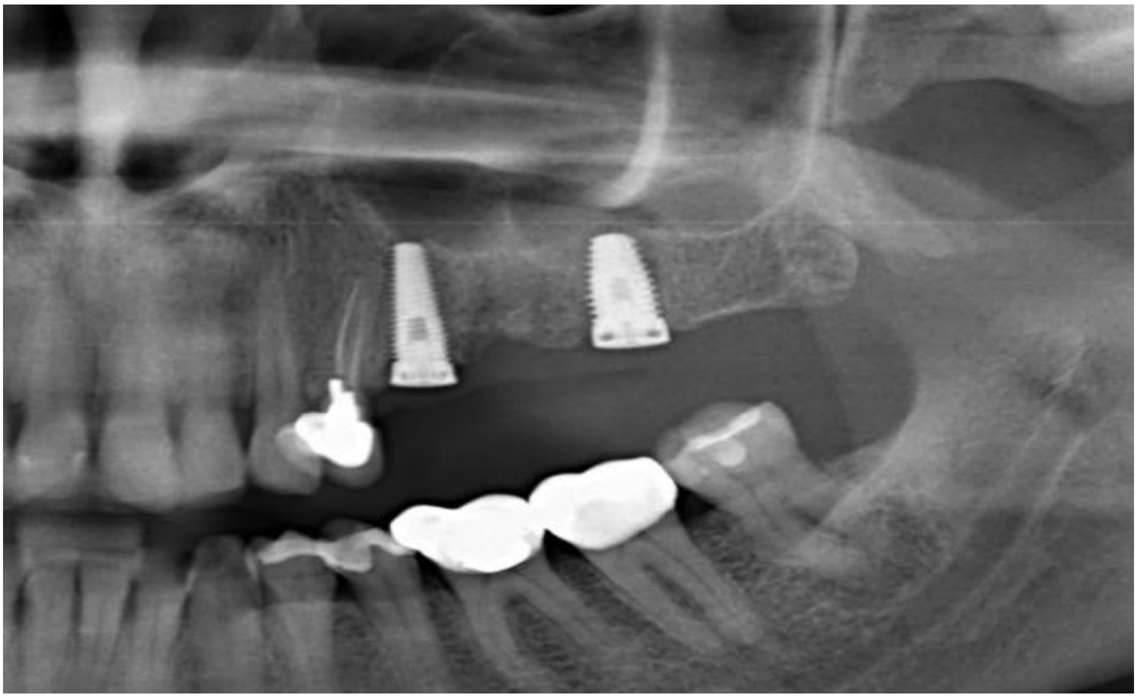


Figure 4.20: Magnified pantomograph (archival records: UWC) presenting with two Southern implants indicating variations of morphological characteristics.

4.2.9 Straumann

For this research study, three different Straumann examples were imaged radiographically as part of the reference instrument. Two examples presented with a crown already attached to the abutment. Straumann dental implants presented with a round apex with threading starting above the apex, allowing the apex to appear slightly longer in comparison with the other types of implants. The number of twirls presented was three, five and six respectively, owing to different lengths. The neck is smooth and relatively long with a prominent outward curve, before a sharp inward angle at the edge of the implant (Figure 4.21a-c).

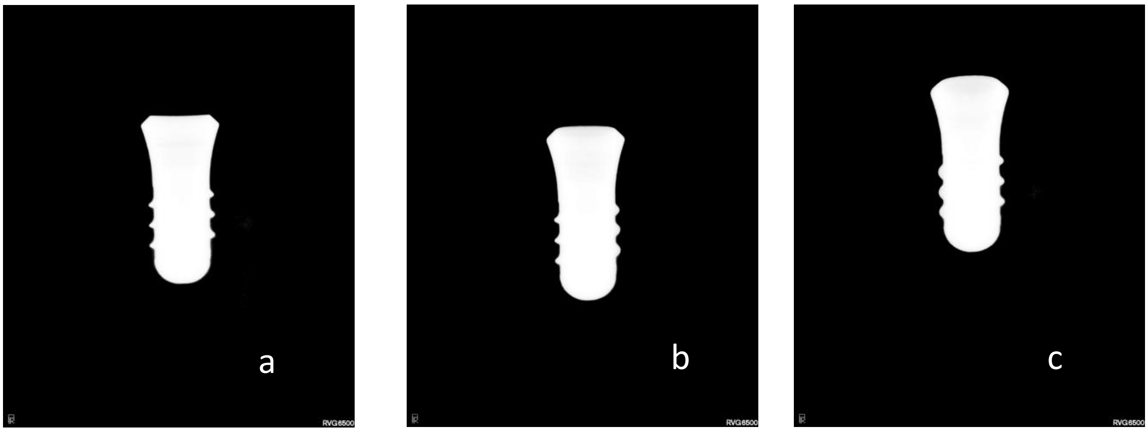


Figure 4.21a-c (example 1): Straumann dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

The Straumann dental implant examples, imaged radiographically, with the crown already attached indicated that it was not possible to visualise the neck of the dental implant, but in cases where the dental implants on the pantomographs presented with crowns, a positive identification was made using the apex and thread of the dental implant (Figure 4.22a,b).

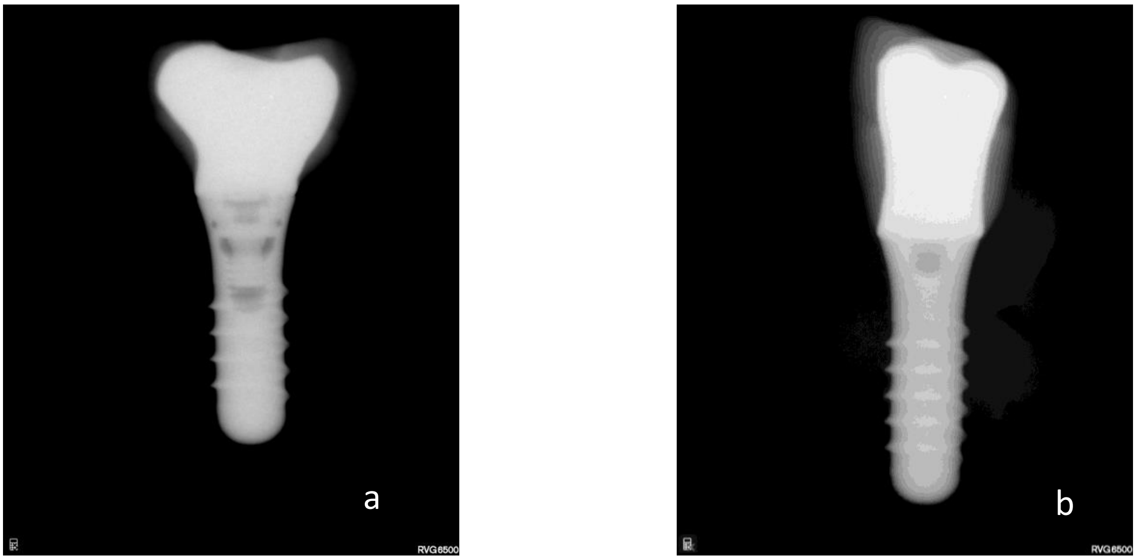


Figure 4.22a,b: Straumann dental implant examples presenting with crowns:
a – example 2, b – example 3.

A total of 49 dental implants were identified as Straumann among the pantomographs reviewed, with all 49 being identified by at least the apex. As mentioned earlier, the apex of the Straumann dental implant is quite long in comparison with the other dental implant types, which assisted in positive identification. Of the 49 Straumann dental implants, only 42 dental implants were identified using the example in the reference instrument. The additional seven Straumann dental implants were identified according to the apex (Figure 4.23).

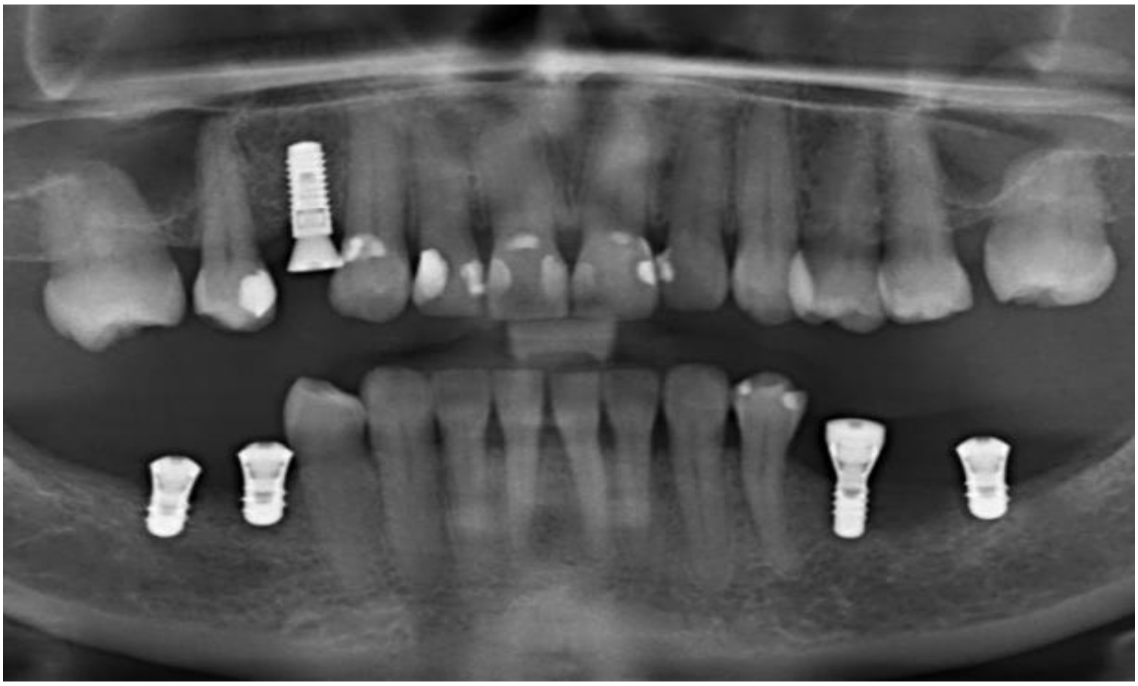


Figure 4.23: Magnified pantomograph (archival records: UWC) presenting with five Straumann dental implants. The dental implant in the maxilla (anatomical placement 14) is from the Regular CrossFit (RC) implant system. The four dental implants in the mandible are from the Regular Neck (RN) implant system used for the reference instrument.

4.2.10 Zimmer

Two different Zimmer dental implant examples were imaged radiographically for this research study: the SwissPlus 4.8mm x 14mm and SwissPlus 4.8mm x 10mm (with healing cap). These dental implants also presented with a round apex, but with threading starting at the apex. These Zimmer dental implants had ten and five sharp, prominent twirls respectively. The neck of both implants is long and smooth, with a prominent outward curve. The dental implant example with the healing cap presented with a round curve at the edge of the neck. This is in contrast to the example without the healing cap presenting with a sharp edge curving inwards. Refer to Figure 4.24 and Figure 4.25 for comparison of Zimmer dental implant examples.

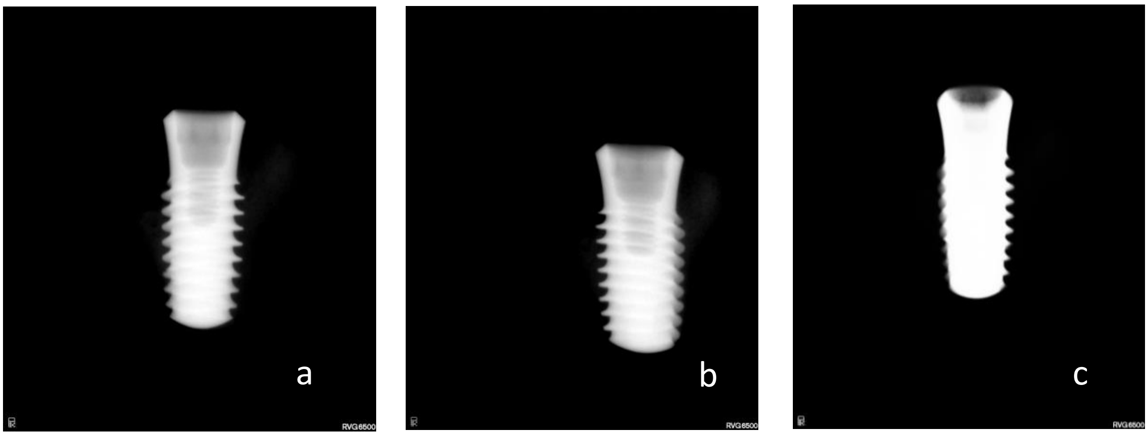


Figure 4.24a-c (example 1): Zimmer SwissPlus 4.8mm x 14mm dental implant example used in the reference instrument: a - ST, b - OC and c - SOC.

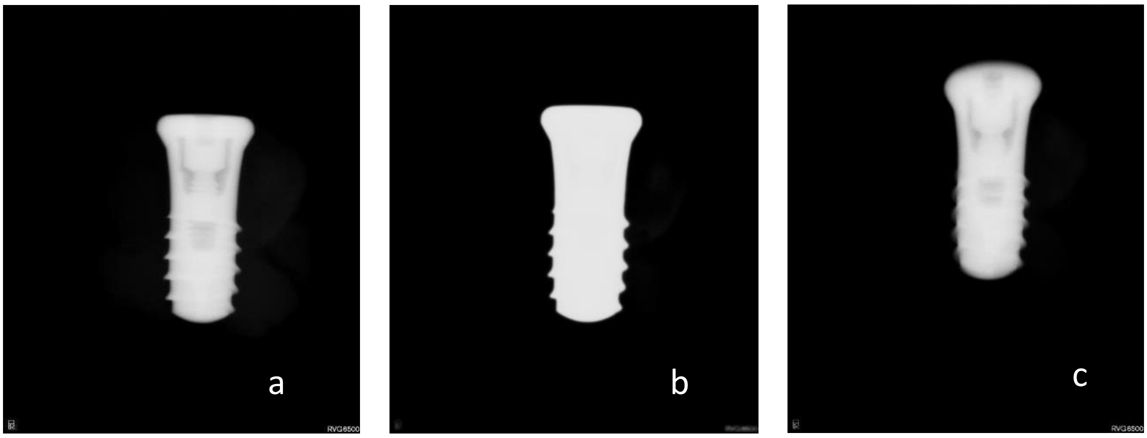


Figure 4.25a-c (example 2): Zimmer SwissPlus 4.8mm x 10mm dental implant example with healing cap used in the reference instrument: a - ST, b - OC and c - SOC.

The Zimmer dental implant has quite similar morphological characteristics compared with that of Straumann. The primary morphology separating the Zimmer from the Straumann was the appearance of the thread and apex (Figure 4.26).

The SwissPlus implant system from Zimmer is a copy of the Straumann 4.1mm x 10mm RN implant. Owing to Straumann's copyright on the dental implant with the 1.8mm neck, Zimmer is not allowed to produce a SwissPlus dental implant with a 1.8mm neck. They produce a dental implant with a 2.8mm neck, but this dental implant cannot be used for any anterior placement.

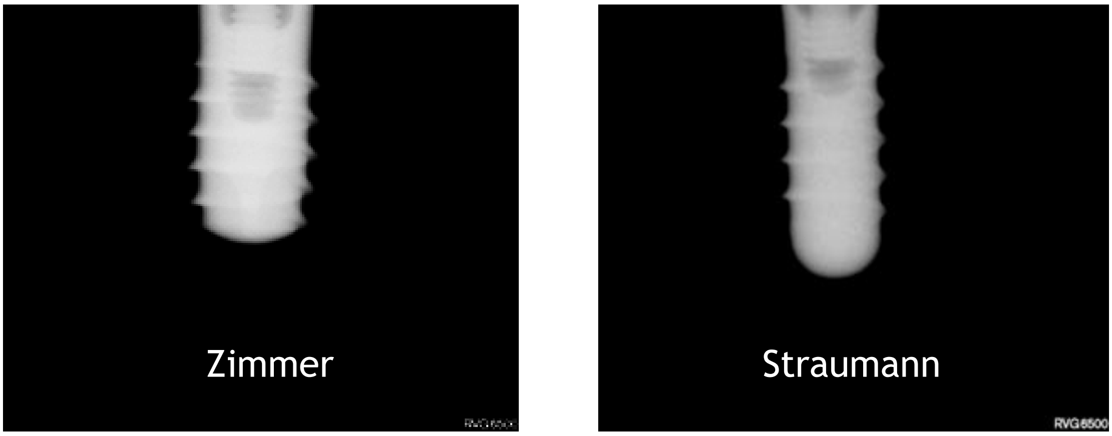


Figure 4.26: Comparison between Zimmer and Straumann, indicating the apex and part of the body.

A total of 22 dental implants were identified on the pantomographs as Zimmer, with 19 identified on the pantomographs as the type used in the reference instrument. All 19 dental implants were identified from the OC image, but only nine could be identified from the SOC image. On the SOC images (Figure 4.24c and Figure 4.25c), severe distortion can be seen which influenced the identification process. The primary morphological characteristics used were the apex and thread, and all 19 dental implants were identified with at least those two characteristics (Figure 4.27).

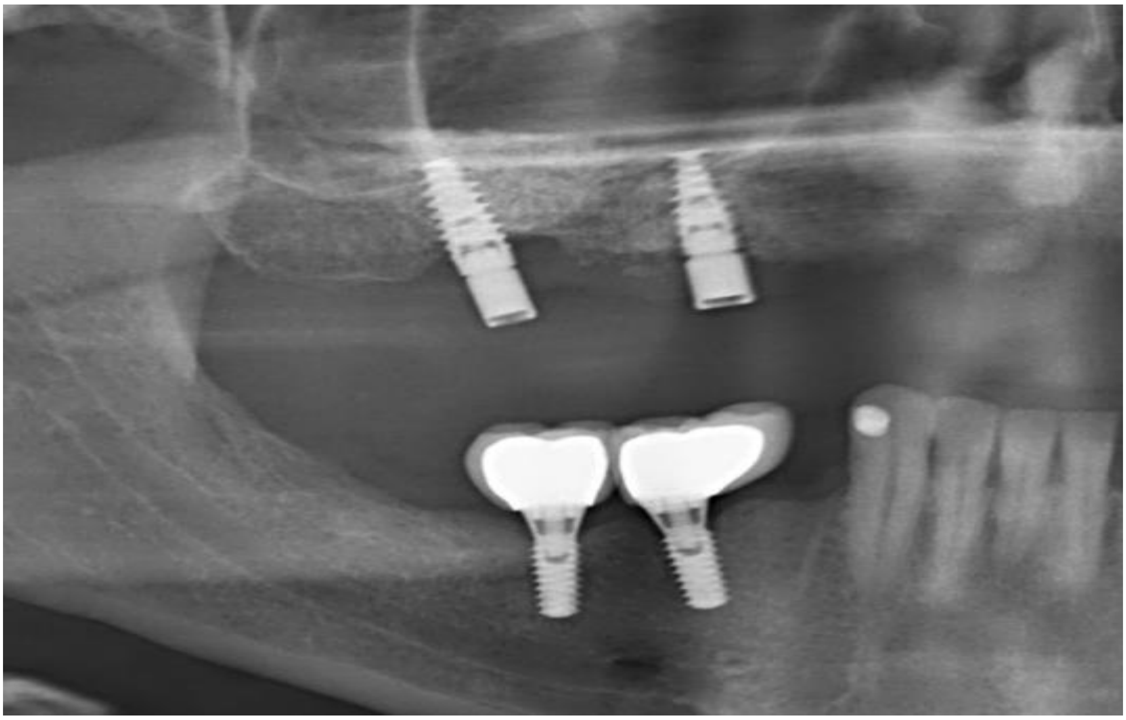


Figure 4.27: Magnified pantomograph (archival records: UWC) presenting with two Zimmer dental implants in the mandible.

4.3 Dental implant type identification on pantomographs

The flow chart below gives a broad overview of the dental implants that could be identified versus those that could not be identified.

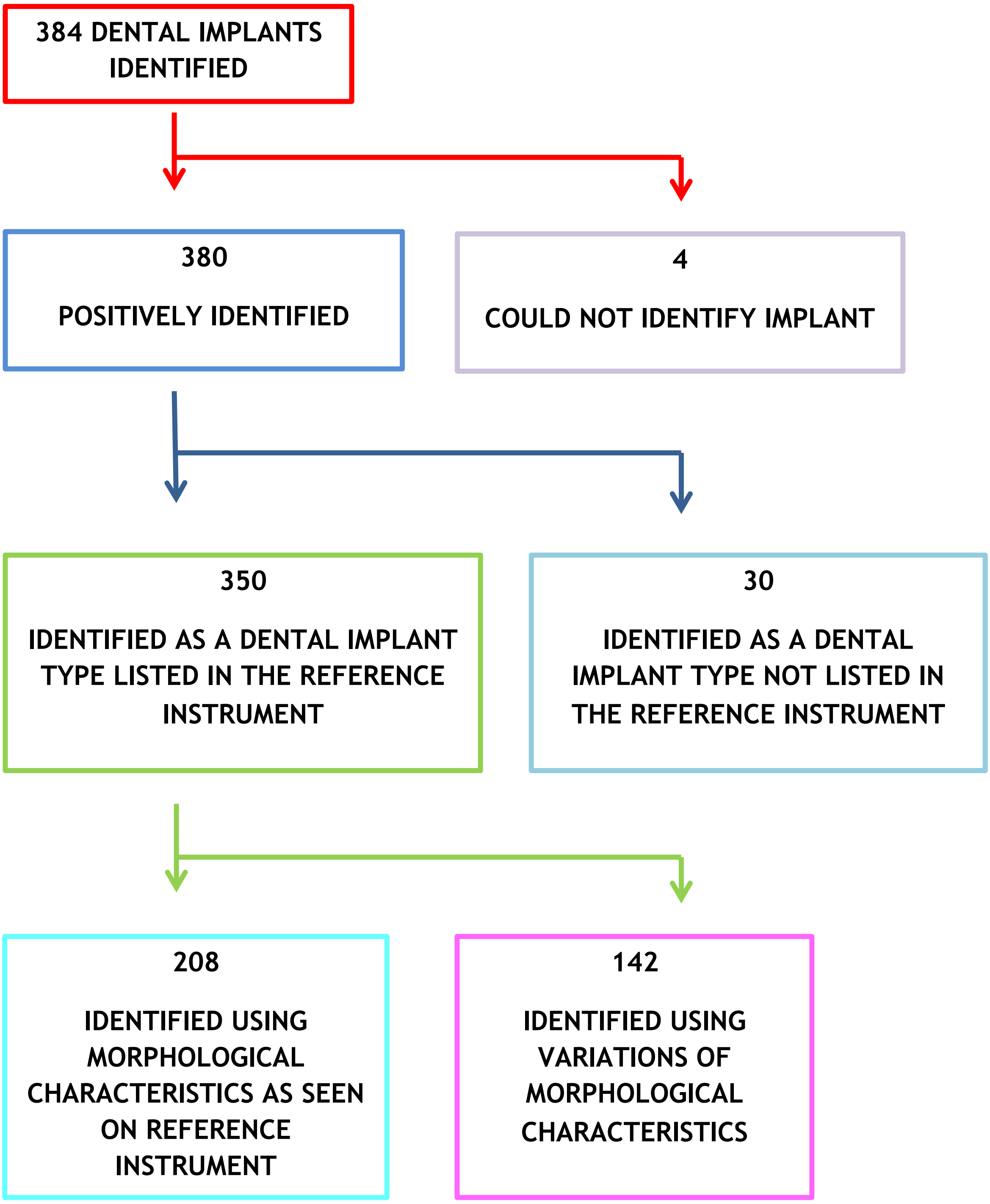


Figure 4.28: Flowchart indicating number of dental implants identified on pantomographs.

As per the flowchart, in the sample of 384 dental implants, 380 dental implants were positively identified on the pantomographs as a dental implant type. Furthermore, of the 380 dental implants, 350 dental implants were identified as a dental implant type used for the reference instrument, but only 208 (54.2%) dental implants from nine dental implant types were identified using corresponding morphological characteristics (apex and/or thread and/or neck) from the ST image (0-degree angulation) used in the reference instrument.

Each of the 208 dental implants was individually compared with the OC image (5-degree angulation) and SOC image (30-degree angulation in opposite direction) as well.

A total of 142 dental implants were identified as a dental implant type listed in the reference instrument using different variations of three morphological characteristics (apex, thread and neck) and in some cases the abutment was used for identification. These variations were observed by the researcher during the viewing of the pantomographs and were confirmed by the periodontist as additional information to aid in the process of positively identifying dental implant types. This aspect is explained in more detail in Chapter Five.

A total of 30 dental implants were identified as dental implant types not listed in the reference instrument and four dental implants could not be identified. As mentioned previously, each dental implant was identified according to corresponding morphological characteristics. The following table (Table 4.1) includes all the dental implant types (15 in total) observed during this research study and the percentage of each morphological characteristic used to make a positive identification of the dental implant type.

Table 4.1: Number of dental implants from each dental implant type identified on pantomographs using the 3 morphological characteristics (apex, thread and neck) as well as other aspects that assisted with identification (i.e. the abutment and horizontal off-set.

Dental implant type	No. of dental implants identified on pantomographs	Apex	Thread	Neck	Other	Implant type not listed in reference instrument
Ankilos	13	-	-	-	-	X
Bicon	13	13	13	13	0	-
Biomet	12	12	12	12	0	-
Calciteck	7	-	-	-	-	X
Champion	7	7	0	6	0	-
Frailit	4	-	-	-	-	X
Megagen	0	-	-	-	-	-
Microvent	4	-	-	-	-	X
MIS	16	5	0	5	11	-
Neodent	15	11	15	15	0	-
NobelActive®	56	49	56	41	0	-
Screwvent	2	-	-	-	-	X
Southern	160	45	153	107	26	-
Straumann	49	49	39	41	0	-
Zimmer	22	20	20	9	3	-
CNII*	4	-	-	-	-	X
Total:	**384**					

*CNII: Could not identify implant

In comparison with the study done by Australian researchers where 51.3% of dental implants were identified (Soukoulis, 2016), a percentage of 54.2% of dental implants was identified during this research study by using only the three morphological characteristics: apex, thread, and neck. After a variation of morphological characteristics was used to analyse the unidentified dental implants, an additional 37% of dental implants was identified as a dental implant type from the reference instrument (Table 4.3).

The following table (Table 4.2) indicates the number of dental implants from each dental implant type identified with corresponding morphological characteristics compared with the example used for the reference instrument.

Table 4.2: Number of dental implants identified from the reference instrument using corresponding morphological characteristics.

Type of dental implant	**No. of implants identified from the reference instrument using corresponding morphological characteristics from the ST image**	**No. of implants identified from the OC image**	**No. of implants identified from the SOC image**
Bicon	13	13	13
Biomet	12	12	2
Champion	7	7	7
Megagen*	0	0	0
MIS	5	5	5
Neodent	15	11	0
NobelActive®	56	56	56
Southern	38	38	38
Straumann	42	42	42
Zimmer	20	20	9
Totals:	**208**	**204**	**172**

*No Megagen dental implants were observed on any of the pantomographs viewed during this research study.

Of the 208 positively identified dental implants from the ST image (used as the point of reference image) in the reference instrument, 204 were identified from the OC image and 172 from the SOC image. The OC and SOC images assisted the researcher in confirming a positive identification of dental implant types. Unfortunately, four and 36 dental implants could not be identified from the OC and SOC images respectively. This indicates that the possibility of not identifying a dental implant type (owing to the unavailability of an ST image) may occur.

4.4 Morphological characteristics

Each dental implant was identified using mainly the following morphological characteristics of the apex, thread and neck. In some cases, dental implants on the pantomographs were identified using other morphological characteristics such as the abutment and horizontal off-set. These dental implants, including the types not listed in the reference instrument, were identified with the assistance of a periodontist. The following table (Table 4.3) indicates the 142 dental implants viewed on the pantomographs identified as dental implant types in the reference instrument using different variations of the morphological characteristics.

Table 4.3: Number and percentage of dental implants identified using variations of morphological characteristics.

Dental implant type	**No. of dental implants identified using variations* of morphological characteristics**	**Percentage identified (out of 384 dental implants)**
Bicon	0	0
Biomet	0	0
Champion	0	0
Megagen	0	0
MIS (subtype)	11	2.9
Neodent	0	0
NobelActive®	0	0
Southern (subtype)	122	31.8
Straumann(subtype)	7	1.8
Zimmer (subtype)	2	0.5
Total	**142**	37%

*Variation of the 3 morphological characteristics may include longer/shorter neck as seen on the reference instrument and/or different shape of apex as seen on the reference instrument.

The following figure (Figure 4.29) is an indication of the number of dental implants identified as a type not listed in the reference instrument. These dental implants were identified by a specialist in the field of implantology.

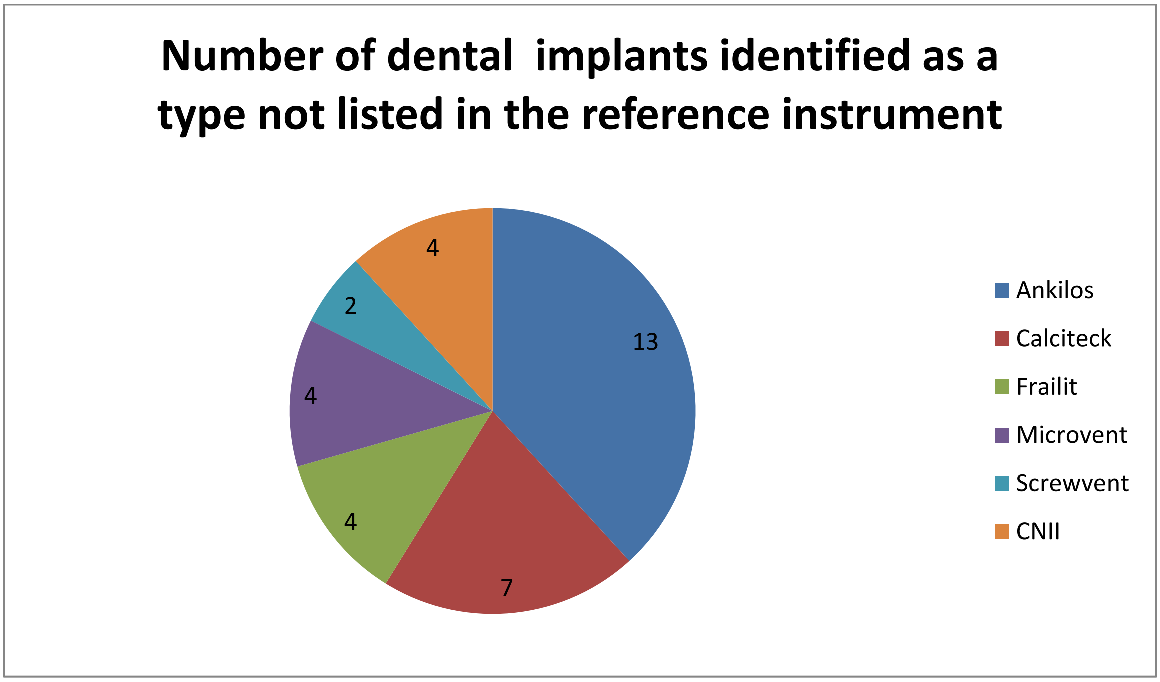


Figure 4.29: Pie chart indicating the number of dental implants identified as a type not listed in the reference instrument.

The next chapter discusses factors that influenced positive identification of dental implants as well as the limitations of the research study.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

One of the main objectives of this research study was to describe the radiographic appearance of dental implants based on the morphological characteristics, specifically the apex, thread and neck of each dental implant type observed. This description was based on the morphology of dental implants and whether they could be positively identified on pantomographs.

The description of the morphological characteristics of the dental implants in Chapter Four allowed the researcher to develop a radiographic dental implant guide for ten commonly used dental implant types, which was one of the main objectives of this research study.

This chapter describes the factors that influenced the identification of dental implants and whether factors such as image quality, radiographic technique and angulation of the dental implants post surgery had an influence on positive identification of dental implants or not. The limitations of this research study are also highlighted.

5.1.1 Factors that influenced positive identification of dental implant types

As mentioned in Chapter Four, a total of 208 dental implants were positively identified as a type used in the reference instrument using corresponding morphological characteristics. The reference instrument allowed for correlation between the morphological characteristics of the dental implants as seen on the pantomographs. During the comparison process, the apex, neck, and thread of each of the ten dental implant types were easily identified following comparisons between the dental implants on the reference instrument and the implants visible on the pantomographs.

A specialist in the field of implantology identified additional morphologies of certain dental implant types which aided the researcher in making a positive identification. In cases where the researcher could not make a positive identification, the specialist indicated to the researcher that in many cases the same type of dental implant will consist of the same morphologies. For example: Southern dental implants have a very compact thread, even though the apex and neck might differ from the example in the reference instrument. The thread of Straumann dental implants starts above the apex, allowing the apex to appear slightly longer in comparison with the other types of implants. This characteristic was used to identify seven other Straumann dental implants not as the type used in the reference instrument.

The specialist also emphasised the importance of the awareness of these variations of morphologies as it would require adding additional information to the radiographic dental implant guide. Five dental implant types were not identified on pantomographs using the reference instrument. These five dental implant types were not listed in the reference instrument and were identified by a specialist in the field of implantology. The reason for the researcher's inability to identify these five dental implant types was attributed to their obsolete use in clinical implantology as confirmed by the specialist.

5.1.2 Tube angulation during dental implant imaging

The ST image was the point of reference and was used to identify all 208 dental implants. Of the 208 positively identified dental implants from the ST image in the reference instrument, 204 were identified from the OC image and 172 from the SOC image (Table 4.3). The OC and SOC images assisted the researcher to confirm a positive identification of dental implant types which validated identification of all these implant types. Unfortunately, four and 36 dental implants could not be identified from the OC and SOC images respectively. This indicates that the possibility of not identifying a dental implant type (due to the unavailability of an ST image) may occur.

In cases where there is distortion of dental implants or where angulation of dental implants may occur owing to placement in the patient's dentition, it might be necessary to use the OC and/or SOC image to assist in making a positive identification of such dental implant types.

5.2 Factors that influenced pantomograph selection

The next section highlights the radiographic technique and patient positioning for pantomographs.

5.2.1 Radiographic image quality

During this research study, a total of 223 pantomographs presented with dental implants. Of the 223 pantomographs, a total of 105 pantomographs presented with 384 dental implants and were regarded as suitable for analysis. A total of 118 were excluded (as discussed in section 4.1). The main reason for excluding the 118 pantomographs was due to suboptimal radiographic quality and radiographic technique errors evident on these pantomographs. The pantomographs with suboptimal image quality in this research study were mainly influenced by distortion over the anatomical region (anterior or posterior) where dental implants were placed.

For pantomographs to be accepted for inclusion the mandible, temporal-mandibular joints, nasal fossae, maxillary sinus, maxilla and zygomatic arches as well as a portion of the cervical spine had to be visible (Bontrager & Lampignano, 2010).

5.2.2 Radiographic technique errors

Radiographic technique errors on pantomographs may be influenced by positioning errors during the radiographic examination. During patient positioning, it is important that the patient is either standing or sitting in an upright position, with the head immobilised, the chin resting in the chin holder and with the patient biting on the radiolucent bite block to provide extra mobility. All artefacts must be removed, including spectacles, earrings and dentures. During the exposure, the patient must place the tongue against the palate to prevent a radiolucent area above the maxillary teeth. Due to the long exposure time, the movement of the machine must be explained to the patient to ensure the patient hold still for the entire exposure. Other technique errors that resulted in exclusion of pantomographs in this research study were due to over- or under-exposed images and inadequate positioning of the patient in the Panorex machine.

Other factors for the exclusion of pantomographs were as follows:

- Patient positioned too far forward or too far back causing the incisors to appear narrowed or widened respectively.
- Patient's head tilted down or up causing the roots of the upper and lower incisors to be out of the focal plane.
- Enlargement or distortion of the mandible or maxilla.
- Non-visibility or cut-off of the symphysis menti (Murray & Whyte, 2002).

5.3 Radiographic dental implant guide

The radiographic dental implant guide developed during this research study, can be used in medical fields such as radiology and dentistry to assist in pattern recognition and morphological characteristic identification of different dental implant types. This guide includes three radiographic images of each dental implant type, acquired at different angles to assist in identification of dental implants that might have been placed at an angle in a patient's dentition. The e-format of this guide (Appendix C) is user friendly and allows the user to switch between dental implant types easily for quick dental implant type identification.

5.4 Limitations

This research study only described the morphological characteristics of one (or in some cases two) dental implants from ten different dental implant types, which was a shortfall. Even though more than 50% of the dental implants could be identified solely from the reference instrument, more dental implant types such as Ankilos and Calciteck and subtypes such as Straumann RC could have been added to enhance the radiographic dental implant guide. Future research studies should involve more dental implant types based on a broader geographical area, unlike this research study that only used dental implant types commonly used in the Western Cape. The modern and improved technology of dental implant manufacturing companies (as mentioned in Chapter Two) has led to an increased variety of dental implant types which necessitates use of more varieties.

In some cases where the dental implant type could not be identified, a specialist in the field was required to make a positive identification. This implies that students in training may be unable to identify outdated and obsolete dental implant types.

Pantomographs (like any other radiographic procedure) are technique sensitive and distortion and suboptimal radiographic quality may occur which may influences the ability to identify dental implants.

Very few publications were found using the morphological characteristics of dental implants for human identification purposes, which influenced contextualising the findings. It is recommended that more studies on this topic be conducted.

5.5 Conclusion

This research study has shown that the morphology of dental implants can be used to differentiate between different dental implant types. Each dental implant type has unique morphological characteristics as well as similarities which enable differentiation between the different dental implant types. It is important to examine all three characteristics - apex, thread, and neck - in order to foster a positive identification.

This research study can be considered successful as the researcher was able to develop a limited radiographic dental implant guide (Appendix B) based on the research steps described in Chapter Three. These steps enabled the researcher to first create a reference instrument (Appendix D) which was achieved by imaging the ten most commonly used dental implant types used by dentists/periodontists in the Western Cape.

This research study succeeded in answering the research question. It was possible to develop a radiographic dental implant guide using commonly used dental implant types in South Africa. During this research study, the reference instrument was compiled by acquiring radiographs of the referenced dental implants at ST, OC and SOC angles. The morphological characteristics of the shape, size and structure of the apex, thread and neck of each dental implant type were identified and used to differentiate between dental implant types; the images of the reference instrument were used and the radiographic dental implant guide was created. The digital version of the guide may be used for the education and training of radiography, dental and medical students to enhance their learning in identifying dental implant types on pantomographs. This radiographic dental implant guide may be useful in the field of forensic dentistry and forensic radiology. This guide can also serve as a user friendly and easy to access guide for identifying different dental implant types. Dental records play an important role in the identification of human remains and this supplementary dental implant guide may support the identification process of unidentified human remains in South Africa.

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APPENDICES

Appendix A: Data collection sheet: Morphological characteristi

Appendix B: Radiographic dental implant guide

Appendix C: E-format of Radiographic Dental Implant Guide

Appendix D: Reference instrument

Appendix E: UWC permission letter

Appendix F: Dr Wolfaardt permission letter

Appendix G: CPUT Ethics permission letter

APPENDIX A

DATA COLLECTION SHEET: Morphological characteristics

This data sheet indicates the morphological characteristic used to identify the specific dental implant type.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
Ankilos	8	Pan027					X	
Ankilos	2	Pan036					X	
Ankilos	2	Pan039					X	
Ankilos	1	Pan055					X	
	13							
Bicon	2	Pan007	X	X	X			
Bicon	4	Pan019	X	X	X			
Bicon	1	Pan055	X	X	X			
Bicon	3	Pan066	X	X	X			
Bicon	1	Pan087	X	X	X			
Bicon	2	Pan092	X	X	X			
	13							
Biomet	2	Pan002	X	X				
Biomet	4	Pan010	X	X				
Biomet	4	Pan014	X	X				
Biomet	2	Pan019	X	X				
	12							

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
Calciteck	3	Pan037					X	
Calciteck	4	Pan054					X	
	7							
Champion	1	Pan057	X	X				
Champion	6	Pan105	X		X			
	7							
CNII	1	Pan016						X
CNII	3	Pan057						X
	4							
Frailit	4	Pan048					X	
	4							
Megagen	0							
	0							
Microvent	4	Pan022					X	
	4							
MIS7	2	Pan006*				X		
MIS7	1	Pan059*				X		
MIS7	1	Pan060*				X		
MIS7	3	Pan067*				X		

*Dental implants identified using variations of morphological characteristics observed by the researcher, or other characteristics to make a positive identification.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
MIS7	4	Pan098*				X		
MIS7	5	Pan103*				X		
	16							
Neodent	4	Pan086		X	X			
Neodent	3	Pan100	X	X	X			
	15							
NobelActive	4	Pan001	X	X				
NobelActive	3	Pan003	X	X				
NobelActive	2	Pan004	X	X	X			
NobelActive	2	Pan012	X	X	X			
NobelActive	4	Pan016	X	X	X			
NobelActive	6	Pan018	X	X	X			
NobelActive	3	Pan019	X	X	X			
NobelActive	4	Pan023	X	X	X			
NobelActive	2	Pan035	X	X				
NobelActive	3	Pan036	X	X				
NobelActive	3	Pan042	X	X	X			
NobelActive	3	Pan044	X	X	X			
NobelActive	1	Pan052	X	X				

*Dental implants identified using variations of morphological characteristics observed by the researcher, or other characteristics to make a positive identification.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
NobelActive	2	Pan071	X	X				
NobelActive	2	Pan079		X	X			
NobelActive	4	Pan080	X	X	X			
NobelActive	3	Pan088	X	X	X			
NobelActive	3	Pan100		X	X			
NobelActive	2	Pan103		X	X			
	56							
Screwvent	2	Pan029					X	
	2							
Southern	1	Pan005*		X	X			
Southern	1	Pan008*		X	X			
Southern	2	Pan011*		X	X			
Southern	10	Pan015*		X	X			
Southern	7	Pan020*		X	X	X		
Southern	5	Pan024	X	X		X		
Southern	7	Pan024*				X		
Southern	4	Pan025*		X	X			
Southern	8	Pan025	X	X				
Southern	4	Pan028	X	X				

*Dental implants identified using variations of morphological characteristics observed by the researcher, or other characteristics to make a positive identification.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
Southern	2	Pan031	X	X				
Southern	6	Pan033*		X	X			
Southern	2	Pan035*		X	X			
Southern	2	Pan040*		X		X		
Southern	1	Pan041*		X	X			
Southern	1	Pan046	X	X		X		
Southern	1	Pan047	X	X		X		
Southern	3	Pan049*		X	X			
Southern	5	Pan050*		X	X			
Southern	2	Pan051	X	X				
Southern	2	Pan058	X	X				
Southern	3	Pan062*		X	X			
Southern	1	Pan063*		X	X			
Southern	3	Pan064	X	X		X		
Southern	3	Pan065*	X	X				
Southern	3	Pan068*		X	X			
Southern	1	Pan069*	X	X				
Southern	6	Pan070*		X	X			
Southern	1	Pan073*	X	X	X			

*Dental implants identified using variations of morphological characteristics observed by the researcher, or other characteristics to make a positive identification.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
Southern	3	Pan074	X	X				
Southern	8	Pan076*		X	X			
Southern	1	Pan077*	X	X				
Southern	4	Pan078*		X	X			
Southern	6	Pan081*		X	X			
Southern	1	Pan082*		X	X			
Southern	10	Pan083*	X	X	X			
Southern	3	Pan084	X	X				
Southern	2	Pan085*		X	X			
Southern	1	Pan089*		X	X			
Southern	6	Pan090*		X	X			
Southern	1	Pan091*		X	X			
Southern	2	Pan092*	X	X	X			
Southern	4	Pan093*	X	X				
Southern	5	Pan094*		X	X			
Southern	1	Pan095	X	X	X			
Southern	2	Pan097*		X	X			
Southern	1	Pan101*		X	X			
Southern	1	Pan102*		X	X			
Southern	1	Pan104*	X	X	X			
	160							

*Dental implants identified using variations of morphological characteristics observed by the researcher, or other characteristics to make a positive identification.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
Straumann	2	Pan017	X		X			
Straumann	1	Pan028	X	X	X			
Straumann	4	Pan030	X	X	X			
Straumann	5	Pan034*	X	X	X			
Straumann	2	Pan043	X	X				
Straumann	1	Pan044	X	X				
Straumann	2	Pan045*	X	X				
Straumann	1	Pan053	X	X	X			
Straumann	2	Pan056	X	X	X			
Straumann	1	Pan061*	X		X			
Straumann	2	Pan072*	X	X	X			
Straumann	2	Pan075	X	X	X			
Straumann	4	Pan076	X	X	X			
Straumann	2	Pan077	X	X				
Straumann	9	Pan080*	X	X	X			
Straumann	4	Pan096*	X		X			
Straumann	4	Pan102	X	X	X			
Straumann	1	Pan103*	X		X			
	49							

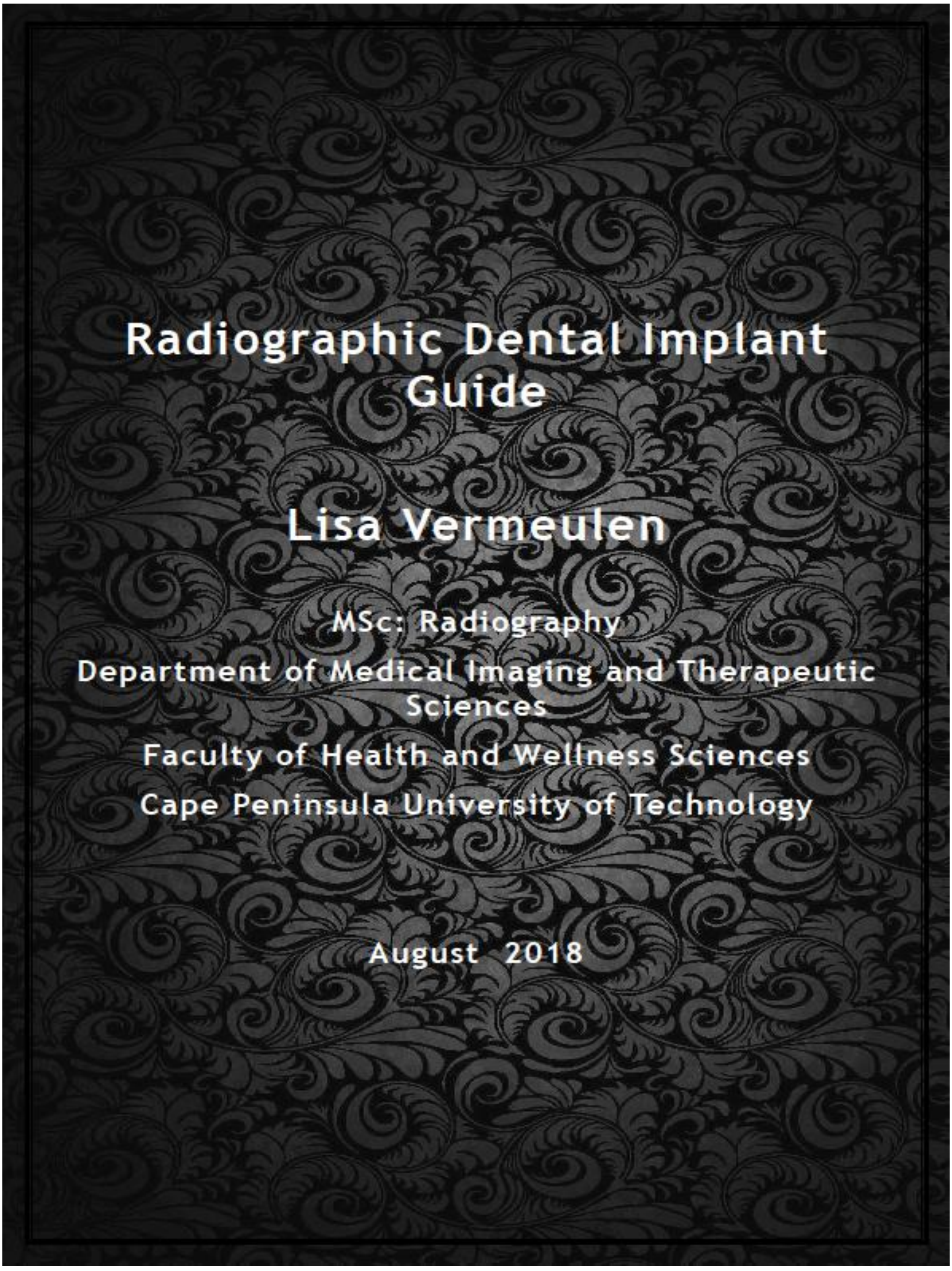
*Dental implants identified using variations of morphological characteristics observed by the researcher, or other characteristics to make a positive identification.

Type of dental implant observed	No. of dental implants present	No. of pantomograph viewed	Morphological characteristic: Apex	Morphological characteristic: Thread	Morphological characteristic: Neck	Other	Implant type not listed	Could not identify implant (CNII)
Zimmer	2	Pan013	X	X	X			
Zimmer	3	Pan016	X	X				
Zimmer	7	Pan021	X	X	X			
Zimmer	6	Pan026	X	X				
Zimmer	1	Pan032	X	X	X			
Zimmer	2	Pan038				X		
Zimmer	1	Pan099	X	X		X		
	22							
Total:	**384**							

APPENDIX B

Radiographic Dental Implant Guide

Double click on the frontpage below to access PDF version.


Radiographic Dental Implant Guide

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August 2018

This radiographic dental implant guide was created as part of an MSc: Radiography research study.

I wish to acknowledge the following contributors:

- Principal supervisor: Mr A Speelman
- Co-supervisor: Mrs V Daries
- External supervisor: Prof. VM Phillips
- Mentor: Dr P Wolfaardt

The research study has proved that the morphology of dental implants can be used to differentiate between different dental implant types. Each dental implant type has unique morphological characteristics as well as similarities which enable differentiation between the different dental implant types. It is important to look at all three characteristics – apex, thread, and neck - in order to obtain a positive identification on a pantomograph.

RADIOGRAPHIC DENTAL IMPLANT GUIDE

The following radiographic dental implant guide describes the morphological characteristics of ten different dental implant types. A dental implant is a titanium screw that is placed within the alveolar bone of the maxilla or mandible to replace a missing tooth or teeth. It supports the dental prosthesis through the biological process called osseointegration and fuses with the surrounding bone in the jaw to secure a permanent fit (Deepalakshmi & Prabhakar, 2014).

Each dental implant in this guide was radiographed in three positions: straight tube (ST) acquired at 0-degree tube angulation, off centre (OC) acquired at a 5-degree angulation and severe off centre (SOC) acquired at a 30-degree angulation in the opposite direction to the OC image. This guide can be used as an aid to identify different dental implant types on pantomographs.

The ten dental implants described in this guide are:

1. Bicon: example dental implant
2. Biomet: Full Osseotite® 3.25mm x 11.5mm
3. Champion: example dental implant
4. Megagen: AnyRidge 4mm x 10mm
5. MIS: MIS7 internal hex 6mm x 10mm
6. Neodent: example dental implant
7. Nobel Biocare: NobelActive®
8. Southern: IB 3.75mm x 12mm
9. Straumann: three example dental implants (the same type, just different lengths)
10. Zimmer: two SwissPlus dental implants (the same type, just different lengths)

Bicon

Bicon dental implant example presents with the abutment and healing cap already attached to the neck of the implant.

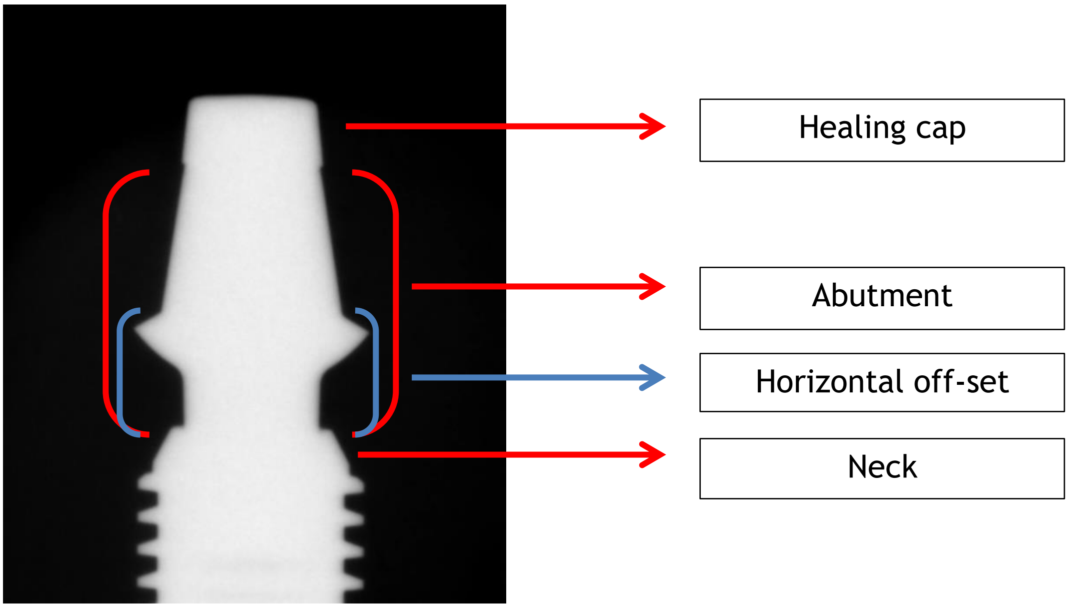


Figure 1: Bicon dental implant indicating part of the body (thread), neck, horizontal off-set, abutment, and healing cap.

This dental implant presents with 13 individual, sharp-edged threads, covering the body of the dental implant in horizontal twirls. The apex of the dental implant is flat and the apical end presents with four spiral channels separating 11 threads towards the neck. The two final threads continue around the body of the implant. The neck of the dental implant is short and smooth with an inward curve allowing for a horizontal off-set where the abutment connects to the neck.

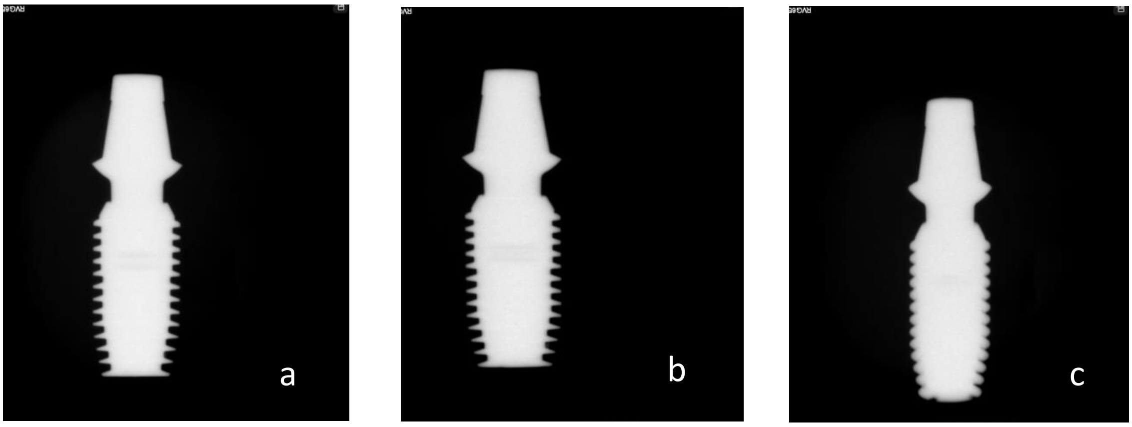


Figure 2: Bicon dental implant example: a - ST, b - OC and c - SOC.

Bicon dental implants are known to be a short dental implant type and have an accentuated horizontal off-set which can also be used as an additional identification morphology (as seen in Figure 1). The threads and apex appear to be round on the SOC image, but corresponding Bicon characteristics can still be observed.

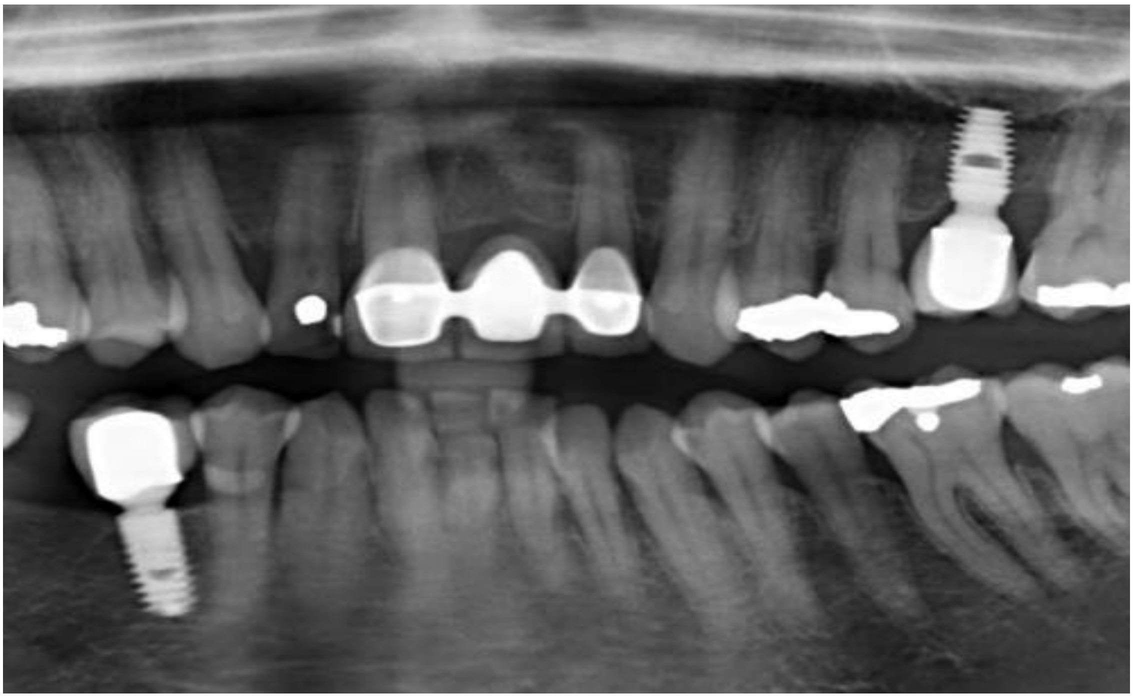


Figure 3: Magnified pantomograph (archival record) presenting with two Bicon dental implants.

As seen on Figure 3, the dental implant in the 45 anatomical region (dental implant on the left) is slightly distorted. This could be due to the patient's dentition or the angle of placement. The accentuated horizontal off-set is an additional characteristic to make a positive identification.

Biomet

A Full Osseotite® 3.25mm x 11.5mm implant presents which is a relatively long dental implant. The dental implant has a semi-round apex with the thread starting just above the apex, continuing around the body with 12 twirls. The neck of the dental implant is short, smooth and straight with no curves around the edge. No abutment or healing cap is present.

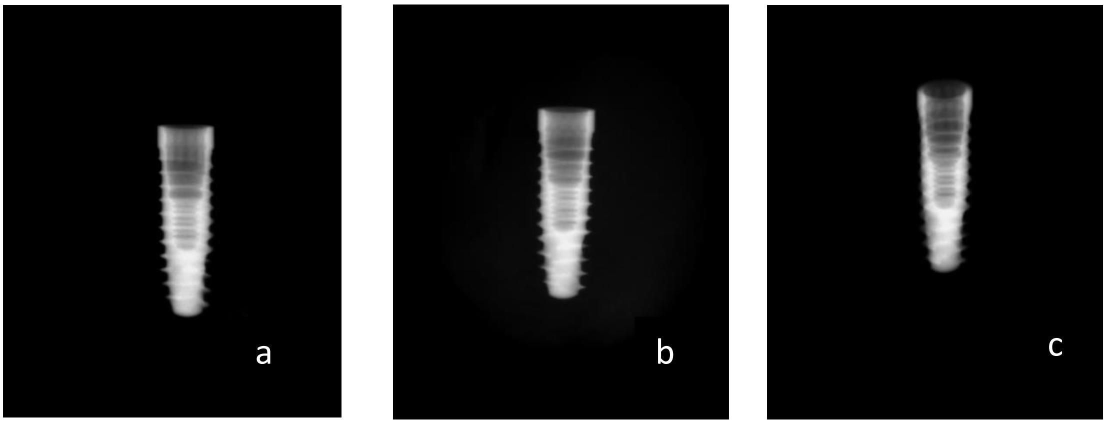


Figure 4: Biomet dental implant example: a - ST, b - OC and c - SOC.

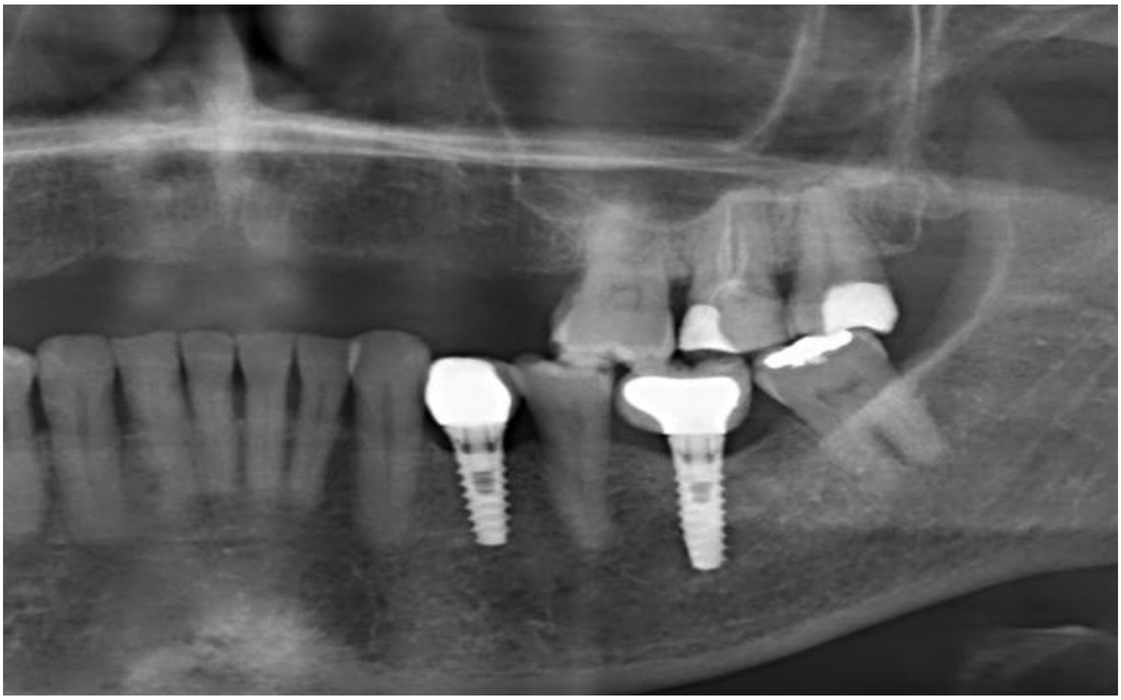


Figure 5: Magnified pantomograph (archival record) presenting with two Biomet dental implants.

Champion

Champion dental implant example with the abutment already attached to the neck of the dental implant.

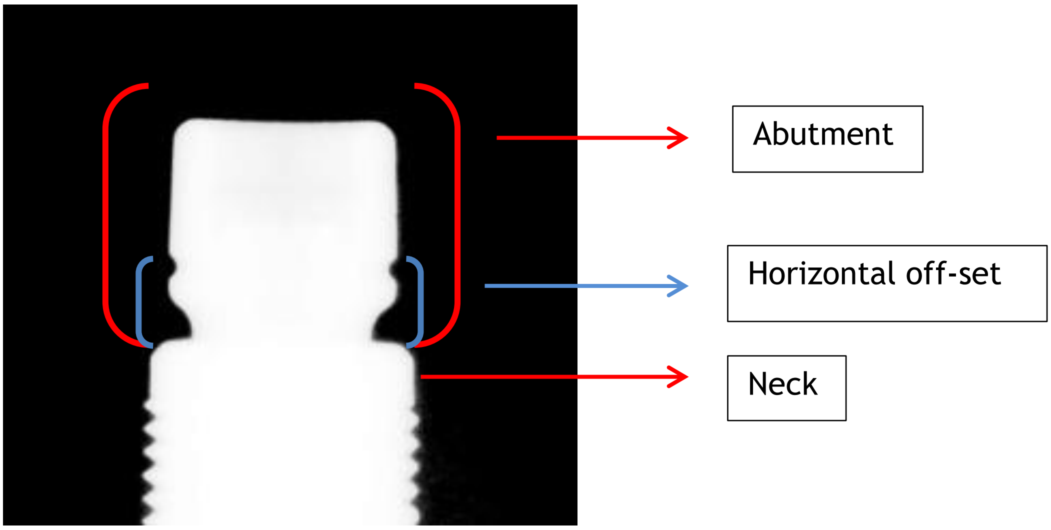


Figure 6: Part of the Champion dental implant indicating the body, neck, horizontal off-set, and abutment.

This dental implant presents with a sharp, screw-like apex. The thread is quite prominent with large spaces between each twirl in comparison with the smaller threading at the neck of the dental implant.

At the edges of the neck, the dental implant curves inward (this can be clearly seen in Figure 6). There are five twirls on the body and six smaller twirls on the neck.

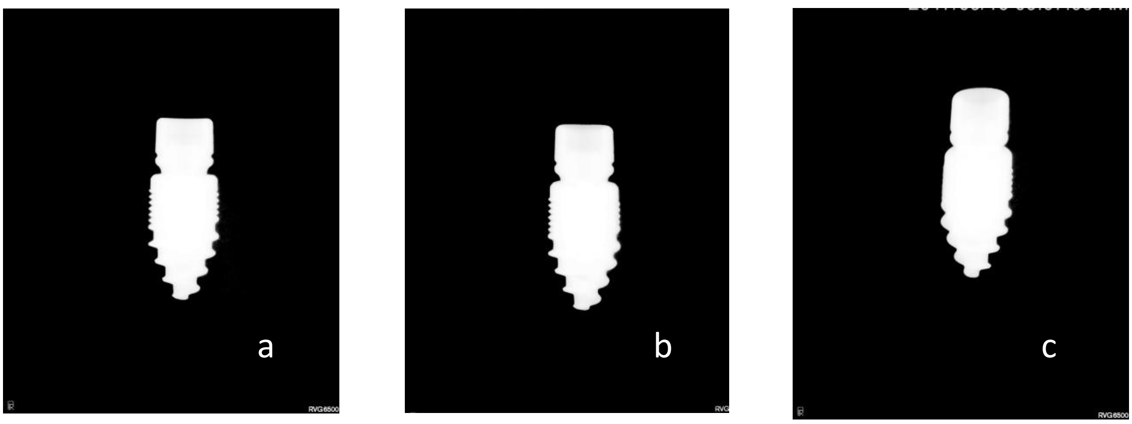


Figure 7: Champion dental implant example: a - ST, b - OC and c - SOC.

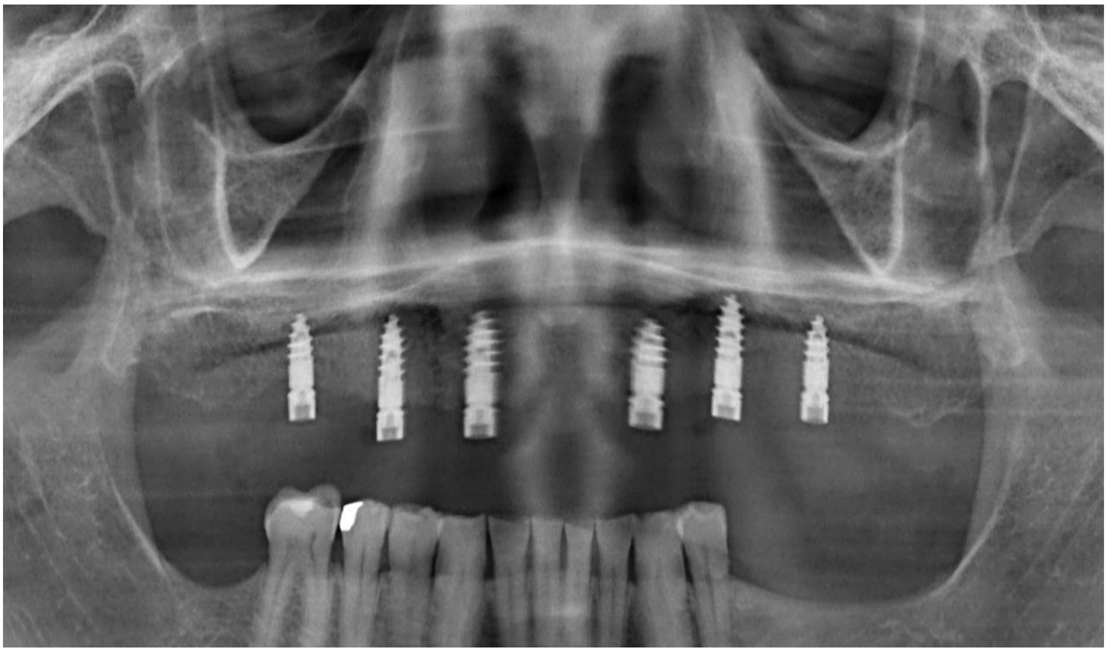


Figure 8: Magnified pantomograph (archival record) presenting with six Champion dental implants. All six dental implants have abutments already connected.

In this image (figure 8), distortion can be seen, but the morphological characteristics can still be identified.

Megagen

The AnyRidge 4mm x 10mm dental implant is presented. This dental implant type is relatively new to the field of implantology and this dental implant is quite similar in morphological characteristics to the Biomet dental implant (as indicated in Figure 9). It can be primarily distinguished by the length and edge of the neck. The neck of the Biomet dental implant is slightly longer and rounder at the edge in comparison with the shorter neck of the Megagen, presenting with an inward curve at the edge. The thread of the Megagen is also sharper at the edges, more prominent and the dental implant is wider.

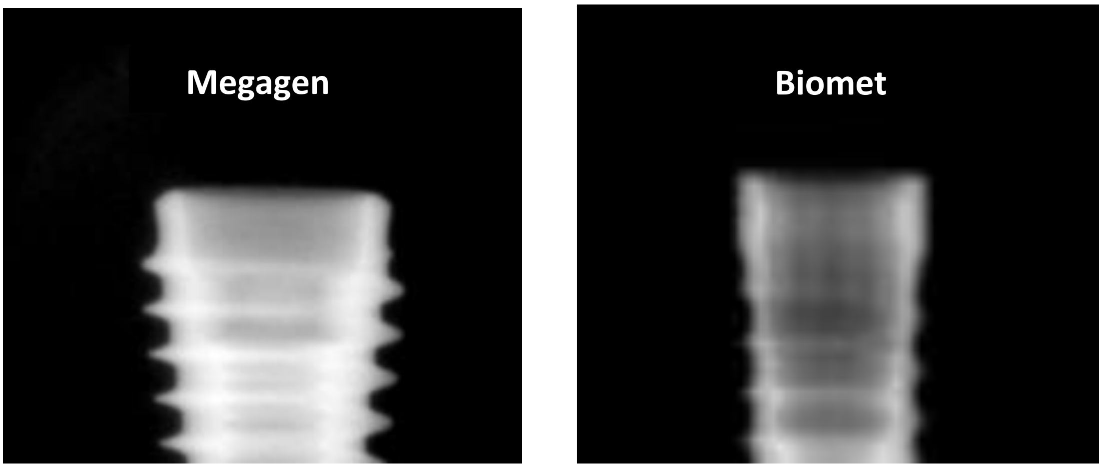


Figure 9: Comparison between Megagen and Biomet, indicating the neck and part of the body.

The apex of the Megagen is semi-round with threading starting just above the apex, continuing around the body with nine twirls. The neck of the dental implant is short, smooth and presents with an inward curve at the edge.

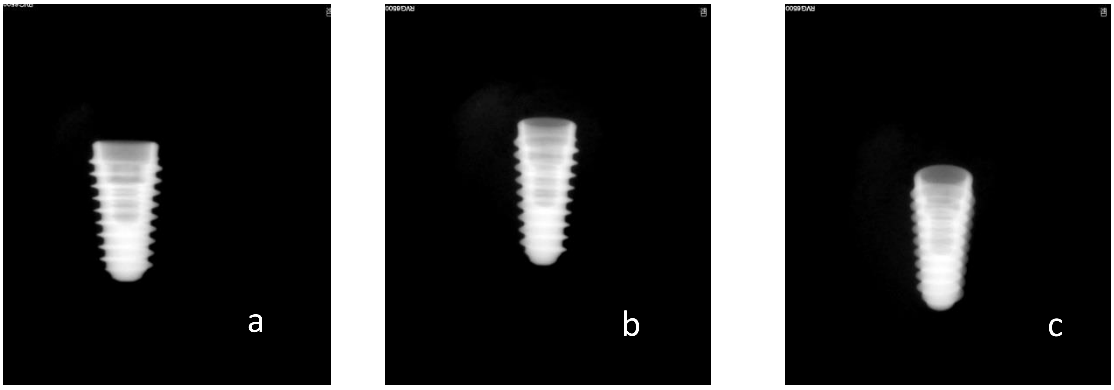


Figure 10: Megagen dental implant example: a - ST, b - OC and c – SOC.

Referring to Figure 10, as seen on the SOC image (c), the thread appears to be smooth around the edges in contrast to the other two images.

MIS

The MIS7 internal hex 6mm x 10mm is presented. This dental implant is relatively short, with six twirls around the body and micro-rings around the neck. The apex appears semi-round with three spiral channels at the apical end of the dental implant separating three threads and to support the self-tapping properties. The three final threads continue around the body.

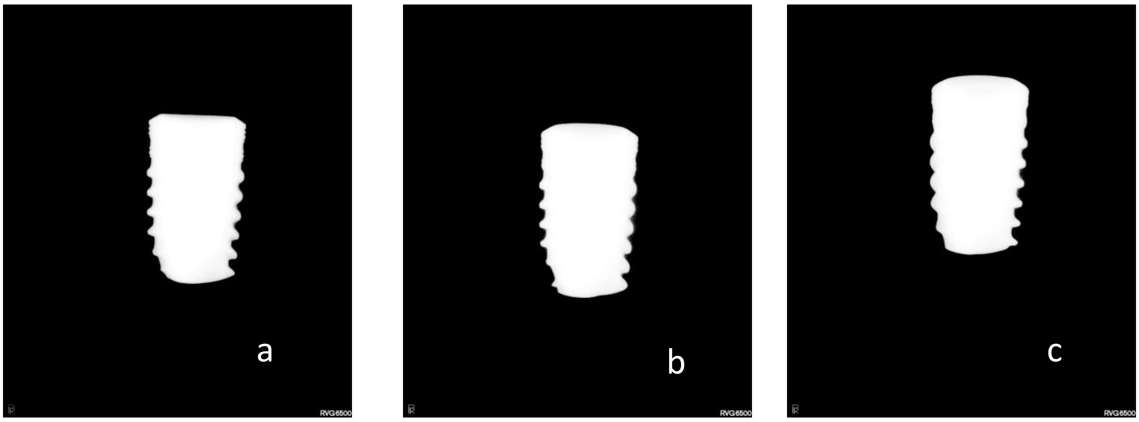
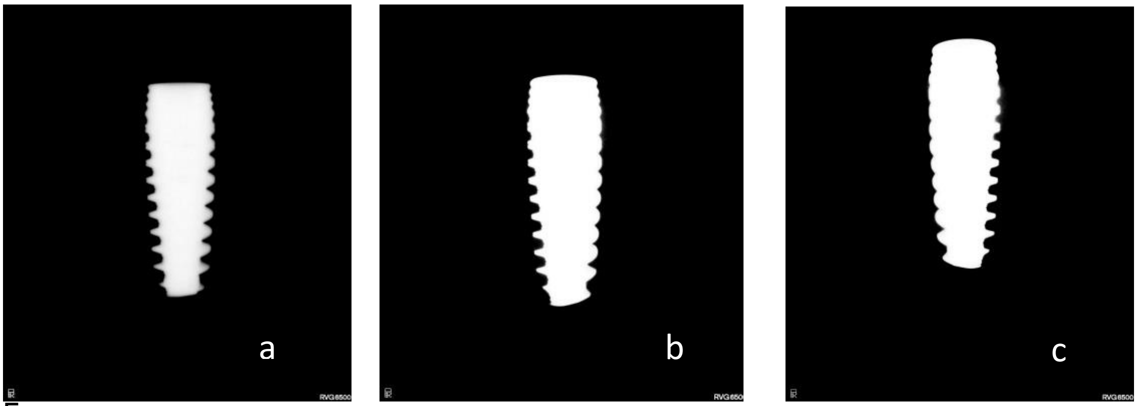


Figure 11: MIS7 dental implant example: a - ST, b - OC and c - SOC.

Figure 12: Magnified pantomograph (archival record) presenting with four MIS dental implants in the mandible.

Neodent

Neodent dental implant example presents with a width and length of 4.3mm x 13mm. This dental implant is relatively long, with a screw-like apex and thick threading which appears double with each twirl. The implant has ten twirls around the body and four around the neck. The final twirl at the neck allows for an outward curve around the edge.



F

Figure 13: Neodent dental implant example: a - ST, b - OC and c - SOC.

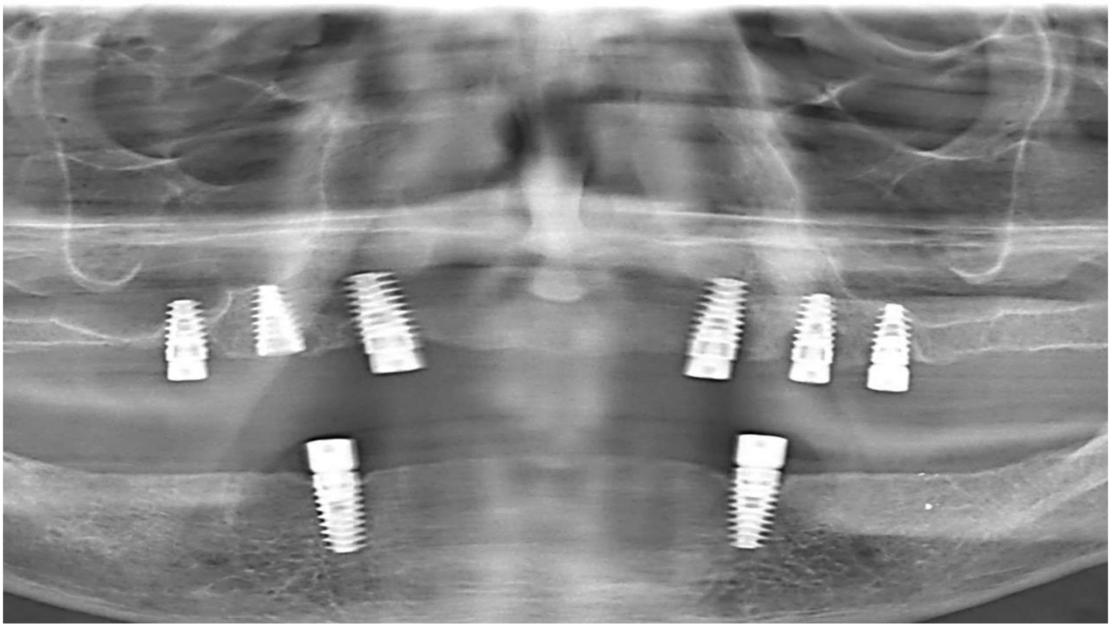


Figure 14: Magnified pantomograph (archival record) presenting with eight Neodent dental implants.

In Figure 14, distortion can be clearly seen.

NobelActive®

The NobelActive® dental implant presented is of shorter length. This dental implant has an expanding tapered body with a double lead design to condense bone gradually. There are six main threads visible on the body that move up vertically on each turn of the implant. The neck is more vertical, in contrast to its tapered body, with three threads surrounding it.

The NobelActive® and Bicon dental implant present with similar apex and thread morphologies (refer to Figure 15). Both dental implant types have a flat apex and prominent threading. The prominent threading allows for more stability when placed in soft bone.

The primary difference was the shape of the neck with the NobelActive® presenting with a longer neck with twirls. The Bicon dental implant has a short, smooth neck curving inwards, allowing for a horizontal off-set where the abutment connects to the neck (as seen in Figure 1).

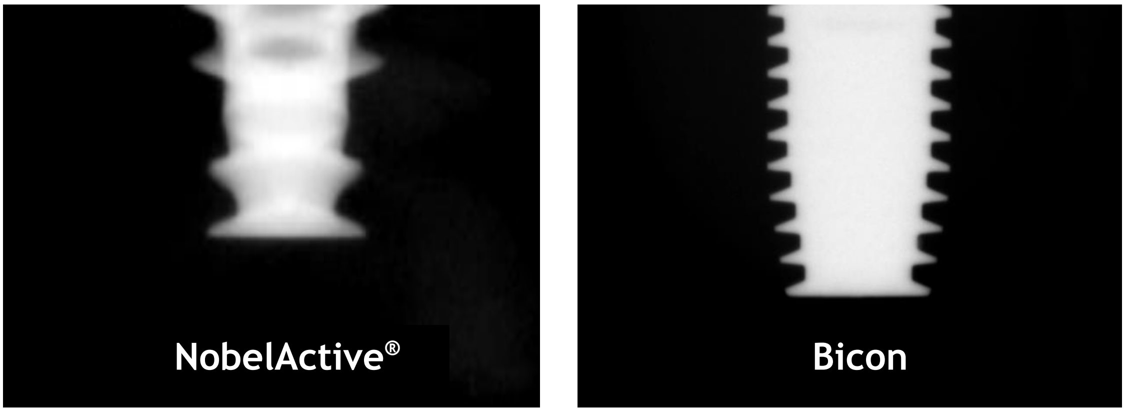


Figure 15: Comparison between NobelActive® and Bicon indicating the apex and part of the body.

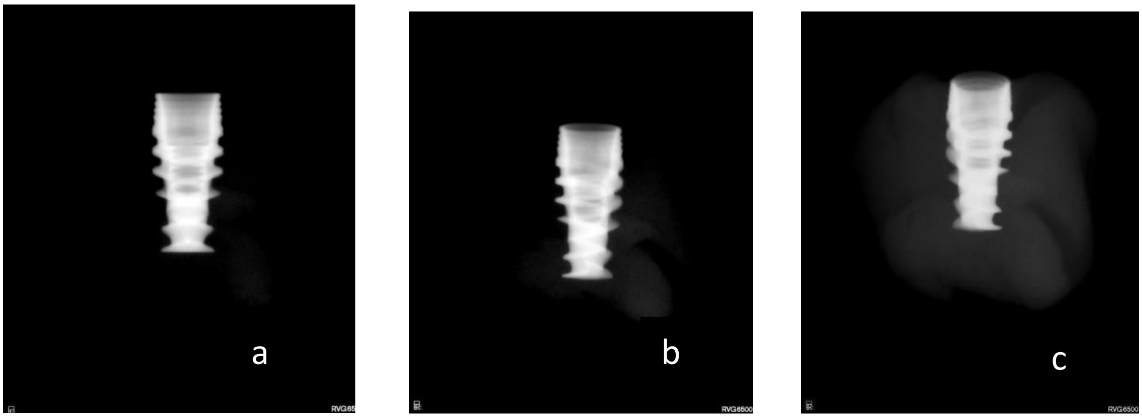


Figure 16: NobelActive® dental implant example: a - ST, b - OC and c - SOC.

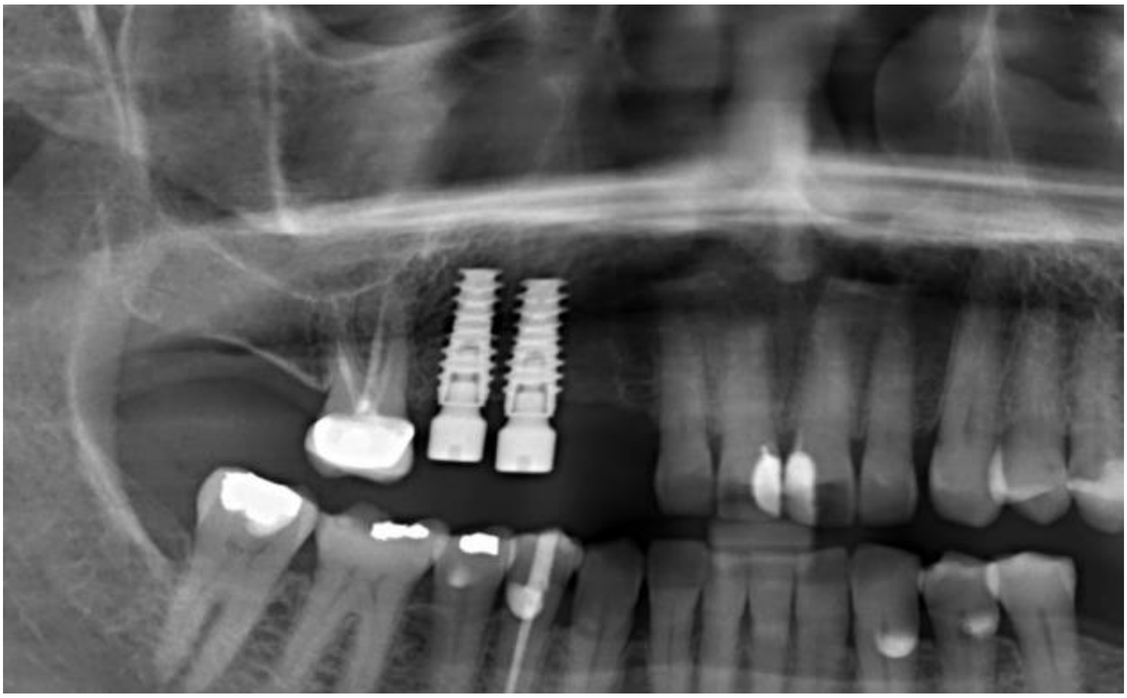


Figure 17: Magnified pantomograph (archival record) presenting with two NobelActive® dental implants.

Southern

The Southern dental implant presented is the IB 3.75mm x 12mm external hex. This dental implant presents with a flat apex, curving slightly outward before threading starts. There are 19 twirls indicating that the thread is very compact and non-prominent. The thread is also sharp at the edge with a small space between each twirl. The neck is short, smooth and curves outward before presenting with a 90-degree inward angle to create an attachment for the abutment. This dental implant has no horizontal off-set and is therefore a bone-level implant.

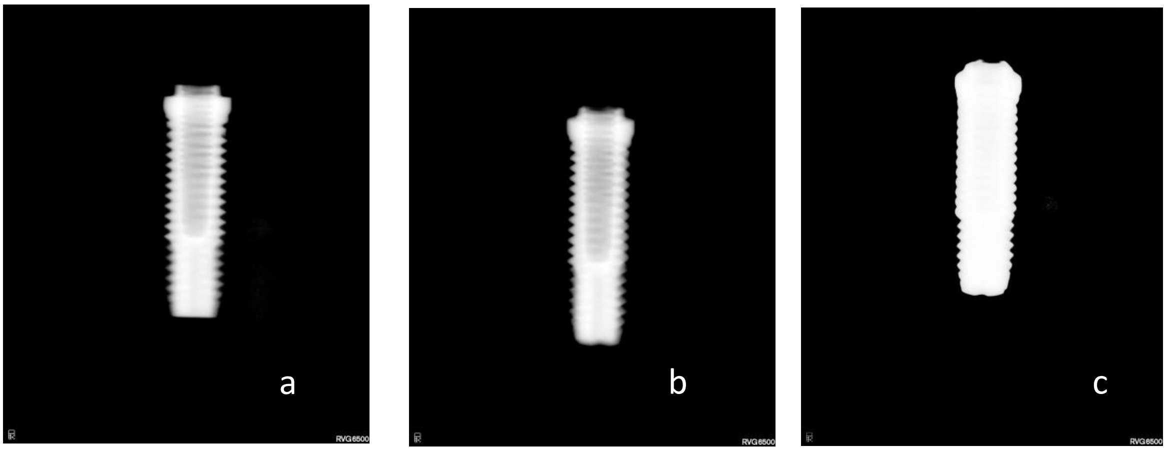


Figure 18: Southern dental implant example: a - ST, b - OC and c - SOC.

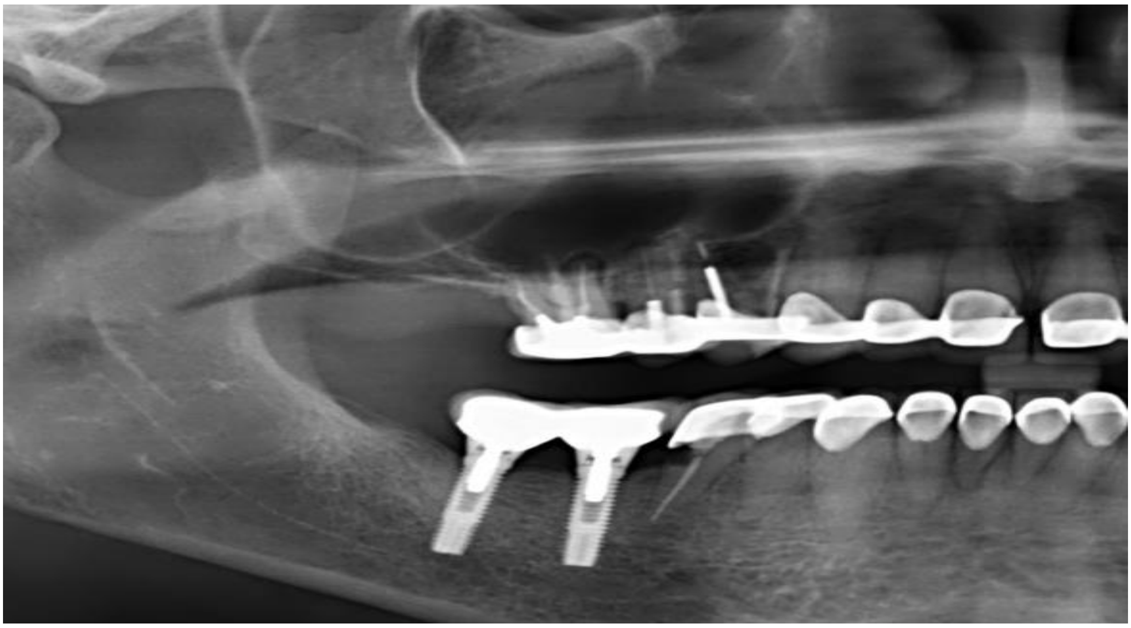


Figure 19: Magnified pantomograph (archival record) presenting with two Southern implants.

Variations of the morphological characteristics of a Southern dental implant may include: round apex, increased width towards the neck and slightly longer neck. As seen in Figure 20, the thread corresponds with the example in Figure 19. However, the apex and neck appear to vary with the apex being round and the neck slightly wider and longer.

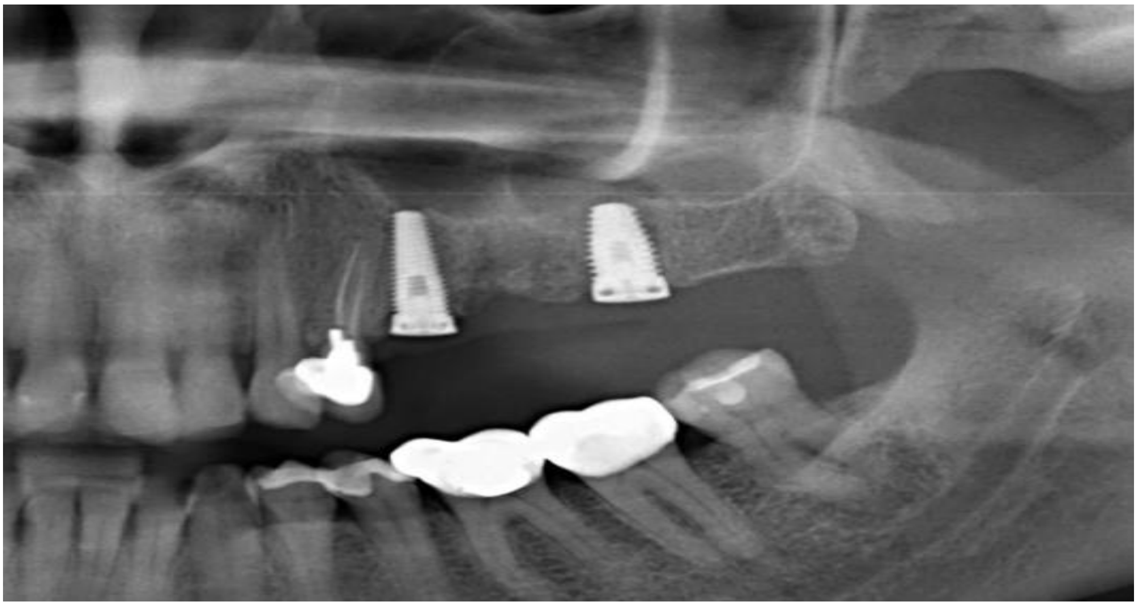


Figure 20: Magnified pantomograph (archival record) presenting with two Southern implants indicating variations of morphological characteristics.

Straumann

Three different Straumann sample dental implants are used in this guide. Two examples present with a crown already attached to the abutment. These dental implants present with a round apex with threading starting above the apex, allowing the apex to appear slightly longer in comparison with the other types of implants. The number of twirls presented is three, five and six, owing to different lengths. The neck is smooth and relatively long, with a prominent outward curve, before a sharp inward angle at the edge of the implant. This is known as a tissue-level implant with two variations: 1.8mm and 2.8mm neck.

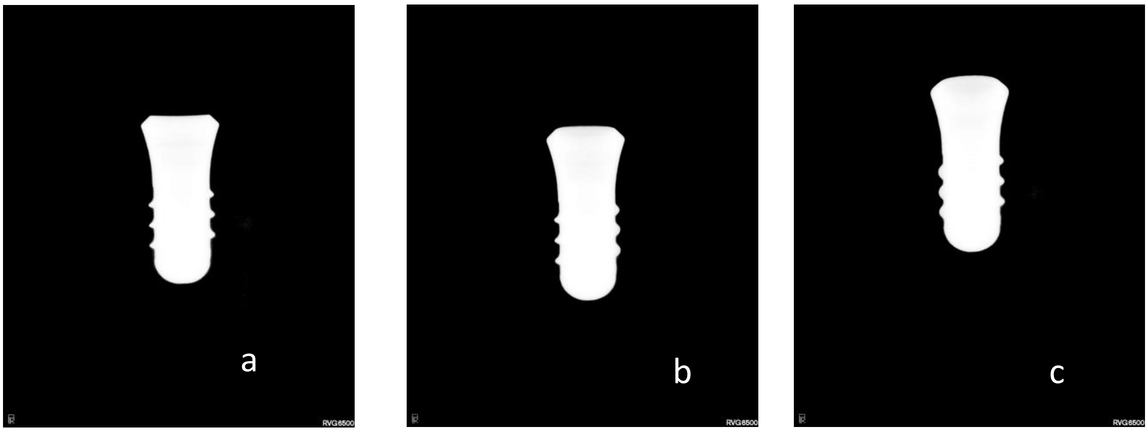


Figure 21: Straumann dental implant example: a - ST, b - OC and c - SOC.

The dental implant examples with the crown already attached are included for variety. It is not possible to visualise the neck of the dental implant, but in cases where the dental implants on the pantomographs presents with crowns, a positive identification can be made using the apex and thread of the dental implant.

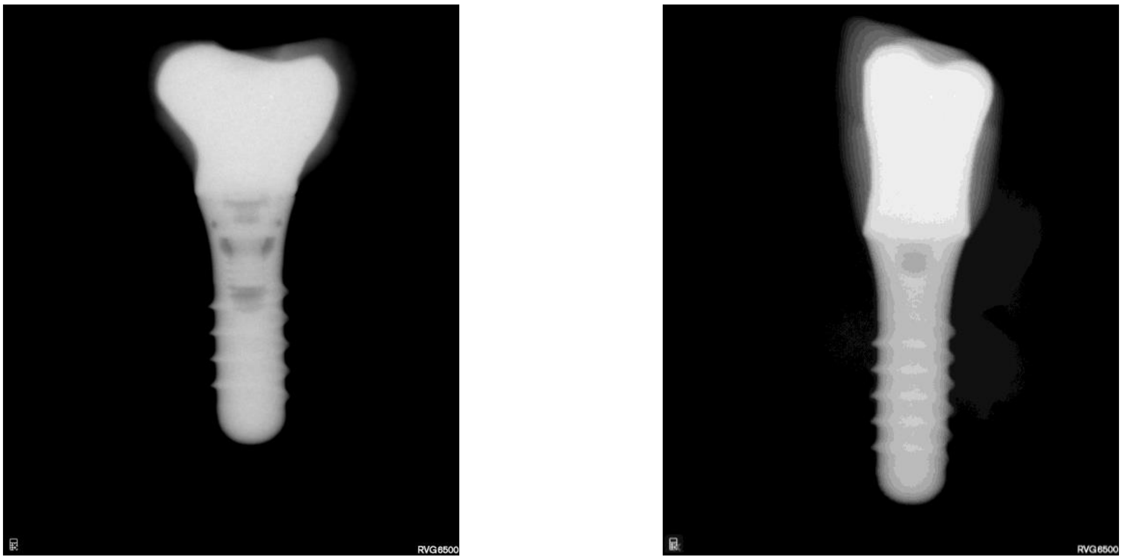


Figure 22: Straumann dental implant examples presenting with crowns.

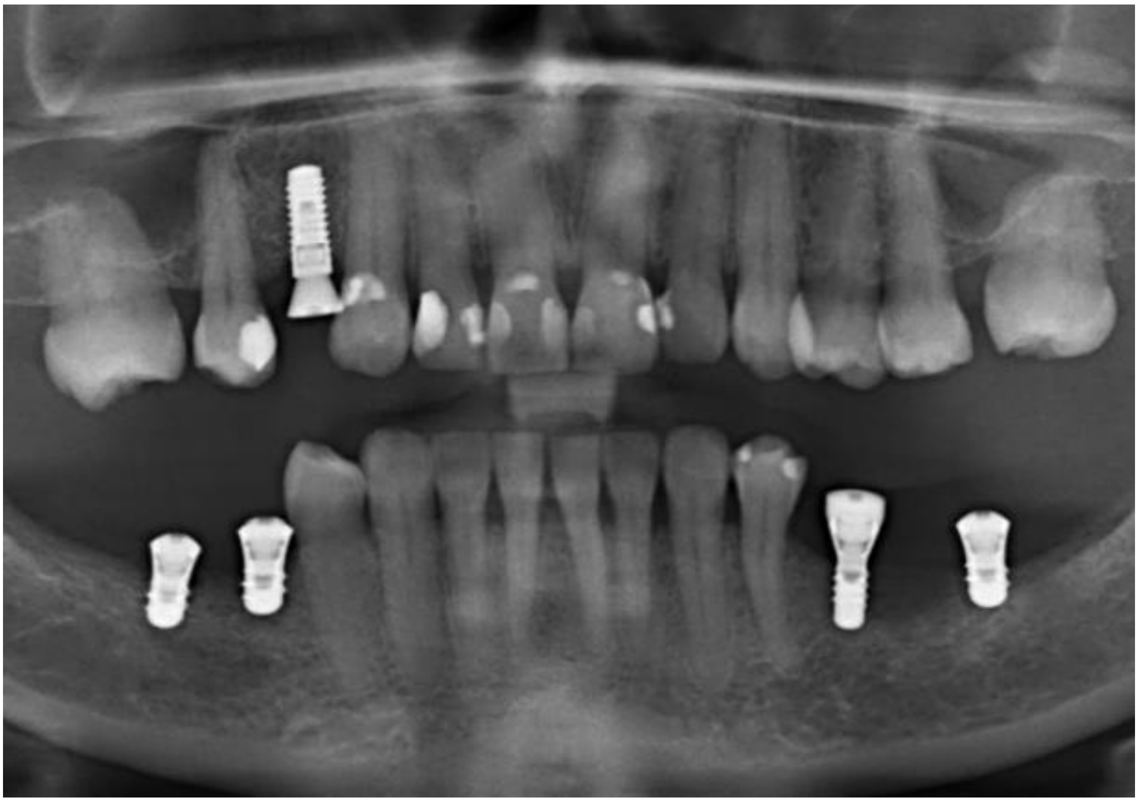


Figure 23: Magnified pantomograph (archival record) presenting with five Straumann dental implants. The dental implant in the maxilla (anatomical placement 14) is from the Regular CrossFit [(RC) – bone level implant with a horizontal offset] implant system. The four dental implants in the mandible are from the Regular Neck (RN) implant system.

Zimmer

Two different Zimmer examples have been used for this guide: The SwissPlus 4.8mm x 14mm and SwissPlus 4.8mm x 10mm (with healing cap). These implants presents with a round apex, but with threading starting at the apex. These implants have ten and five sharp, prominent twirls respectively. The neck of both implants is long and smooth, with a prominent outward curve. The dental implant example with the healing cap presents with a round curve at the edge of the neck. This is in contrast to the example without the healing cap that presents with a sharp edge curving inwards.

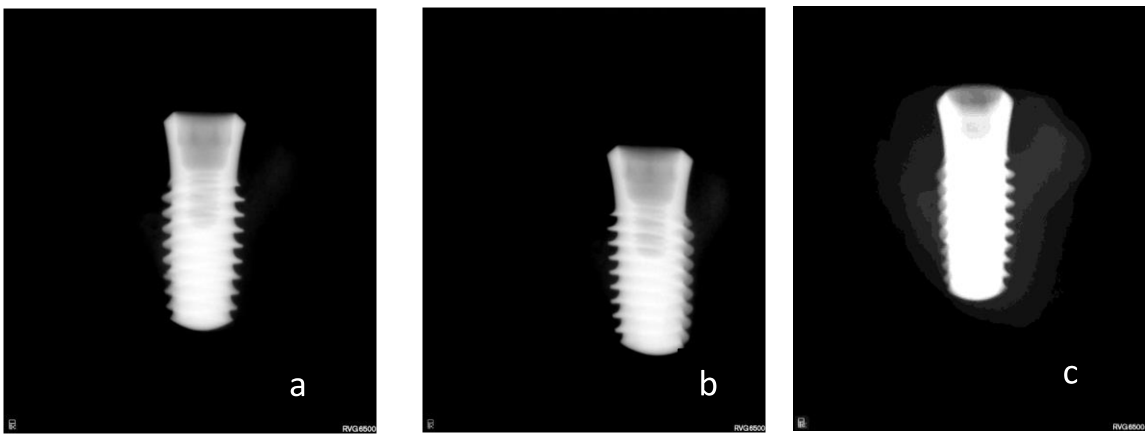


Figure 24: Zimmer SwissPlus 4.8mm x 14mm dental implant: a - ST, b - OC and c - SOC.

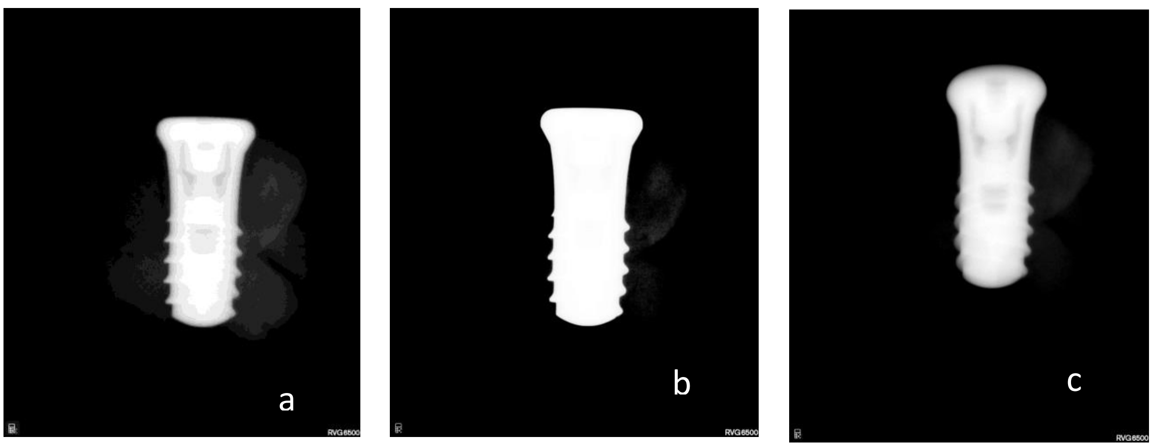


Figure 25: Zimmer SwissPlus 4.8mm x 10mm dental implant example with healing cap: a - ST, b - OC and c - SOC.

The Zimmer dental implant has quite similar morphological characteristics compared with Straumann. The primary morphology separating the Zimmer from the Straumann is the appearance of the thread and apex. The SwissPlus implant system from Zimmer is a copy of the Straumann 4.1mm x 10mm RN implant.

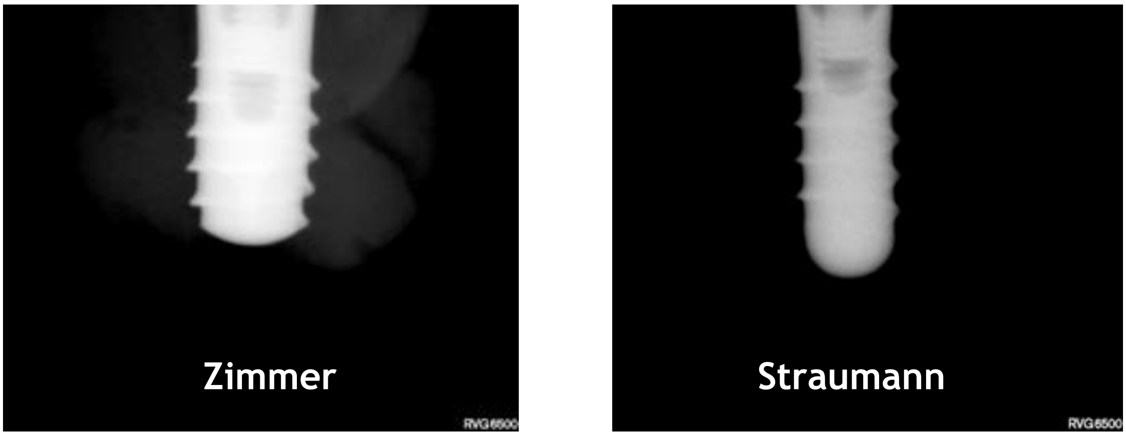


Figure 26: Comparison between Zimmer and Straumann indicating the apex and part of the body.

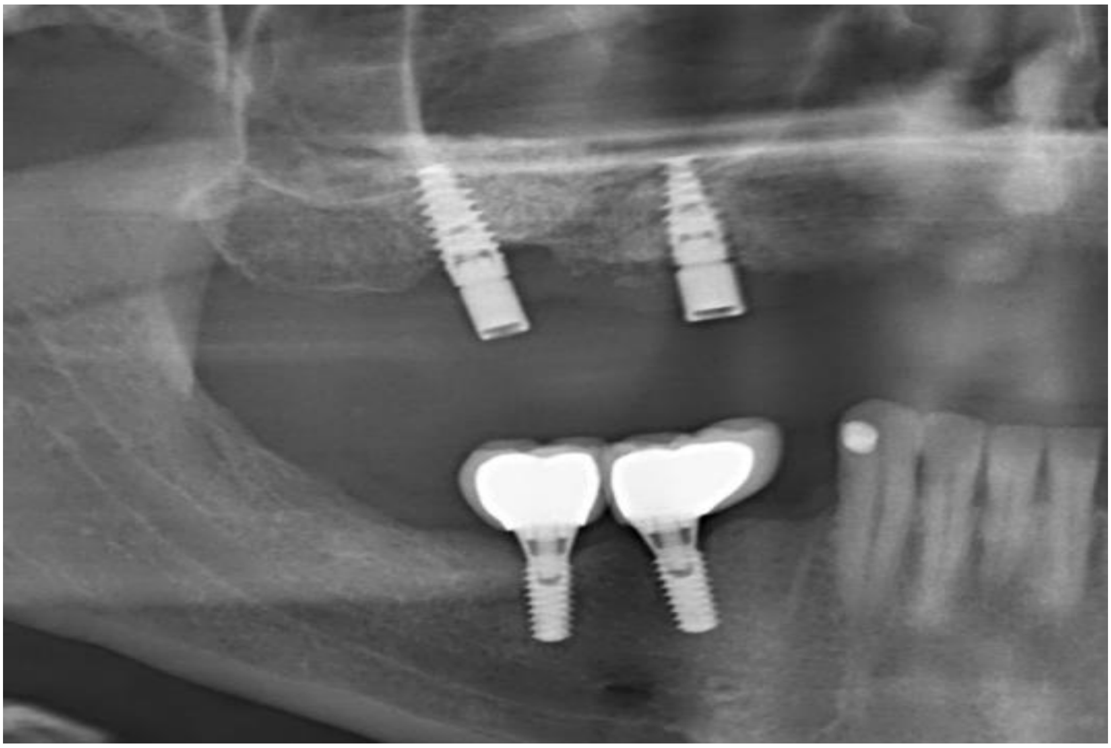


Figure 27: Magnified pantomograph (archival record) presenting with two Zimmer dental implants (mandible).

Appendix C

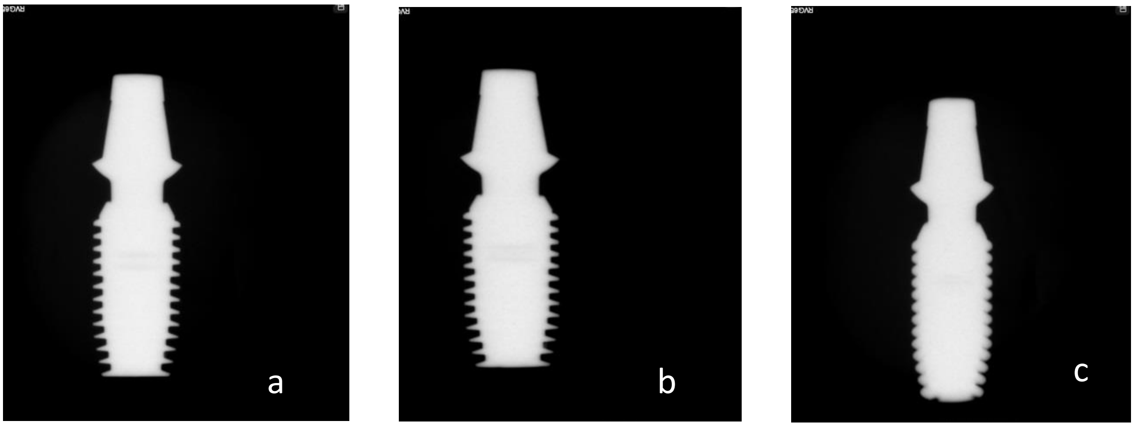
E-format of Radiographic Dental Implant Guide

E-format of Radiographic Dental Implant Guide.swf

APPENDIX D

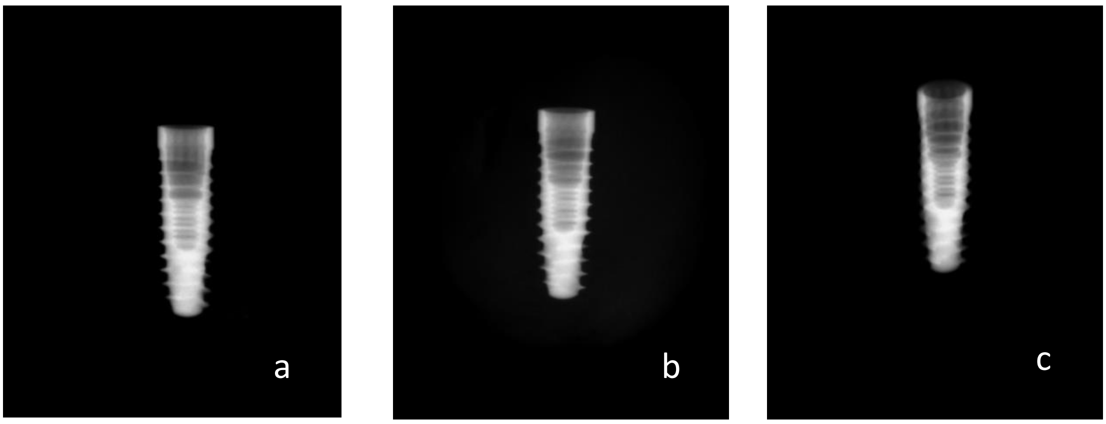
Reference instrument: 10 commonly used dental implant types in the Western Cape, South Africa.

Bicon



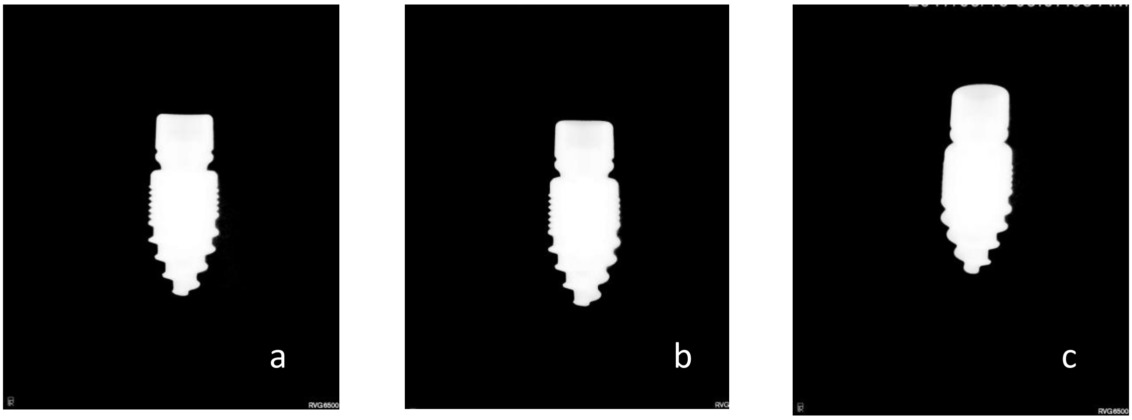
Bicon dental implant example: a - ST, b - OC and c - SOC.

Biomet



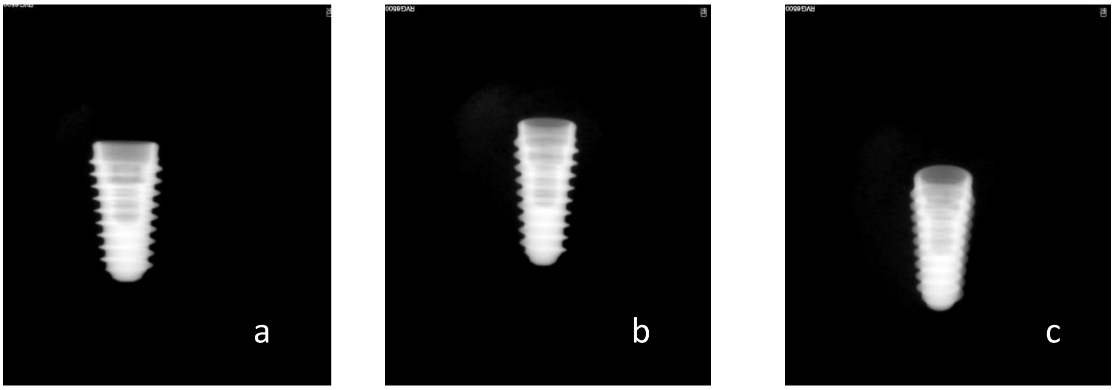
Biomet dental implant example: a - ST, b - OC and c - SOC.

Champion



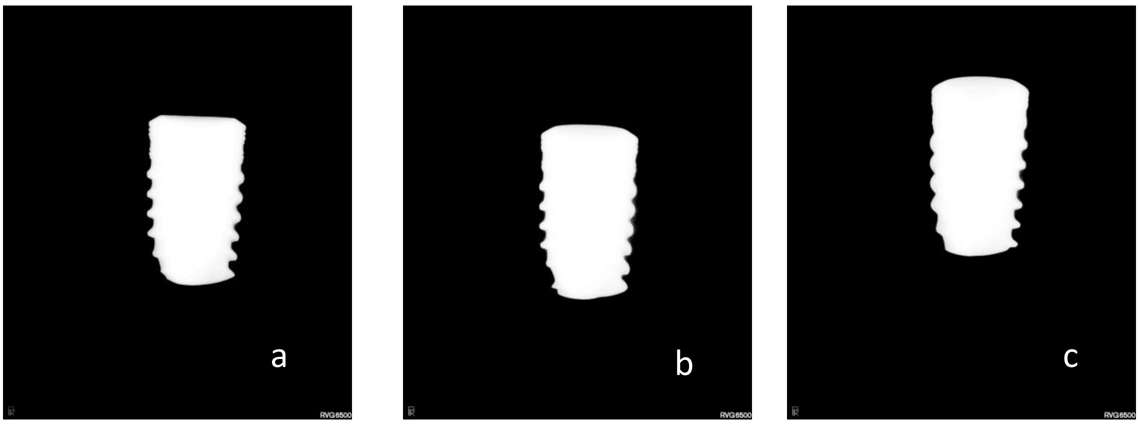
Champion dental implant example: a - ST, b - OC and c - SOC.

Megagen



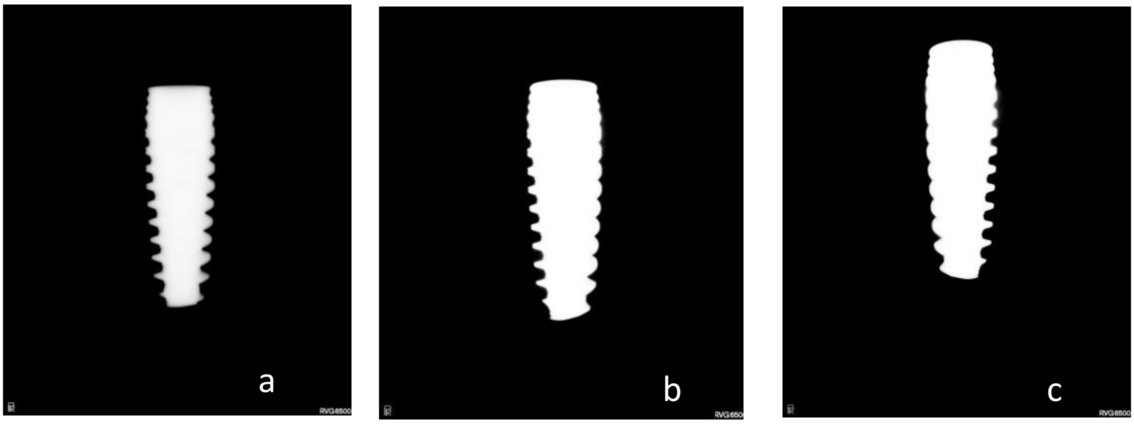
Megagen dental implant example: a - ST, b - OC and c - SOC.

MIS



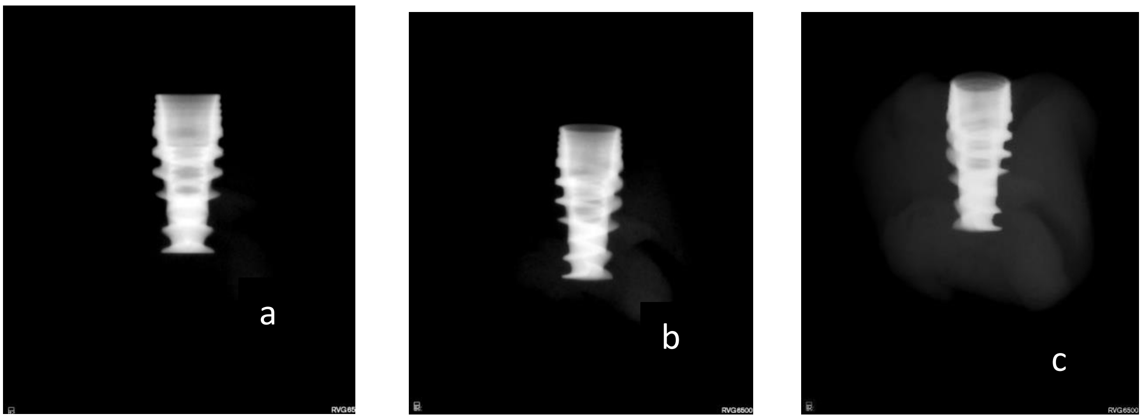
MIS dental implant example: a - ST, b - OC and c - SOC.

Neodent



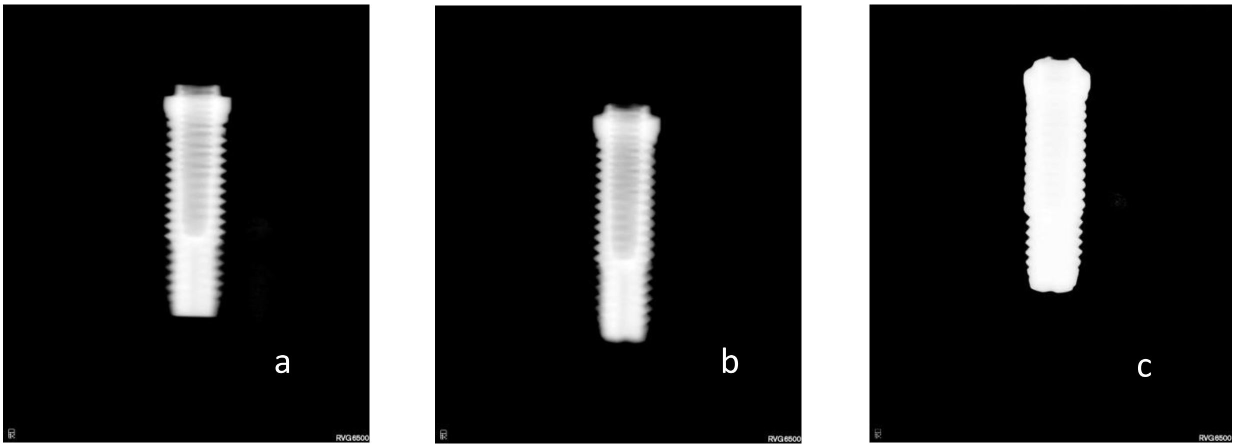
Neodent dental implant example: a - ST, b - OC and c - SOC.

NobelActive®



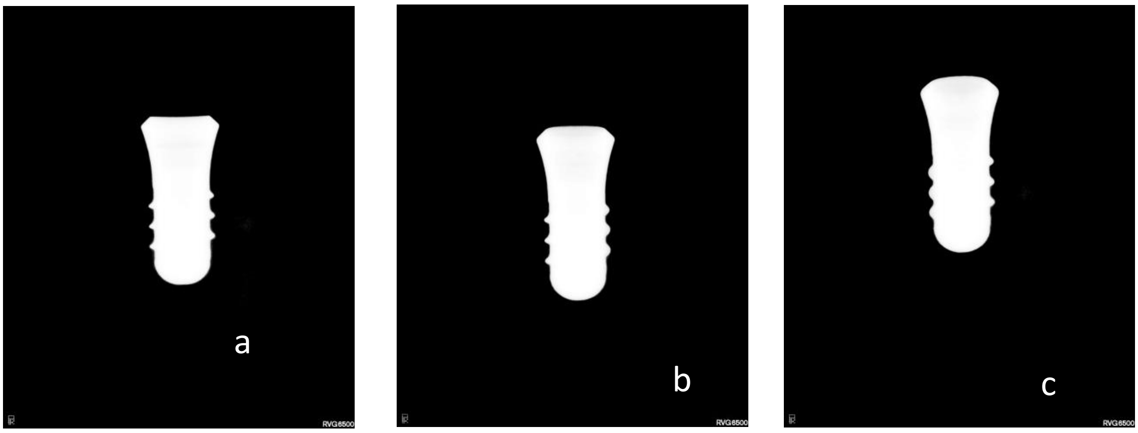
NobelActive® dental implant example: a - ST, b - OC and c - SOC.

Southern

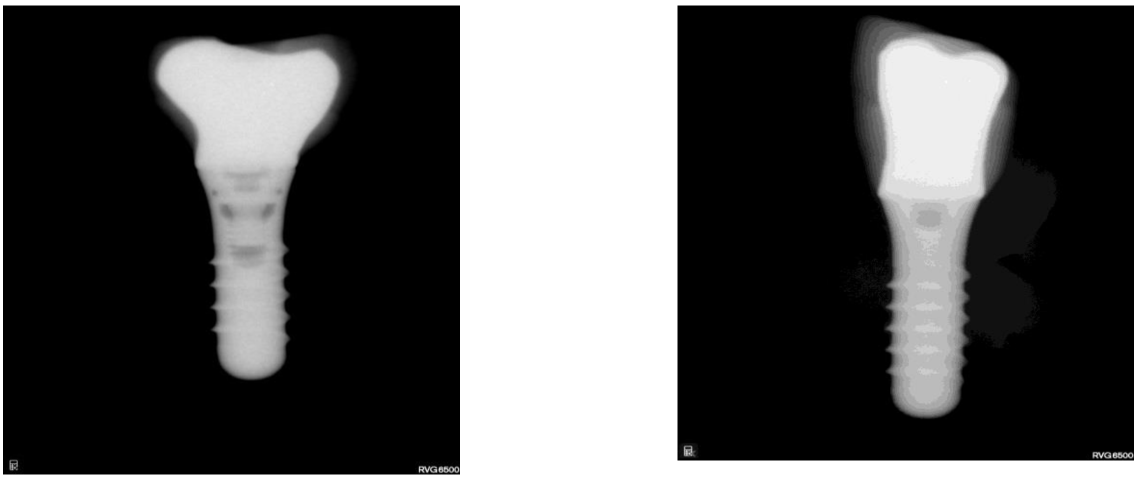


Southern dental implant example: a – ST, b – OC, c – SOC.

Straumann

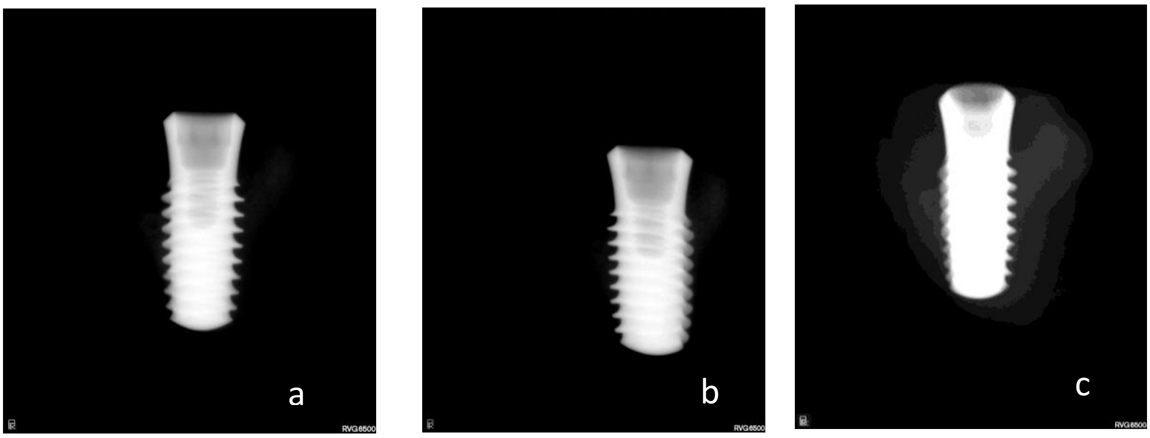


Straumann dental implant example: a - ST, b - OC and c - SOC.

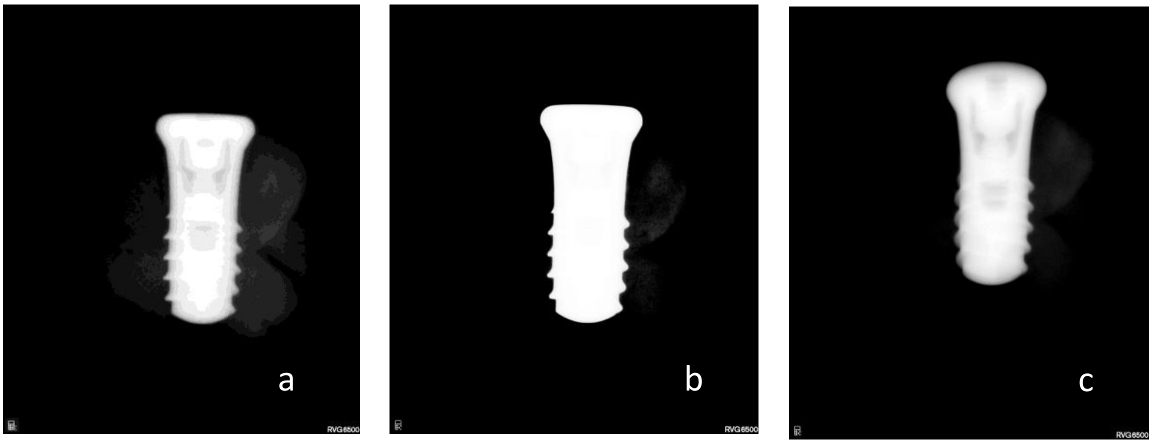


Straumann dental implants presenting with crowns.

Zimmer



Zimmer SwissPlus 4.8mm x 14mm dental implant: a - ST, b - OC and c - SOC.



Zimmer SwissPlus 4.8mm x 10mm dental implant example with healing cap: a - ST, b - OC and c - SOC.

APPENDIX E

UWC permission letter

UNIVERSITY *of the* WESTERN CAPE

Faculty *of* DENTISTRY share your smile

11 May 2017

Prof V.M. Phillips
Dept. Oral and Maxillofacial Pathology and Forensic Sciences
Tygerberg Dental Hospital
Parow
7500

Dear Prof Phillips

Re: Lisa Vermeulen: MSc Research Project

I hereby grand permission for Miss Lisa Vermeulen to have access to our Archival Radiology Library for her proposed MSc Research Project.

I hereby also grand permission to her to contact Mrs Marlize Coetzee to assist her in her endeavor to complete this Research Project.

Sincerely

PROF C.J. NORTJE

Approved.

11/05/2017

Private Bag x17, Bellville 7535, South Africa

A place of quality,

APPENDIX F

Dr Wolfaardt permission letter

DR. P. WOLFAARDT (Inc)
B.Ch.D. (Stell) M.Ch.D. (Stell)
PERIODONTIS/MONDGENEESKUNDIGE
PERIODONTIST/ORAL MEDICINE

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Tel: (021) 919-8334 Fax: (021) 919 7087 PR. NO. 9200398

CLAREMONT
Wildernessweg 12 Wilderness Rd
Claremont
7700
Tel: (021) 683 4802

15 May 2017

To whom it may concern

Herewith I, Dr P. Wolfaardt, give authorisation to Lisa Vermeulen to use the necessary resources, as mentioned in her proposal for her planned research study.

The date and time still needs to be confirmed.

Regards

Dr. P. Wolfaardt

APPENDIX G

CPUT Ethics permission letter

Cape Peninsula
University of Technology

HEALTH AND WELLNESS SCIENCES RESEARCH ETHICS COMMITTEE (HW-REC)
Registration Number NHREC: REC- 230408-014

P.O. Box 1906 • Bellville 7535 South Africa
Symphony Road Bellville 7535
Tel: +27 21 959 6917
Email: sethn@cput.ac.za

18 April 2018
REC Approval Reference No:
CPUT/HW-REC 2017/H8(extension)

Faculty of Health and Wellness Sciences – Medical Imaging and Therapeutic Sciences

Dear Ms Vermeulen

Re: APPLICATION TO THE HW-REC FOR ETHICS CLEARANCE

Approval was granted by the Health and Wellness Sciences-REC on 30 March 2017 to Ms Lisa Vermeulen – 212077880 for ethical clearance. This approval is for research activities related to student research in the Department of Medical Imaging and Therapeutic Science at this Institution.

TITLE: Development of a radiographic dental implant guide using current dental implants

Supervisor: Mr A Speelman, Prof V Phillips and Ms V Daries

Comment:

Data collection permission is required and has been obtained.

Approval will not extend beyond 19 April 2019. An extension should be applied for 6 weeks before this expiry date should data collection and use/analysis of data, information and/or samples for this study continue beyond this date.

The investigator(s) should understand the ethical conditions under which they are authorized to carry out this study and they should be compliant to these conditions. It is required that the investigator(s) complete an **annual progress report** that should be submitted to the HWS-REC in December of that particular year, for the HWS-REC to be kept informed of the progress and of any problems you may have encountered.

Kind Regards

Mr. Navindhra Naidoo
Chairperson – Research Ethics Committee
Faculty of Health and Wellness Sciences