

**A COMPARATIVE ANALYSIS OF TRADITIONAL
DENTAL SCREENING VERSUS TELEDENTISTRY
SCREENING**

by

SABESHNI BISSESSUR

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy in Dental Public Health

The logo of the University of the Western Cape, featuring a classical building facade with columns and a pediment, with the text 'UNIVERSITY of the WESTERN CAPE' below it.
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A COMPARATIVE ANALYSIS OF TRADITIONAL DENTAL SCREENING VERSUS TELEDENTISTRY SCREENING

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KEYWORDS

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Teledentistry

ICT

DMFT

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eHealth



ABSTRACT

A COMPARATIVE ANALYSIS OF TRADITIONAL DENTAL SCREENING VERSUS TELEDENTISTRY SCREENING

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Background: Teledentistry is the use of information and communications technology (ICT) to provide oral health care services and enhance oral health care delivery to communities in geographically challenged areas. The public health services in South Africa needs to be overhauled to address the inadequacies in the current system. As an attempt to minimise or repair the inadequacies in the public health sector, South Africa has identified the use of ICT's as a potential tool in improving the delivery of health care. However, although SA has recognised telemedicine as a potential solution to improve access to health care, teledentistry does not feature at all in the dental public health sector.

Teledentistry and mobile health has the potential to eliminate or minimise the oral health disparities that exist in South Africa with the use of health information systems. Teledentistry can be initiated in an incremental approach by 'piggy-backing' on existing telemedicine sites, thus reducing ICT costs for the public health sector. Stake holders and government officials need to embrace technology to address some of the challenges that exist in the South African public health sector. This study could aid in providing evidence-based information to assist in the introduction of teledentistry in South Africa as an innovative dental screening and management tool.

The most recent SA National Oral Health Survey showed that at least 80% of dental caries in children is untreated (Department of Health, 2003) and this poses a significant public health problem. To reduce the double burden of dental caries in children and human resource shortages in the public sector, the use of teledentistry as a school screening tool has been recommended. Teledentistry screening has the potential to improve access and delivery of oral health care to children in underserved and the rural areas.

The aim of the study is to compare traditional dental screening versus teledentistry screening for dental caries in children.

Methodology: This study consists of two parts: the first part a concordance study and the second part the determination of user satisfaction with regards to the technology used. The concordance study assessed the diagnostic agreement between traditional and teledentistry screening of dental caries in school children aged between 6-8 years old. The methodology included traditional face-to-face dental screening by two trained and calibrated evaluators, and the teledentistry screening method included the same two evaluators together with two trained and calibrated teledentistry assistants (who were of non-dental background). For the traditional face-to-face dental screenings the two evaluators examined 233 children at selected rural primary schools and scored them for DMFT. For the teledentistry screening method the teledentistry assistants captured intraoral images of the same children and web-based stored the images in corresponding eFiles. After a two week wash out period these intraoral images were then examined by the same two evaluators and scored for DMFT. To determine concordance across methods, Kappa Statistics was applied to the data and this revealed intra-examiner reliability.

To determine user satisfaction levels, close-ended questionnaires were designed based on the role of the evaluators and TAs in the teledentistry screening process.

Results: The intra-rater agreement and reliability across methods for evaluator one was 98.30%, and for evaluator two it revealed a result of 95.09%. Kappa statistics thus revealed that both evaluators were in agreement between a range of 95%-98.30% of the classifications, or 92.79% of the way between random agreement and perfect agreement ($p=0.000$). The high concordance level indicated that there was no statistical difference between the traditional dental screening method and the teledentistry screening method (intra-rater reliability), thus suggesting that the teledentistry screening method is a reliable alternative to the traditional dental screening method.

For the user satisfaction part, both of the evaluators agreed with 8 of the 13 statements (62%). The statements that were agreed upon related mainly to user satisfaction on the technology which included accessing the intraoral images for screening and the ease of scoring decayed and missing teeth off the images; time and technology suggested the screening process of the images saved time; and indicated teledentistry as being an innovative and easy system to use that will save clinical time for dental professionals. The statements they disagreed with related to the clarity of the images, scoring interproximal caries off the images, and the dental screening method of choice.

Both of the TAs agreed with 7 of the 11 statements (64%). They agreed upon statements related mainly to perception of children's attitudes & behaviour which suggested the children were comfortable during the imaging process and in addition they were excited to see pictures of their teeth; they found teledentistry to be an innovative and easy system to use; they found teledentistry to be a sterile process and hence they were happy with infection control. Both TAs disagreed with the statement that suggested clear images could be captured irrespective of poor lighting. Discordant statements related mainly to user satisfaction on technology which related to ease of using the intraoral camera, ease of storing the captured images into the eFiles and ease of deleting unwanted images.

Conclusion: The key findings of this study highlights the reliability of utilising teledentistry as a dental screening and diagnostic tool which can be valuable in the delivery of oral health care in South Africa.

This research study further revealed valuable data on user satisfaction levels of the evaluators and TAs, and has an impact on the utilisation of the teledentistry screening system. To ensure adoption and adaptation of the screening process all users must be satisfied with the ICTs used in the teledentistry system. User friendliness can impact negatively on the adoption of teledentistry.

DECLARATION

I declare that the thesis entitled *A Comparative Analysis of Traditional Dental Screening versus Teledentistry Screening* is my own work, that it has not been submitted before for any degree or examination at any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Sabeshni Bissessur



Date

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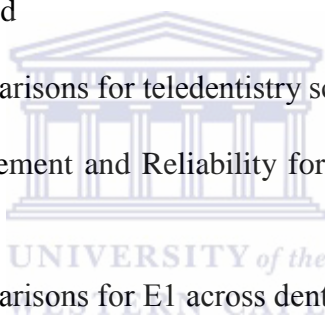
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LIST OF ABBREVIATIONS

ECC	Early Childhood Caries
SA	South Africa
DMFT	Decayed, Missing, Filled Teeth
ICT	Information and Communications Technology
SMS	Short Message Service
eFiles	Electronic Files
NOHS	National Oral Health Survey
WHA	World Health Assembly
LED	Less Economically Developed
MED	More Economically Developed
TAs	Teledentistry Assistants
NHI	National Health Insurance
WHO	World Health Organization
POTS	Plain Old Telephone System
GDP	General Dental Practitioner
ISDN	Integrated Services Digital Network
WWW	World Wide Web
RAM	Random Access Memory
NHS	National Health Services
CAR	Caries Risk Assessment
CAMBRA	Caries management By Risk Assessment
HIPAA	Health Insurance Portability and Accountability Act and System Security with Teledentistry
CHC	Community Health Centre
N	Number
DOE	Department of Education
E1	Evaluator 1
E2	Evaluator 2
IA1	Image Assessor 1
IA2	Image Assessor 2

CHAPTER 1

INTRODUCTION

1.1 Background

Dental caries is defined as a disease of the hard tissues of the teeth caused by the action of the microorganisms found in plaque, on fermentable carbohydrates (principally sugars) (Kidd, 2005). When caries affects the labial surface of the upper anterior teeth in young children, it is termed early childhood caries (ECC). Systematic reviews suggest that the aetiology of early childhood caries is multifactorial (Shaw, 1999; Ismail *et al.* 1999) and the determinants include poor dietary and lifestyle factors, inadequate access to oral health services, poor socio-economic status, environmental and political factors, behaviour and culture (Watt, 2007; Ismail, 1998).

Dental caries is the single most common chronic disease of childhood that occurs five times as frequently as asthma and seven times more commonly than hay fever (Department of Health and Human Services (DHHS), 2000). It is a preventable and reversible infectious disease process, which if left untreated, can cause pain, infection, speech disorders, poor mastication, low self-esteem, premature tooth loss and harm to the developing permanent dentition (Kagihara *et al.* 2009). There are many evidence-based preventive oral health programmes that are effective at preventing dental caries. For example, supervised school brushing programmes with fluoridated toothpaste and the topical applications of fluoride varnish at least twice a year for young children who are at increased risk of dental caries (Scottish Intercollegiate Guidelines Network, 2005).

Caries prevention measures may be ineffective if not directed at specific target groups. One of the ways to determine caries risk groups is dental screening programmes at primary schools. Currently, in South Africa (SA), dental screening programmes are done via the traditional method of a face-to face visual dental screening. The Decayed, Missing and Filled teeth (DMFT) status is determined by a registered oral health worker who carries out the visual inspection of teeth in the child's mouth using an intra-oral mirror, a portable chair and a light source. A registered dental assistant is often required to function as the recorder of the DMFT (Patterson *et al.* 1998).

The charting of DMFT is done on paper, and each child has their own charting form. In addition, infection control must be adhered to at all times. This is often a long, tedious and expensive method that often requires the use of human resources from dental public health facilities. Since South Africa is a developing country, it is vital that new and improved methods of delivering oral health care be investigated and a significant opportunity presents with the use of Teledentistry. Information and Communications Technology (ICT) includes tools such as Skype, short message services (SMS) technology, telecommunications technology, digital imaging and the internet to improve access to dental care (Summerfelt, 2011; Jampani *et al.* 2011; Waclof, 2009). These tools make primary and specialist dental services accessible to individuals from all social backgrounds irrespective of location.

The traditional methods (visual/tactile clinical oral examinations) of dental screening at schools provides early detection of dental caries, however, this requires increased professional human resources, transportation, sterile screening instruments and adequate control of paper records. Research on the comparative effectiveness of using visual/tactile clinical examinations or teledentistry as dental caries screening tools, suggests that the use of teledentistry is just as effective as the traditional dental screening methods (Kopycka-Kedzierawski *et al.* 2011). The advantage of choosing teledentistry as a dental caries screening tool is its viability in increasing oral health care to underserved areas, increasing equity and thereby reducing the oral disease burdens in children. But, can teledentistry be shown to be a reliable dental screening tool in South Africa's health system and in rural settings?

Intra-oral digital imaging facilitates e-consultations and improves dental screening methods. Electronic files (eFiles) can be created and easily stored and accessed for future reference. They can also be forwarded anywhere in South Africa or abroad for specialist diagnosis without the patient having to travel extensive distances (Cederberg *et al.* 2012; Jampani *et al.* 2011). DMFT charting can be carried out using digital imaging, and this is known as the teledentistry examination index (Kopycka-Kedzierawski *et al.* 2006). Furthermore, photographic images and prints of children's carious teeth can be used to motivate parents/guardians to seek dental treatment and institute preventive care. Only a teledentistry assistant is needed for the imaging and this eliminates the need for highly skilled professional human resources. Instead, dental professionals can be better utilised in the dental hospitals/clinics (Kopycka-Kedzierawski *et al.* 2011; Cooper *et al.*, 2007; Kopycka-Kedzierawski *et al.* 2006).

Teleconsultation through teledentistry can take place in two ways – “real-time consultations” or the “store and forward method”. Real-Time Consultation involves video-conferencing, in which dental professionals and their patients at different locations can see, hear and communicate with one another (Jampani *et al.* 2011). Real-time consultations are the closest alternative to conventional, face-to-face consultations and is known as synchronous or interactive teleconsultations. The “Store-and Forward Method” involves the exchange of clinical information and static images are collected and stored by the dental practitioner, who then forwards them for consultation and treatment planning (Jampani *et al.* 2011). This method of teleconsultation is sometimes referred to as asynchronous or pre-recorded.

During the past 20 years three National Oral Health Surveys (NOHS) were conducted in South Africa, the most recent a National Children’s Oral Health Survey was conducted between 1999 and 2002 (Van Wyk *et al.* 2004). The findings of the study showed that at least 80% of dental caries in children is untreated (Department of Health, 2003) - a significant public health problem. The NOHS survey was conducted on children aged 4-5 years, 6 years and 12-15 year olds. The survey further reported that 39.7 per cent of the 6 year old group was caries free; however, this figure is way below the goal that was set for year 2000 in South Africa (Van Wyk *et al.* 2004; Department of Health, 2003). This indicates that dental caries remains a serious problem, especially in the 6 year old age group. Compounding this problem is the shortage of oral health care workers in South Africa’s public health sector where the demand is high. It has been reported that more than 80% of oral health care workers (includes dentists, dental therapists, hygienists and dental technicians) are employed in the private sector (Van Wyk *et al.* 2004) where the demand is low in comparison to the public sector. To reduce the double burden of dental caries in children and human resource shortages in the public sector, the use of teledentistry as a school screening tool has been recommended. Teledentistry screening has the potential to improve access and delivery of oral health care to children in underserved and the rural areas.

Kopycka-Kedzierawski *et al.* (2006) implemented a teledentistry project in New York in six inner city elementary schools and seven child care centres. Teledentistry assistants (TAs) recorded images of children’s teeth using intraoral cameras, which were then forwarded to a paediatric dentist at a distant site to review and make treatment and referral recommendations.

The study found that almost 40% of the children had active dental caries, and that for the first time many children attending these inner city schools and child care centres had their teeth examined with prompt feedback on the need for dental care. This project increased access to dental care to children in underserved areas, thus making it possible for the children to have had a paediatric dentist reviewing their individual cases without having to travel any distances, thereby saving cost and time (Kopycka-Kedzierawski *et al.* 2006).

The store-and-forward method used in Kopycka-Kedzierawski's study has shown that this technology yields excellent results without excessive costs for equipment and connectivity (Jampani *et al.* 2011).

It is anticipated that the proposed introduction of an innovative system of healthcare financing in South Africa - a National Health Insurance (NHI) will ensure that everyone has access to appropriate, efficient and quality health services regardless of their socio-economic status (DoH, 2011). The objectives of the NHI are to (i) provide improved access to quality health services for all South Africans; (ii) pool risks and funds so that equity and social solidarity will be achieved through the creation of a single fund; (iii) procure services on behalf of the entire population and efficiently mobilize and control key financial resources and (iv) strengthen the under-resourced and strained public sector so as to improve health systems performance (DoH, 2011).

Appropriateness is one of the guiding principles of the NHI and refers to adopting new and innovative health service delivery models that focus on local needs (DoH, 2011). Teledentistry is an intervention that can enhance opportunities for the new primary healthcare model that has the capacity to take service delivery and accessibility to newer and improved levels.

ICTs have endless benefits for communities that are disadvantaged (Friction *et al.* 2009). For example, general dental practitioners can successfully provide orthodontic services to disadvantaged children via 'real-time' supervision by an orthodontist (Bradley *et al.* 2007). With 'real-time', there is interaction, a two-way transfer of information and oral health data that occurs at two sites simultaneously, the hub site and the spoke site (Waclof, 2009). Orthodontic services that may be inaccessible to children in rural communities may now be offered with the use of ICTs.

Evidence-based studies have reported that teledentistry has a positive role in improving access to dental care in rural, inaccessible areas to disadvantaged populations (Kopycka-Kedzierawski, 2007; Kopycka-Kedzierawski, 2006). Therefore, ICTs are a good concept to introduce in South Africa to assist with and enhance in the provision of services of the dental public health system. ICTs may also assist the South African public to become more aware of oral health care and dental services that are available and accessible to the child, thus promoting a healthy oral health environment for children, especially the marginalized communities.

However, the reliability of alternate methods of traditional dental screening needs to be determined in South Africa, as countries differ in many ways, such as culture, infrastructure and health professionals that may be more skilled in medical and dental advancements due to the varying developmental phases of countries. It is anticipated that the present study may be able to determine the reliability and feasibility of using intraoral imaging as a dental screening tool that can assist with policy making for the most cost-effective ways of substantially reducing or eradicating dental caries as a public health problem.

One of the focal points of the NHI is the re-engineering of the primary health care system which includes the delivery of primary health care services into three streams: the district-based clinical specialist support teams, school-based primary health care services and municipal ward-based primary health care agents (Department of Health, 2011). In this regard, it may be a strategic opportunity to introduce teledentistry into the school-based primary health care policy, so as to improve oral health promotion and service delivery.

The importance of good oral health needs to be instilled in young 5-8 year old children so that they can carry the principles into adulthood, thus reducing dental caries, early tooth loss and other oral diseases. This is a very important age group as the caries incidence can play a vital role in determining the caries risk assessment. Children can be categorized into different risk categories namely, social and economic aspects, oral health behaviours (dietary habits, oral hygiene, intraoral biological factors, fluoride use) and systemic health. New validated risk factors can also be considered as new evidence emerges. This categorization of the caries risk factors then allows for focused recommendations to minimize the risk of developing new carious lesions and/or the progression of existing lesions in the future (Pitts, 2011).

As technology progresses, there should be a progression of dental and medical interventions to prevent oral and dental diseases. Technologies when proficiently adapted, almost always increases efficiency. While new technologies and techniques are becoming more easily available, the challenge however is, to have the vision and impetus to ensure that they are used and are of benefit to all concerned (Eaton *et al.* 2008). In this regard, South Africa has developed a new eHealth strategy to assist with health information systems.

The World Health Organization (WHO) defines eHealth as “the use of information and communication technologies (ICTs) for health to, for example, treat patients, pursue research, educate students, track diseases and monitor public health” (Department of Health, 2012).

One of the strategic priorities to leverage eHealth to strengthen healthcare transformation in South Africa is the applications and tools to support healthcare delivery (Department of Health, 2012). Therefore, it is anticipated that this study will play a vital role in highlighting the importance and value of ICT tools when used in the assessment and management of dental caries, thus underpinning the above mentioned strategic priority of the eHealth strategy of South Africa. In addition, dental screening via teledentistry can be introduced incrementally by pairing with already existing telemedicine sites in South Africa.

1.2 Significance of the present study

There have been no studies carried out on teledentistry in Sub-Saharan Africa. South Africa is a developing country and as such is faced with many challenges with the most important being poverty and poor delivery of health care due to poor infrastructure and limited medical and dental professional human resources to deliver health care. Hence, this study was carried out in an economically challenged environment and can provide evidence based information to determine if the teledentistry method of dental screening can work in an African setting which is less economically developed (LED) as opposed to a more economically developed (MED) country. This study can be used as a source of motivation for these Sub-Saharan countries to initiate their own teledentistry projects that can then possibly enhance the delivery of oral health care to underserved communities.

Historically, the healthcare system in South Africa has been two tiered, with a privileged minority benefitting from this system (DoH, 2011). There have been attempts over many years (pre- and post-democracy) to rectify this situation however large sectors of the population still have poor access to healthcare (DoH, 2011). Even though there has been a slight improvement with access in the public sector, the quality of healthcare services has either remained poor or has deteriorated (DoH, 2011). To address the disparity in the health system, the National Health Insurance (NHI) has been proposed (DoH, 2011). One of the key aims being the re-engineering of school-based primary health care services, and this is where teledentistry has a significant role to play. It is therefore anticipated that the present study will assist the Department of Health policy making decisions regarding the adoption and use of teledentistry as an innovative dental screening and management tool.

In 2005 the World Health Assembly (WHA) passed a resolution urging countries to take advantage of the potential offered by eHealth to strengthen their health systems (Asamoah-Odei *et al*, 2007). In addition, in 2006, the WHA also requested WHO Member States, in another resolution, to use ICTs to address the global shortage of health workers, with a particular reference to Sub-Saharan Africa which has a health worker density below a critical minimum necessary for the provision of basic health services. However, Africa remains the most disenfranchised region in the world as regards to internet access. Even though the cellular service is booming, the internet access remains low. Only 19 per 1000 Sub-Saharan inhabitants have access to internet, the lowest rate of any developing region (Asamoah-Odei *et al*, 2007). Therefore, this sets Sub-Saharan Africa far behind in comparison to the MED countries.

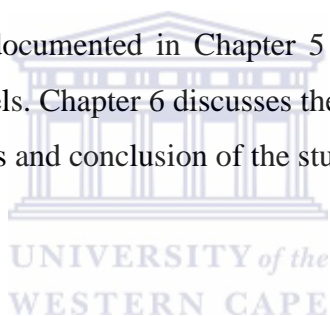
Therefore, this study has the potential to provide evidence-based information to enhance the proposed eHealth patient-centred strategy for South Africa (DoH, 2012-2016) to eliminate the oral health disparities that exist in South Africa, with the use of health information systems. Teledentistry can be initiated in an incremental approach by 'piggy-backing' on existing telemedicine sites, thus possibly reducing ICT costs for the public health sector.

1.3 Structure of thesis

This thesis begins with the introduction, including the background and the significance of the study in Chapter 1. The literature review follows in Chapter 2, which includes telemedicine and its origin, teledentistry and its origin, defining teledentistry and related terminology, telemedicine in SA, methods of teleconsultations and uses of teledentistry. The benefits and problems associated with teledentistry are also included in this chapter. In addition, the role of teledentistry in the different disciplines together with dental caries and teledentistry and the ethical and legal issues of teledentistry are also incorporated in Chapter 2.

Chapter 3 documents the aims and objectives of the study. This is followed by Chapter 4 which includes a detailed methodology of the study. The methods chapter is detailed in two parts: Part 1 is the concordance study and Part 2 is the user satisfaction levels.

The results of the study are documented in Chapter 5 in two parts: the concordance study and user satisfaction levels. Chapter 6 discusses the findings and limitations of the study and the recommendations and conclusion of the study are covered in Chapter 7.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This review will begin with a brief overview of the origin of telemedicine in South Africa and thereafter will focus on the concept and use of teledentistry; its origin and terminology used. In addition, the benefits, challenges, ethical and legal issues of teledentistry will be reviewed. Finally the use of teledentistry and its impact on the overall management of dental caries will be described.

2.2 Telemedicine and its origin

“Telemedicine” is the use of information-based technologies and communication systems to deliver healthcare across geographic distances (Zimlichman, 2005). It is essentially the use of electronic information to communicate technologies to provide and support healthcare when distance separates the participants (Dasgupta, 2008). Telemedicine is a concept that has its roots deep-seated from the inception of the “telephone” in the 1900s. The telephone has been used as a key instrument for medical communication for more than 50 years until the present time (Ferra-Roca *et al.* 1998) and has therefore been documented as one of the first tools of telemedicine.

Authors traced the history of long-distance communication from its humble origins in semaphore, and much later the telegraph, and radio to advanced digital communication and computer processing systems. Telemedicine provided the tools for connectivity when providers and recipients of care cannot be in the same place at the same time (Ryu, 2010). The origin of modern telemedicine applications was traced back to Europe, where a Dutch Physician, Willem Einthoven, carried out long distance transfers of electrocardiograms in 1905, and it can be attested that the first clinical application of telemedicine was in fact in cardiology and not in radiology (Ryu, 2010). Radiology was the next medical specialty to utilise telecommunication in 1959 when Albert Jutra used a communication cable to transmit videotaped telefluoroscopy examinations between two hospitals in Montreal, five miles apart (Shirolkar *et al.* 2011).

As information and communications technology has advanced, so too have the terms used to describe health care services that are provided from a distance - “telehealth”, “e-health”, and “telemedicine”, are some of the terms that have evolved (SOHIP Teledentistry Workgroup, 2006). Currently, “telehealth” and “e-health” are used as umbrella terms to describe the variations of healthcare services that utilise telecommunications, such as the support of long-distance clinical health care, patient and professional health-related education, public health and health administration (SOHIP Teledentistry Workgroup, 2006). “Telemedicine” on the other hand, refers to the direct provision or support of clinical care at a distance through the use of electronic communication and information technology, treating or following up with a patient at a distance (Brown, 2005). The applications of telemedicine include “teleradiology,” “telepathology,” “teledermatology” and “teledentistry.” However, the literature review that follows will focus on “teledentistry” and all aspects associated with this application.

2.3 Teledentistry and its origin

Teledentistry is a new concept in dentistry that is practiced globally (Mittal *et al.* 2011; Friction *et al.* 2009; Kopycka-Kedzierawski *et al.* 2007). It is considered as an alternate mode of dentistry that makes dental health care more accessible especially to areas that are underserved and inaccessible (Friction *et al.* 2009). Teledentistry is considered an application of telemedicine and was developed as part of a blueprint for dental informatics, a new domain combining computer and information science, engineering and technology in all areas of oral health that was drafted at a 1989 conference (Folk, 2001). It was the United States (US) army who put teledentistry into practice in 1994, in a military project (Total Dental Access Project) that aimed at improving patient care, dental education and to enhance the communication between dentists and dental laboratories. They found that teledentistry reduced total patient care costs, improved the delivery of dental care to patients in rural and distant areas (Rocca *et al.* 1999) and offered complete information required for deeper analysis (Jampani *et al.* 2011). This project initially used a traditional telephone system (POTS) with two different communication methods: real-time and store-and-forward. In 1995, Rocca *et al.* conducted a pilot study in Haiti to connect a general dentist to a dental specialist in Washington DC, via a satellite system (Shirolkar *et al.* 2011).

Two years later, integrated services digital network (ISDN)-based teledentistry was tested in Germany, Belgium, and Italy. Studies to examine ISDN-based teledentistry have also been conducted in Scotland, Japan, England and Taiwan (Shirolkar *et al.* 2011). The positive step by the US army to improve the delivery of dental health care over geographic distances has evolved with many innovative advances in technology.

Teledentistry has the possibility to revolutionise the way in which oral healthcare is delivered, specifically to communities that are geographically remote locations. In fact, dental practitioners have been inadvertently performing teledentistry, for example, when using the telephone or the fax machine to discuss clinical dental cases and treatment planning. With the global rise of the cellular industry and ICT technologies, teledentistry has the potential to revolutionise oral healthcare service delivery. It is a fast growing segment of dentistry exceptionally in the past five years and has shown promise in eliminating the gap between the underserved patient in rural areas and access to specialists (Arora *et al.* 2014). However, the uptake of teledentistry in South Africa, has been slow.



2.4 Defining teledentistry and related terminology

Early definitions of teledentistry have referred to it as the practice of using video conferencing technologies to diagnose and provide advice about treatment over a distance (Chhabra *et al.* 2011) and more recently as the ‘use of dental information transmitted from one site to another to improve oral health’ (Kopycka-Kedzierawski and Billings, 2006). Teledentistry is dentistry evolving in the new era of technology. It has been defined by Wacloff (2009) as a developing area of dentistry that integrates electronic health records, telecommunications technology, digital imaging, and the internet to link dental providers and their patients. This definition, however, focuses more on the technologies of teledentistry and does not incorporate one of the main aspects, which is to utilise ICTs to make oral health care accessible to all people, especially people who reside in the rural or remote areas.

Kopycka-Kedzierawski *et al.* (2006) defines teledentistry as the use of information and communications technology to transmit dental information from one site to another to improve oral health care. Zimlichman (2005) provides an all-encompassing definition of telemedicine as the use of information-based technologies and communication systems to deliver healthcare across geographic distances.

“Tele” is a Greek word meaning “distance” and “mederi” in Latin means “to heal”. Telemedicine has been referred to as “healing by wire” (Zimlichman, 2005) and therefore teledentistry can be understood be an alternate mode of making oral health care available over geographic distances via information and communication technologies. The definition of terms commonly used in Teledentistry is shown in Table 1 (Wacloff, 2009).

Table 1: Definition of terms commonly used in teledentistry

Term	Definition
Accessibility	Level of access to the vendor's in terms of sales, timely delivery, and equipment maintenance (SOHIP, 2006).
Band width	A primary factor in the performance of a network. Wider bandwidth allows for greater information carrying capacity. Bandwidth is supplied by wires, cables, radio waves or satellite transmission. The more sophisticated the bandwidth, the more complex the telecommunication can be. Bandwidth is also positively correlated with cost. Standard phone lines can support some teledental applications but higher bandwidth technologies are required for more advanced procedures.
Broadband	Telecommunication in which a wide band of frequencies is available to transmit information.
Compatibility	Newer versions of telehealth technologies should be compatible with earlier versions of similar technologies, decreasing the likelihood of rapid product obsolescence (SOHIP, 2006).
Dental informatics	The application of computer and information sciences to improve dental practice, research, education and management (Saxena <i>et al.</i> 2014).
eHealth	An emerging field referring to health services and information delivered or enhanced through the Internet and related technologies. It encompasses not only technical development, but also a state of mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology (Eysenbach, 2001).
Hub site	The location of the teledental consulting provider receiving the electronic data.
Interoperability	Technologies need to meet the Health Resources and Services Administration, Office for the Advancement of Telehealth (OAT) recommended guidelines and standards for telehealth networks to interface and create a national infrastructure that can share information (SOHIP, 2006).

Term	Definition
mHealth	Mobile health technology is a sub section of eHealth in that it refers specifically to the use of mobile information technology to improve health service delivery. Mobile health technology involves portable hardware devices (such as cell phones, digital pens or other hand held devices) as well as the software applications and satellite and internet and wireless networks that allow for the rapid transmission, storage and retrieval of electronic data (The Rockefeller Foundation, 2010). Mobile health is depicted by the letter ‘m’ followed by the specific health discipline, and is referred to as m-teledentistry and m-optometry (Daniel <i>et al.</i> 2014).
Media	The material used to link computers together via a network.
Latency	Measure of the performance of a network. Together, latency and bandwidth define the speed and capacity of a network. Latency is the time it takes for transmitted data to be received at its destination. It is measured in milliseconds. Video conferencing becomes unusable with latency greater than 300 milliseconds. High latency degrades the performance of even the largest capacity networks. Variations in latency create “jitter” – data packets reach the destination with different delays. Jitter can seriously affect the quality of streaming audio and/or video (SOHIP, 2006).
Real-time	Interactive, two-way transfer of information and oral health data occurs at two sites simultaneously: the hub site and the spoke site.
Reliability	The network and equipment will work as intended, that the end user can consistently use the equipment for its intended purpose without operational error, and that the technologies can be reliably serviced with minimum downtime (SOHIP, 2006).
Scalability	Telehealth technology should be capable of migrating into expanded capabilities without total replacement. Additionally, features and functions should be available as options rather than impacting the base cost of the technology (SOHIP, 2006).
Spoke site	The location where the patient is receiving the service and from which the data is being transmitted.
Store-and forward	The transfer of patient data from one site to another through the use of an intermediate station. The intermediate station is a data storage device such as a hard drive, flash drive, jump drive, CD or DVD.
Telecommunication services	Media used to link computers together, supplied by a wired or a wireless service. The availability of services may vary, with fewer options available in remote areas. The higher the speed of data transmission the higher the associated costs.

Term	Definition
Videoconference	A live connection that provides transmission of images and text between people located in separate facilities for the purpose of communication. The connection can be site to site or among multiple sites. In its most advanced form, it can provide transmission of full motion video images and high quality audio between multiple locations.
Wireless Media	Various wireless network medias, each using different transmission protocols. Typically, a wireless network uses infrared light or radio transmissions to distribute data (SOHIP, 2006).

2.5 Telemedicine in South Africa

A national telemedicine system for South Africa was planned in 1998. In 1999 the first phase started with 28 pilot sites established in six provinces (Gulube *et al.* 2001). The initial applications included teleradiology, teleultra-sound for antenatal services, telepathology and teleophthalmology. Connectivity was via the integrated services digital network (ISDN) (Gulube *et al.* 2001) however, there was a relatively low usage of the system due to technical and organizational challenges (Gulube *et al.* 2001). Furthermore, it was found that the health information systems have been characterized by fragmentation and lack of coordination, prevalence of manual systems and lack of automation, and where automation existed there was a lack of interoperability between different systems (DoH, 2012). Despite the considerable resources invested in the health information systems, it did not generate the expected returns on investment (DoH, 2012).

“Although Telemedicine has long been recognized as an effective means to overcome the challenges in rural health settings in South Africa, there has also been a lot of scepticism about the practicalities of the technology” (MRC, 2011). *This may partly be blamed on the limited success of the national Telemedicine Programme initiated by NDoH and NHIS/SA in 1999 and 2000 (DoH, 2012). Despite the slow start, it still holds much promise as a tool to support the delivery of healthcare, especially in rural settings in South Africa. Telemedicine attracts considerable interest and innovation among academics, researchers, private enterprise and health professionals. Since 1999 there have been some noteworthy achievements within the public health domain. The NDoH recognizes the potential of telemedicine as an “enabling tool that could bridge the gap between rural healthcare and specialist facilities”* (MRC, 2011).

However, after installation of the hardware, the various services were handed over to the provinces to maintain and expand. *“While aspects of the programme showed promise there was limited uptake of the project and it was not successful. There is little to suggest that circumstances have changed, as a major problem factor in the implementation of the project was the shortage of healthcare workers in the State sector and their reluctance to take on any additional work. A second factor was the top down approach and the lack of capacity and failure to manage change”* (Mars *et al.*, 2008).

In the past decade over eighty-eight telemedicine projects were initiated by the NDoH and implemented in various parts of South Africa (Nkgapele, 2010). The majority of them are now defunct, mainly due to lack of funding (Fortuin *et al.* 2015). There are only a few telemedicine services at provincial level that are still functioning, and this includes teleradiology and teledermatology (Fortuin *et al.* 2015).

The poor outcome of the health information systems led to the development of an eHealth Strategy for South Africa. This strategy aims to support the strategic objectives of the Department of Health in a way that is comprehensive, pragmatic and innovative (DoH, 2012). It defines eHealth as a broad domain that includes mHealth, telemedicine and all information and communication technologies to promote, support and strengthen healthcare (DoH, 2012). This eHealth strategy provides an opportunity for South Africa to initiate teledentistry into the public healthcare system. The National Department of Health (NDoH) is optimistic about the success of the new eHealth strategy, and implementation is being closely monitored by the Ministry of Health and the National Health Council to ensure that the previous errors are not repeated (DoH, 2012). Hence, the eHealth Strategy brings about optimism and new horizons of a successful future of a well-oiled fully functional health information system for South Africa.

2.6 Methods of teleconsultations via teledentistry

2.6.1 The store-and-forward method

The store-and-forward method (Figure 1) Involves the exchange of clinical information and static images collected and stored by the dental practitioner, who forwards them for consultation and treatment planning (Chang *et al.* 2003) via established networks and/or the internet, and treatment is thus provided in a far timelier, targeted, and cost-effective manner (Panat *et al.* 2012). This method allows data to be stored in a local database to be forwarded as needed (Shirolkar *et al.* 2011).

2.6.2 Real-Time Consultation

Real-Time Consultation (Figure 2) involves a videoconference in which dental professionals and their patients, at different locations, may see, hear, and communicate with one another (Bhambal *et al.* 2010). Interactive videoconferencing may be connected via POTS (plain old telephone service), satellite, ISDN, internet or intranet (Chhabra *et al.* 2011). This method of consultation actually uses ultra-high-bandwidth network connections (Bhambal *et al.* 2010). With the real-time method information is transferred immediately (Shirokar *et al.* 2011). “Near-Real-Time” consultations involves low resolution, low frame rate product that looks like jittery television (Jampani *et al.* 2011), it the least popular method of teleconsultation.

2.6.3 Remote Monitoring Method - where patients are monitored at a distance and can either be hospital-based or home-based (Jampani *et al.* 2011).

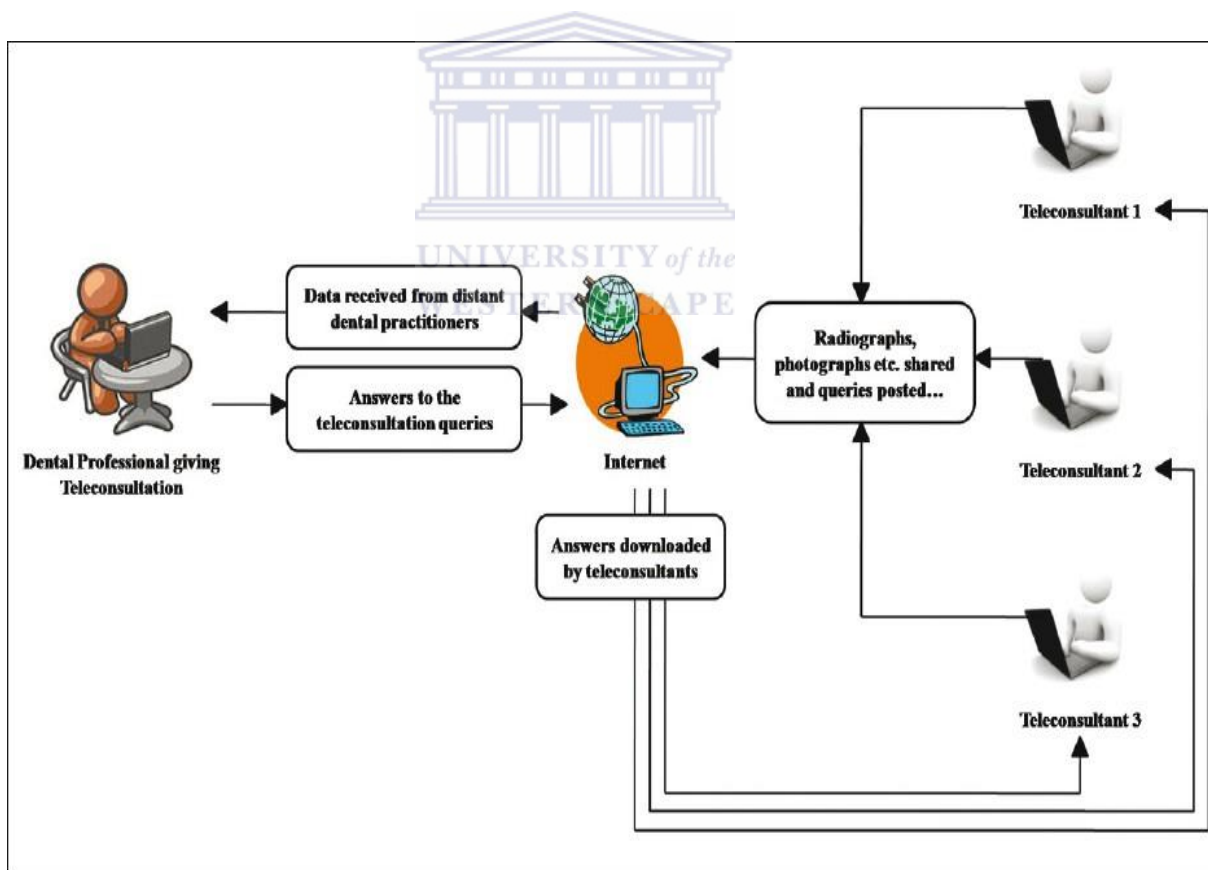


Figure 1. Store-and-forward consultations (Jampani *et al.* 2011)

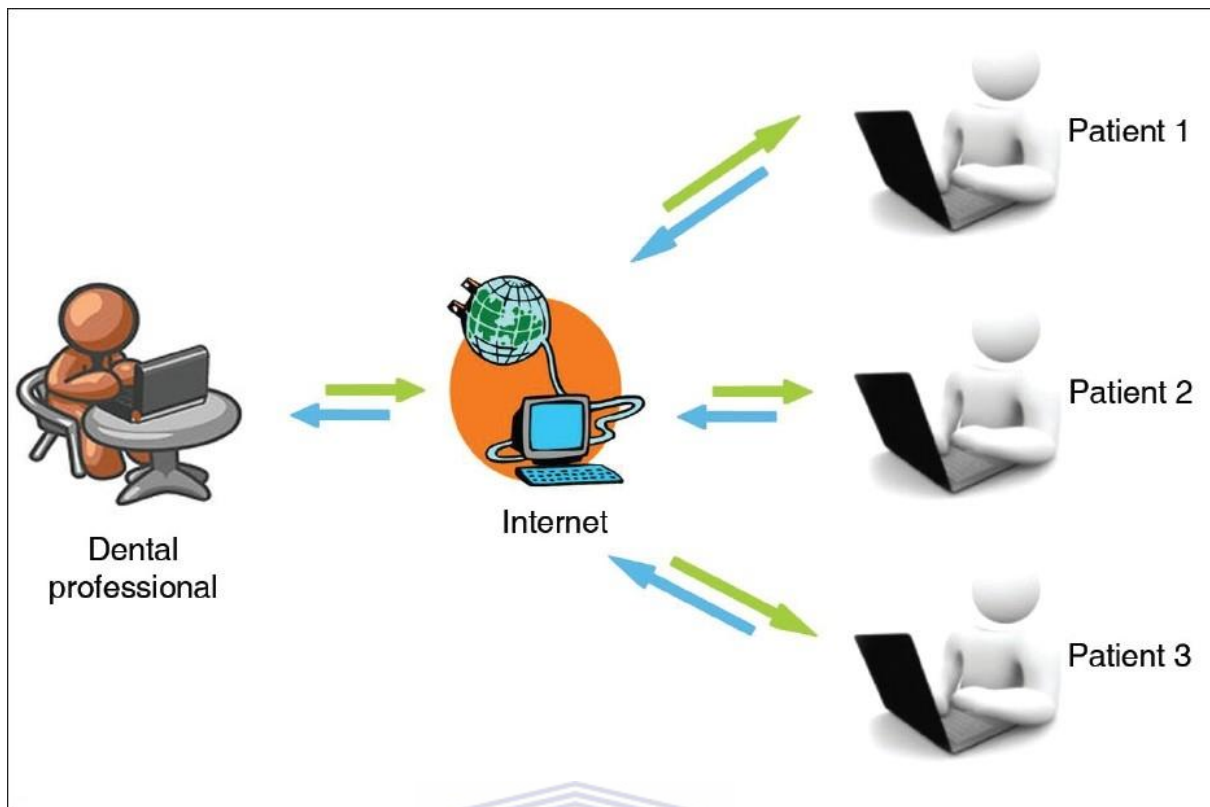


Figure 2. Real -time consultations (Jampani *et al.* 2011)

In most health care applications, whether utilizing store and forward or two-way interactive (real-time) technology, clarity and detail of the data are the most important factors to be considered (SOIHP, 2006). Speed of data transfer and the compatibility, interoperability, scalability, accessibility, and reliability of the technology are also significant (SOHIP, 2006).

For the above teleconsultation methods to be successfully carried through there are various tools that can be used. Panat *et al.* (2012) describe the tools as follows:-

POTS- Plain old telephone system, which is the most widely used system as it is low cost. Data exchange is possible with the help of a fax machine.

ISDN- Integrated services digital network provides high speed and information can travel in both directions simultaneously.

World Wide Web (www) – The www was invented in 1989 by Berners-Lee (Eaton *et al.* 2008). This is a popular tool now-a-days, as it does not require special networks like ISDN.

T1- This is the backbone of digital service provided to the end user (typically business) in USA today which transmits voice and data digitally at 1.554 megabits per second (Mbps). It can be used to carry analogue and digital voice, data and video signals and can even be configured for ISDN service (Dasgupta *et al.* 2008).

POTS works through a telephone company often with low speed and unreliable connection (Shirolkar *et al.* 2011), however it is the most widely available telecommunication technology in the world (Dasgupta, 2008). With the ISDN there is increased accessibility and reliability in teledentistry, however, building an international ISDN network is expensive and impractical (Shirolkar *et al.* 2011). Web-based teledentistry, unlike ISDN, does not require a special network, and, hence is more cost-effective. However, there are no rules, no licensure, no verification and little accountability with internet services (Shirolkar *et al.* 2011). In addition, web-based networks can be infiltrated by hackers, presenting security problems. An ISDN network, on the other hand, is connected from one point to another with no network sharing. Live videoconferencing can also be conducted through satellite (Panat *et al.* 2012). It is essential to have a desktop or laptop computer with substantial hard drive memory, a significant amount of random access memory (RAM), and a speedy processor (Shirolkar *et al.* 2011). For the imaging process, a digital camera, video camera, intraoral camera, and a panoramic digital X-ray unit (preferably portable), is needed to provide consulting dentists with images of maximum clinical value (Shirolkar *et al.* 2011). With PC-based videoconferencing, a microphone, headset or external speaker, and a webcam are highly desirable (Shirolkar *et al.* 2011). Initially, the tools required to make teledentistry possible, are expensive, however, great value may be derived in the long term.

2.7 Uses of teledentistry

2.7.1 Specialist referral and diagnosis services

Involves a specialist assisting a general dental practitioner (GDP) to diagnose and manage a patient (Sudarshan *et al.* 2013). Teledentistry specialist consultations can take place using either the store-and-forward or the real-time method. Through the use of telecommunications and computer technologies, it is now possible to provide interactive

access to specialist opinions that are not limited by the constraints of either space or time (Jain *et al.* 2013), thus making specialist care accessible to critical access areas.

In this process the referring GDP logs into a secure web server and enters the patient's details, the reason for the consultation, the chief complaint(s), and provisional diagnosis information and attaches the digital intraoral images and dental radiographs. The specialist consultant then logs into the secure web server, reviews the submitted case and within a limited time frame makes a diagnosis and suggests a possible treatment plan (Chhabra *et al.* 2011). This is an asynchronous teleconsultation (store-and-forward) method.

The synchronous teleconsultation (real-time) method will involve a videoconference between the patient, GDP and the specialist, where the communication between the professionals and the patient is synchronous and all parties can see and hear each other. The advantage of this method is that the user can receive immediate feedback (Chen *et al.* 2003). Specialist consultations via videoconferencing was well received in a study in Minnesota where the majority of patients felt comfortable visiting the doctor through a videoconference service (Chen *et al.* 2007). Many patients felt that the teledentistry visit was “the same as in-surgery or in person”, “just through the TV” (Chen *et al.* 2007).

2.7.2 Teledentistry and Dental Education

A systematic review of the literature revealed that the most common use of teledentistry is in education, followed by diagnosis, consultation and treatment (Marino *et al.* 2013). Videoconferencing and internet technologies allow low-cost, real-time interactive, two-way communication between instructors and trainees, making long-distance education more virtual and affordable (Friction *et al.* 2009). Continuing dental education and long distance clinical training can be carried out via videoconferencing and internet technologies (Friction *et al.* 2009), although most professionals are unaware that teledentistry can be used not only for increased access to dental care but also for advanced dental education (Ozkan Ata *et al.* 2009). Teledentistry provides an opportunity to supplement traditional teaching methods in dental education, and provides new opportunities for dental students and dentists (Chen *et al.*, 2003).

Teledentistry has the potential to increase the number of dental specialist trainees and specialists in sparsely populated areas. Ignatius *et al.* (2006) carried out a study in Finland from 2002 to 2005 for dental specialist training. A total of 26 dental specialist

trainees who were resident in eight different cities participated: Turku, Tampere, Vaasa, Seinajoki, Jyvaskyla, Forssa, Salo and Pori (Ignatius *et al.* 2006). University lectures were transmitted to various training locations using IP-based videoconferencing, and the lectures were carried out on average twice a week.

The overall rating of videoconferencing as a tool for specialist training was rated as excellent (15%), good (62%), neutral (15%) and poor by 8% (Ignatius *et al.* 2006). If teledentistry was not available to the participants in this study, they would have needed to travel to the University of Turku approximately 80 times each year (over a three year training period) (Ignatius *et al.* 2006). In this way opportunities were created for specialist training without having the trainees travel long distances thereby saving them time and money.

Online education can be of two types: web-based self-instruction and interactive videoconferencing. The web-based self-instruction system contains information that has been developed and stored before the user accesses the program. The advantage of web-based self-instruction is that the user can control the pace of learning and can review the material as many times as he/she wishes (Mittal *et al.* 2011). A disadvantage of web-based self-instruction is dissatisfaction which may be due to the lack of face-to-face communication with peers and instructors (Mittal *et al.* 2011), however, there may be professionals who prefer web-based self-instruction to face-to-face communication as they can then review material in their own time.

The interactive videoconferencing system is conducted via POTS, satellite, ISDN, internet or intranet. Interactive videoconferencing includes both a live interactive videoconference with a proper camera set up where the patient's information can be transmitted; and supportive information (such as the patient's medical history, radiographs, etc) that can be sent before or at the same time (for example, via fax) as the videoconference (Chen *et al.* 2003). The advantage of interactive videoconferencing is that, there is two-way communication between instructors and trainees, and the user can receive immediate feedback, which enhances students' enthusiasm for learning (Chen *et al.* 2003, Spallek *et al.* 2002). The teledentistry videoconferencing system can be used to help train dentists, dental students, assistants, and other office support staff at remote sites in the clinical management of orofacial disorders and other conditions (Friction *et al.* 2009).

2.7.3 Teledentistry remote patient monitoring or home-healthcare

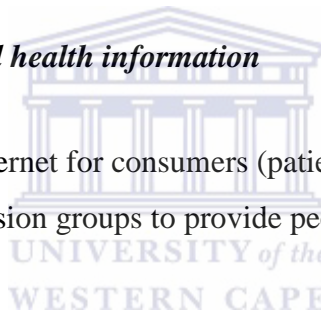
Remote patient monitoring uses medical devices attached to a patient that collect and send patient data to a remote monitoring station for interpretation (Chandra *et al.* 2012).

2.7.4 Patient consultations

Telecommunication is used to provide medical and dental/oral health data, which may include audio, still or live images. Data is exchanged between a patient and a health professional for use in forming a diagnosis and treatment plan (Sudarshan *et al.* 2013). This method of consultations via teledentistry can eliminate the hundreds of miles some patients have to travel (especially patients in the underserved areas) to receive dental care. Laboratory communications via teledentistry could also improve patient care (Chen *et al.* 2003).

2.7.5 Consumer medical and health information

This includes the use of the internet for consumers (patients) to obtain specialized health information and on-line discussion groups to provide peer-to-peer support (Sudarshan *et al.* 2013).



2.7.6 Dentist – Laboratory Communications

Communication between the dentist and the technical laboratory is enhanced via teledentistry. Difficult cases that need to be submitted to the lab (that requires direct contact between the dentist and the lab technician) can be more efficiently addressed with teledentistry which has the ability to send colour images of the patient's teeth and these images are then discussed between the dentist and lab technician (Chen *et al.* 2003). Thus this process can essentially save travel costs for both the patients and the laboratory by preventing poor quality and ill-fitting dental appliances.

2.8 Benefits of teledentistry

Teledentistry has the capacity to improve oral health care in various ways. Teledentistry allows one to receive specialty care in one's own community (Kopycka-Kedzierawski *et al.* 2007). In developing countries like India, most of the population lives in rural areas, where healthcare facilities are not enough (Baheti *et al.* 2014). Teledentistry can have a meaningful contribution in bridging the gap between the demand and supply (Shelley *et al.* 2007).

Communities can have greater access to specialist care and advice via teledentistry. A study carried out at the School of Dentistry, University of Minnesota highlighted the advantages of using a combination of electronic health records and videoconferencing to increase access of dental specialty care for underserved communities (Chen *et al.* 2007). Specialty consultations for patients with orofacial disorders including TMD, orofacial pain, oral medicine, and oral pathology conditions such as xerostomia, burning mouth and oral lesions were carried out (Chen *et al.* 2007). A provider satisfaction survey showed that even though none of the providers had previous experience with the teledentistry system, in over 90% of the visits, the specialists were satisfied with the teledentistry consultation (Chen *et al.* 2007).

In many instances specialist care requires more than one visit and many patients particularly those in the underserved communities may not be able to afford to travel for specialist care. The use of teledentistry reduces the stress associated with transportation, will save travel costs, time and access to continuing care (Chen *et al.* 2007). A study carried out in Minneapolis showed high patient satisfaction levels with the teledentistry service, with the greatest benefit being convenience and access to care. Patients travelled 13 miles to visit the teledentistry clinic - on average less than two hours, compared to eighteen hours if the patient had to travel to Minneapolis (Chen *et al.* 2007). Teledentistry allows the general dental practitioner (GDP) to relay multimedia patient records to dental specialists, often enabling the specialist to make a diagnosis and develop a treatment plan without having to see the patient (Jain *et al.* 2013). Thus this improves diagnostic services, as the GDP is getting a specialists input without the patient having to travel to the specialist. In addition the GDP can have immediate access (via real-time teleconsultations) to specialist advice when required, thus fast tracking diagnostic services.

Furthermore, the GDP does not feel isolated as teledentistry offers increased peer contact, easy access to specialist support and postgraduate education (Bauer *et al.* 2001; Steed, 2000) and thereby improving oral healthcare service delivery.

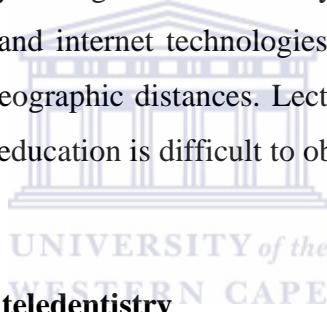
Teledentistry improves the integration of dentistry into the overall health care delivery system (Jain *et al.* 2013). For example, if a patient presents with HIV oral lesions, the GDP can liaise with the patient's general practitioner to determine a holistic treatment plan. Many interventions for chronic diseases such as diabetes, hypertension, tobacco cessation, and obesity management work best when supported by coordinated and collaborative care among several types of healthcare providers (Schleyer *et al.* 2012). Interdisciplinary collaboration prevents compartmentalization of dental and medical conditions, which in turn improves general patient care.

An additional benefit of teledentistry is its ability to increase access to dental care, as dentists are able to use networked computers to deliver dental care in ways that do not require face-to-face contact with patients (Cooper *et al.* 2007). If a dentist does not need to be physically present to perform an examination on a patient, more patients who do not normally have access to dental care may be consulted, managed and treated (Cooper *et al.* 2007). For instance, a dental therapist in a remote site can engage a teledental consult with a dentist or a dentist in a remote site can engage a teledental consult with a dental specialist for guidance on management of a patient. This thus makes specialist consults accessible to patients who do not have access to this type of care. This type of teledental consults can also eliminate unnecessary specialist or dentist travel costs if the problem can be attended to by the dental clinician based in the clinic. People living in rural areas often have substantial oral health care needs and limited access to dental providers (Allokian, 2000). For example, in South Africa it is estimated that in the public sector there is 2.31 dentists per 100,000 population (Health Systems Trust, 2012a), and a fair percentage of people in rural areas do not have access to oral health care. Oral healthcare should be an individual's right, not a privilege irrespective of geographic location. Hence, teledentistry can facilitate the provision of dental care in areas underserved by oral health care workers, and overcome social and geographic barriers (Chang *et al.* 2003).

Some studies have shown poor/no cost savings (Scuffham *et al.* 2002) or undetermined cost factors related to the use of teledentistry (Mandall *et al.* 2005) however, it is surmised that the cost factor is beneficial in the long term, it is usually an initial

investment that can be used to record data for many years as compared with regular investment in the on-going purchase of paper records (Chandra *et al.* 2012). In addition, there may be added cost savings with regards to the reduced time required for teledentistry patient visits and the elimination of paper record will decrease carbon footprints and assist in combating global warming. Second opinions, preauthorization and other insurance requirements will be met almost instantaneously online, with the use of real images of dental problems rather than tooth charts and written descriptions (Bauer *et al.* 2001). The electronic transmission of data can save time (for both the practitioner and the patient) and omits costs incurred for postage.

Occasionally, cases submitted to the dental laboratories have subtle complications or aesthetic nuances that require direct contact between the dentist and the laboratory technician (Rocca *et al.* 1999). In these instances, the ability to send colour images of the patient's teeth and then to discuss issues face-to-face can help prevent improperly constructed appliances, thereby saving time and money (Rocca *et al.* 1999). Through the use of videoconferencing and internet technologies, continued dental professional development can occur over geographic distances. Lectures can be broadcasted to any clinic where continuing dental education is difficult to obtain (Rocca *et al.* 1999).



2.9 Problems associated with teledentistry

It has been documented that one of the major challenges in a teledentistry visit is the collaboration between the hub site and the remote site (Chen *et al.* 2007; Friction *et al.* 2009). Because the consultation is remote in nature, the dental teams at both sites must collaborate for a smooth teledentistry process. The challenge begins with making the concurrent appointment time at both sites, progresses through the collection of patient information and its transmission to the specialist, facilitating the remote real-time examination, and ends with facilitating the plan for treatment and future care (Friction *et al.* 2009).

The specialist may be at a disadvantaged in that he/she has to rely on the hands-on examination process that has been carried out by the dental team at the remote site and important information may sometimes be overlooked. (Friction *et al.* 2009). With an asynchronous teledentistry method (store-and-forward), the specialist will need to make a diagnosis based on the data collected by the dental team at the remote site.

Another challenge as documented in a study at the School of Dentistry, Minnesota was that teledentistry visits were as time-consuming as a regular in-office visit and in some instances took even more time particularly when providers were new to the system. Efficiency was found to improve with experience (Chen *et al.* 2007). (Chen *et al.* 2007). Although teledentistry may present as a promising alternative in making oral health care accessible to the underserved, there are legal and ethical issues, including licensure, malpractice, privacy and security (Baheti *et al.* 2014).

2.10 Uses of teledentistry in different disciplines

Teledentistry is part of a broader application of telemedicine that has various discipline-related subsets (Figure 3). These are described individually below.

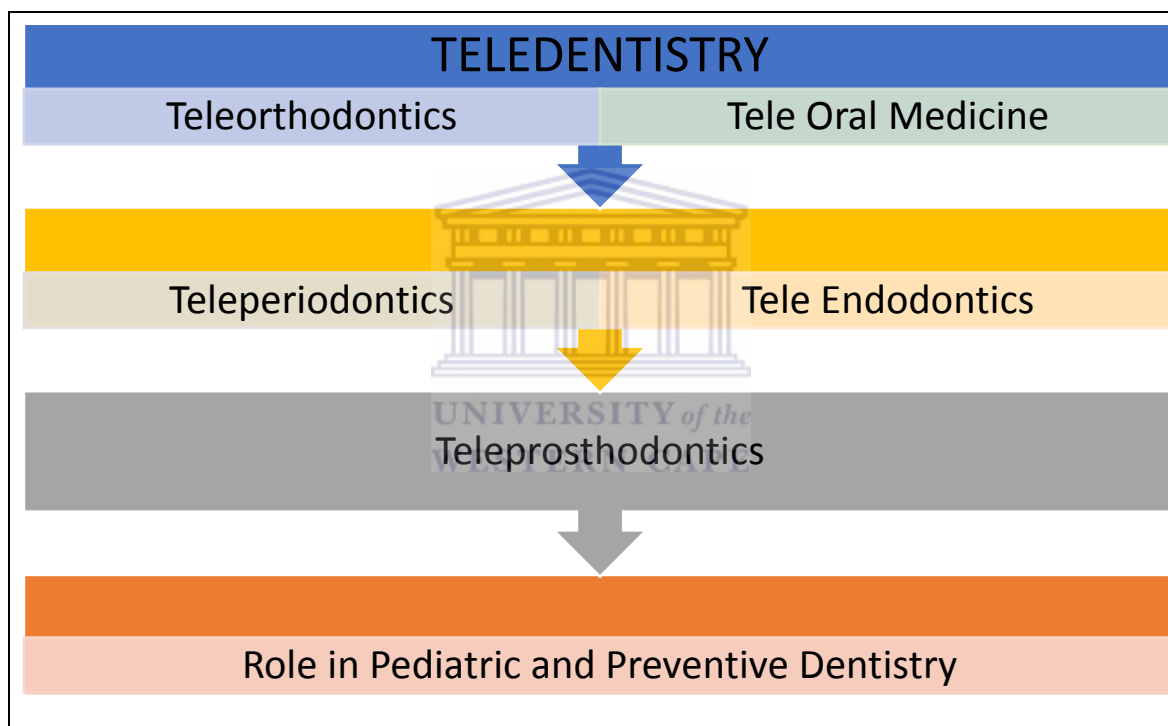


Figure 3. Diagrammatic representation of the subsets of Teledentistry

2.10.1 Teleorthodontics

Teledentistry can serve as a valuable tool in the field of orthodontics, where orthodontic specialty services can be made available to communities who so not have access to such care (Krupinski *et al.* 2001). A feasibility study carried out by Berndt *et al* (2008) suggests that interceptive orthodontic treatments provided by sufficiently prepared GDPs and supervised remotely by orthodontic specialists through teledentistry is a viable approach to reduce the severity of malocclusions in disadvantaged children when referral to an orthodontist is not feasible (Berndt *et al.* 2008).

In the United Kingdom teleorthodontics is widely practiced (Arora *et al.* 2014). There are 920 orthodontists for a population of 56 million (Scuffham *et al.* 2002; Stephens *et al.* 2002) and almost all the children who receive orthodontic care in the United Kingdom, do so within provisions of the United Kingdom National Health Services (NHS) (Cook *et al.* 2002). The NHS appoints GDPs to undertake orthodontic treatment (Stephens *et al.* 2002). Cook *et al.* (2001) tested an online teledentistry service and showed that it helped to reduce the high level of inappropriate orthodontic referrals to consultants and provided GDPs with quick access to advice that would enable them to manage a wider range of orthodontic cases, saving costs, time and travel expenses for the patient. A survey by Bradley *et al.* (2007) reported that GDPs had a positive attitude towards the benefits of using teledentistry to obtain advice from orthodontic consultants (Bradley *et al.* 2007). With plans for the implementation of the National Health Insurance (NHI) in South Africa, there is potential to utilize teledentistry and its subsets. For example, using the same system that the NHS used, GDPs in the dental clinics/hospitals can provide orthodontic specialist advice to children in SA who currently probably are not even exposed to this type of specialist care due to the shortage of dental specialists in South Africa.

Interceptive orthodontic care via teledentistry was provided at a rural and an inner-city clinic in the state of Washington (Bhambal *et al.* 2010). Using the Peer Assessment Rating (PAR) index to score the outcomes of the procedure, the authors found that the general dentist fared nearly as well with the aid of teledentistry as the students did under direct supervision (Bhambal *et al.* 2010). GDPs were able to provide orthodontic care to patients under the guidance of an orthodontist via teledentistry and reduced the number of inappropriate referrals (Cook *et al.* 2001).

In Melbourne, Australia, a teledentistry study was carried out to increase specialist care to children in rural and regional areas. One of the specialties studied was orthodontics. A trained dental practitioner at a remote site examined patients using an intraoral camera (Marino *et al.* 2014). Patients received virtual assessments by the orthodontist, and did not need to travel to receive specialist advice. The study demonstrated that teledentistry can be a highly effective mechanism for enhancing early diagnosis and referral for patients who otherwise might not receive early orthodontic care (Marino *et al.* 2014). Orthodontic consultations via teledentistry have been shown to save time and money by avoiding unnecessary travel for both the patient and the specialist (Mihailovic *et al.* 2011; Favero *et al.* 2009).

2.10.2 Tele Oral Medicine

Teledentistry has been used for the diagnosis and management of oral mucosal diseases (Panat *et al.* 2012). In many instances, GDPs practicing in remote areas refer patients with oral mucosal lesions to a specialist (who may be located at a distant site) when confronted with pathology they are unfamiliar with or require a second opinion. By using teledentistry, images of the oral mucosal lesion(s) can be captured using an intraoral camera, and these images together with the patient's history can be emailed to a specialist at a distant site for diagnosis and treatment planning.

A pilot study carried out at the Oral Medicine Department, University of California at Los Angeles on the diagnosis and management of oral mucosal diseases found that face-to-face patient examination was more accurate in establishing a correct diagnosis for oral mucosal pathologies than transmitted descriptive patient data alone (Bhambal *et al.* 2010). Younai *et al.* (2000) suggested that until adequate data transfer (including text and visual information) by the consulting practitioner is possible, the e-mail may be best for exchanging ideas, disseminating the latest scientific information, and discussing the potential diagnoses (Younai *et al.* 2000). However, with recent advancements in technology, teledentistry has made 'distant' diagnosis of oral diseases a possibility, especially to communities that do not have access to specialty services. The use of two distant consultants improves diagnostic accuracy (Torres-Pereira *et al.* 2008). Furthermore, advances and availability of smart phone technology have contributed to the feasibility and availability of telemedicine in oral and maxillofacial surgery (Aziz and Ziccardi, 2009).

Despite the fact that tele oral medicine may benefit dental public health clinics where there are no dental specialists an economic analysis from Ireland found no real cost-savings from the use of teledentistry, but suggested that cost-effectiveness improves with greater familiarity and use of equipment and requires long-term evaluation. Benefits and cost-savings are greatest in remote communities, where patients need to travel long distances to hospital for specialist consultations (Scuffham *et al.* 2002).

For example, in South Africa it is estimated that in the public sector there is 2.31 dentists per 100,000 population (Health Systems Trust, 2012a) and 0.33 dental specialists per 100 000 population (Health Systems Trust, 2012b); even though there has been an improvement on this dental practitioner to population ratio (from 1.70 dental practitioner per 100 000 population for year 2000 to now) and dental specialist to

population ratio (from 0.20 dental specialist per 100 000 population for year 2000 to date), there remains a critical shortage of dental professional human resources in the public sector. Therefore, to improve the availability and accessibility of patients to specialist services, teledentistry has the potential to reach a larger population especially areas with a poor dental practitioner/specialist to population ratio.

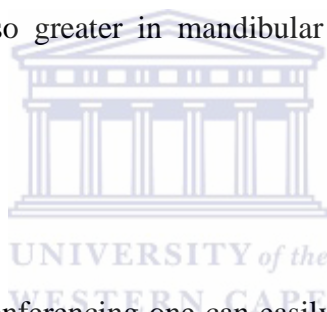
2.10.3 Teleperiodontics

Teledentistry was first tested by the US army at Fort Gordon, Georgia in July 1994 (Rocca *et al.* 1999). Using an intraoral camera, a dental management system captured colour images of a patient's mouth which were then transmitted from the dental clinic to Fort Gordon (a distance of 120 miles) using a 9600 band modem (Bhambal *et al.* 2010). Fifteen patients were referred to Fort Gordon for periodontal surgery. A week after surgery the patients' sutures were removed at Fort McPherson under telesupervision by the periodontist who performed the surgery. During suture removal colour images were captured and forwarded to Fort Gordon for examination by the periodontist. The results of this study showed that 14 of the 15 patients saved the return trip to Fort Gordon. The patients reported that they had received better care than they normally received and were especially grateful for not having to make long trip to Fort Gordon (Rocca *et al.* 1999). From a consultants' point of view, the dentists were comfortable in their ability to make adequate decisions and diagnosis using the equipment (Rocca *et al.* 1999).

2.10.4 Tele Endodontics

Periapical lesions constitute a large portion of dental pathology and their treatment is commonly performed by dentists who are not specialists in endodontics. Problems related to their differential diagnosis and prognosis lesions can result in complications and a waste of time and money for both the patients and the dentists (Mihailovic *et al.* 2011). Teledentistry can prove to be invaluable in gaining access to expert guidance and assistance in this regard. The process of tele-endodontics is similar to other disciplines. The GDP captures the images of the teeth in question with an intraoral camera. These images, together with the accompanying patient history is then forward to the consulting endodontist via email.

Zivkovic *et al.* (2010) demonstrated that teledentistry based on the internet as a telecommunication medium can be successfully utilized in the diagnosis of periapical lesions of the front teeth, reducing the costs associated with distant visits and making emergency care available. Brullmann *et al.* (2011) reported that dentists in remote areas can identify root canal orifices based on images of endodontically treated teeth. In their study 50 images of endodontically treated teeth were taken with an intraoral camera, stored on a laptop and presented to 20 observers who marked the visible canal orifices using software that stored the canal locations in standard files. The marked positions were verified on histological slices and 87% of the canals were marked correctly (Brullmann *et al.* 2011). There was that no statistical difference in the ability to identify periapical bone lesions using a conventional radiograph on a viewbox and interpret the same images transmitted on a monitor screen by a video teleconferencing system (Baker *et al.* 2000). Dentists with more than 10 years of experience were more accurate in detecting canals than those with less experience (Daniel *et al.* 2013). In addition, accuracy of detection was also greater in mandibular molars than maxillary molars (Brullmann *et al.* 2011).



2.10.5 Teleprosthodontics

In rural areas, through videoconferencing one can easily diagnose and plan a treatment for patients that require oral rehabilitation or prosthetic appliances (Panat *et al.* 2012) and it has the potential to increase the total number of dental specialist services in sparsely populated areas (Ignatius *et al.* 2010).

2.10.6 Role of teledentistry in Paediatric and Preventive Dentistry

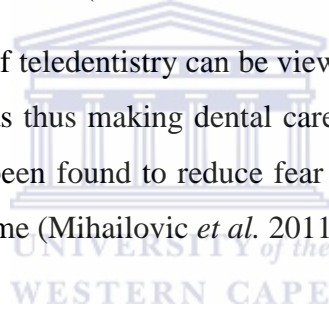
Prevention and early detection are the key to combat dental caries especially in young children. Teledentistry has been successfully applied as a dental screening tool (Kopycka-Kedzierawski *et al.* 2008, Kopycka-Kedzierawski *et al.* 2007), thereby eliminating direct dental clinical examinations.

Furthermore, the distant diagnosis of paediatric dental problems, based on non-invasive imaging, was found to be appropriate for diagnosing dental problems and suggesting treatment options (Amavel *et al.* 2009).

Panat *et al* (2012) found teledentistry to be a good tool for screening dental caries in schoolchildren, and school going children can be divided into different categories of high risk or low risk patients. This risk triage can assist dental professionals in tailoring curative and preventive packages to assist communities in combating dental caries in schoolchildren.

Intraoral cameras are used for visual examination and early detection of childhood caries (Bauer *et al.* 2001). However, the success rate of the teledentistry systems largely depends on the quality of the intraoral cameras used (Mihailovic *et al.* 2011). An intraoral camera should be adequately shaped to be easily placed in any place of interest and take dental photographs from any available angle; in addition, sufficiently strong and focused illumination from the camera itself is required, as well as optical or software reduction of light reflected from the smooth surface of the teeth. Together with the high resolution, the obtained digital image is able to demonstrate initial caries stages or enamel and dentine pigmentations (Mihailovic *et al.* 2011).

One of the primary functions of teledentistry can be viewed as a dental screening tool in distant and critical access areas thus making dental care accessible to the underserved. In addition, teledentistry has been found to reduce fear and anxiety when compared to clinical examinations in real time (Mihailovic *et al.* 2011).



2.11 Dental caries and teledentistry

Dental caries is clinically defined as a disease of the hard tissues of the teeth caused by the action of plaque microorganisms on fermentable carbohydrates (principally sugars) (Kidd, 2005). A more holistic definition being that “Caries is a social, political, behavioural, medical and dental problem that can only be controlled through understanding the dynamic changes that are taking place in society particularly as they pertain to family structure, nurturing of children and socioeconomic status” (Ismail, 1998). The latter definition prevents a compartmentalised approach which essentially separates the mouth from the rest of the body (Watt, 2007).

Dental caries is the single most common chronic disease of childhood, that occurs five times as frequently as asthma, and as seven times more commonly than hay fever (Department of Health and Human Services (DHHS), 2000). It is a preventable and reversible infectious disease process, which if left untreated, can cause pain, infection,

speech disorders, poor mastication, low self-esteem, premature tooth loss and harm to the permanent dentition (Kagihara *et al.* 2009). Even though dental caries is a preventable disease it still persists as a public health problem and in fact dental it is a global oral health problem in both developed and developing countries (Petersen, 2004). The most recent South African National Oral Health Survey reported that only 39.68 per cent of the six year-old age group was caries-free, below the target of 50 per cent set by the National Department of Health for the year 2000 for South Africa. In addition, the report revealed that 80 per cent of carious lesions in children go untreated (Van Wyk *et al.* 2004; DoH, 2003). South Africa is challenged by its high dental needs of children, especially in the rural areas. Unfortunately, due to the shortage of dental professionals in the public sector, these needs are difficult to meet.

Dental caries has underlying multifactorial determinants (Singh, 2011), implicating poor access to and availability of oral health services as one of the causative factors. Teledentistry may assist in making dental care accessible to geographically challenged communities, hence, reducing the dental caries burden in both children and adults. Teledentistry has been shown to improve access to general and specialized dental care especially for the marginalised communities (Friction *et al.* 2009; Berndt *et al.* 2008; Kopycka-Kedzierawski *et al.* 2008; Kopycka-Kedzierawski, 2006; Chang *et al.* 2003).

Teledentistry screening has been successfully used as a diagnostic tool for dental caries in children. In Rochester, New York, within six inner-city elementary schools and seven child-care centres, telehealth centres were established for dental screenings to be performed. Intraoral cameras were used to capture digital images of the children's teeth and these were transmitted to the expert dental site (Eastman Department of Dentistry at the University of Rochester) for diagnosis, referral and treatment recommendations. Nearly half of the children examined were diagnosed with dental caries and the children's parents/guardians were promptly contacted to assist in obtaining the appropriate dental care for their children (Koycka-Kedzierawski *et al.* 2006). This screening system for dental caries could be a beneficial system for South Africa to invest in as it has the potential to enhance the delivery of oral health care to SA's disadvantaged majority. However, the necessary training and education is essential.

Dental caries is a disease that can be prevented and there are numerous effective treatments available.

Use of fluoridated toothpastes: a Cochrane systematic review of 70 trials concluded that fluoride toothpastes were effective in the prevention of dental caries in children and adolescents (Marinho *et al.* 2003). School brushing programmes can be advocated using fluoridated toothpastes.

Topical fluoride varnish: topical fluoride varnish is effective in the prevention of decay in permanent teeth (Marinho *et al.* 2003; Bader *et al.* 2001). Fluoride varnishes should be applied to the dentition at least twice a year for high risk preschool children (Scottish Intercollegiate Guidelines Network, 2005). It can also be incorporated into school oral health programmes.

Communicating oral health messages and oral health promotion: The goal of oral health promotion is the adoption of appropriate dental health habits as socially acceptable behaviour the development of knowledge, skills, and the creation of supportive environments (Rayner *et al.* 2003). Oral health education can be delivered effectively by teachers, care givers and community workers and can be successfully incorporated into established programmes and practices in other sectors (Sprod *et al.* 1996). ICTs can be effectively used to communicate oral health messages to educators, parents and guardians who may in turn relate them to their learners and children. These oral health messages can function as an adjunct to other preventive oral health procedures, for example, use of fluoridated toothpastes together with school brushing programmes which can be reinforced with oral health messages via ICT's to educators and parents.

Fluoride mouth rinses: using fluoride mouth rinses in addition with a twice daily fluoride brushing has shown to remineralise carious lesions (Ten Cate, 2013). The use of a fluoride mouthwash is contraindicated in young children due to their inability to expectorate (Rayner *et al.* 2003).

The use of teledentistry screening and clinical screenings for dental caries in young children has been shown to be both cost-effective and valid (Amavel *et al.* 2009; Kopycka-Kedzierawski *et al.* 2007), with no significant difference between the use of clinical and teledentistry screenings in assessing prevalence of early childhood caries (Kopycka-Kedzierawski *et al.* 2011).

Teledentistry screening does not require professional oral health care workers to carry out the dental imaging, but rather any individual can be trained to carry out the procedure. This means that dental professionals can be better utilised in primary healthcare clinics. For example, due to the shortage of skilled dental health professionals in South Africa, it is imperative that the dentist is available in the clinics to provide curative and preventive care to the patients that travel long distances to get to a clinic. The majority of the dental clinics in rural South Africa are generally staffed by one dentist and if the dentist has to go out to surrounding schools in the community to perform screenings, there will be nobody to perform the high skilled dental treatment in the busy rural clinics. In addition, trained individuals can deliver preventive dental care and oral health promotion messages in remote or critical access areas (Van Hilsen *et al.* 2013).

Children at high-risk for dental caries may be effectively screened for the presence of non-cavitated lesions utilizing telehealth technologies (Kopycka-Kedzierawski *et al.* 2008; Kopycka-Kedzierawski *et al.* 2007). The children's teeth can be screened with an intraoral camera by dental assistants or non-dental personnel that have been trained with the teledentistry system, and these captured images can then be forwarded to a dentist in a remote site for interpretation and assessments.

A potential future alternative to using the intraoral camera for capturing images, is the use of smartphones. A recent study in Australia was carried out using smartphone cameras to capture intraoral images (carried out by teledental assistants) on six volunteers to evaluate a cloud-based telemedicine application for screening for oral diseases (Estai *et al.* 2015). An image acquisition Android application was developed and installed on the smartphone to facilitate entering patient personal details and capturing the dental photos, and then uploading data corresponding to each patient to cloud storage, using either Wi-Fi hotspots or the cellular data networks (Estai *et al.* 2015). Broadband network was used to transmit data from the smartphone to the cloud-based server, which rural areas are likely to have access to. The dental screening data is stored on a Remote-i server which users can log in to using any web browser (chrome, Mozilla, Firefox, Safari) from any location. However, only authorised users (investigators and teledental examiners) can access the data via individual user IDs and passwords. For security purposes, all data transmissions go over encrypted internet connections such as Secure Socket Layer (SSL) and hypertext transfer protocol over SSL (Estai *et al.* 2015).

The assessments of the oral images (30 oral images were obtained and 192 teeth reviewed) were carried out by two offsite dentists and these assessments were compared to those carried out via face-to-face visual oral examinations of the same six volunteers. The intra-grader agreement (kappa value 0.70=70%) indicated that the smartphone imaging and cloud-based screening system of oral diseases can be implemented to provide a valid and reliable alternative to traditional oral screening (Estai *et al.* 2015). However, this study was only a proof-of-concept trial and a full study is needed to confirm the accuracy and reliability of this system (Estai *et al.* 2015). Furthermore, this study must be viewed as a preview to the evolving future potential of technology and how it can be utilised in making oral health care accessible to the underserved. In addition, this method will not work in rural areas if there is an absence of Wi-Fi and poor or no cellular connectivity.

Teledentistry can play a significant role in the more recent concept of Caries Risk Assessment (CAR) that has been developed for the management of dental caries. Strategies for the management of dental caries have increasingly used this concept of CAR (Policy on early childhood caries, 2005; Hale, 2003). Caries risk assessment is the determination of the likelihood incidence of caries in the immediate future, and aims to predict the rate of progression of current non-cavitated carious lesions (Van Hilsen *et al.* 2013). Dental professionals can help prevent cavitation of early incipient lesions by correctly identifying key risk factors and demineralization in the early stages (Crall, 2006; Tsang *et al.* 2006).

The presence of non-cavitated lesions have been shown to have a predictive value for future caries (Van Hilsen *et al.* 2013). Detecting near-surface incipient lesions allows for the arrest or reversing of disease progression through topical therapies and improved oral hygiene and diet, as highlighted in Caries Management by Risk Assessment (CAMBRA) strategies (Ramos-Gomez, 2011). CAMBRA is an evidence-based approach to preventing or treating the cause of dental caries at the earliest stages rather than waiting for irreversible damage to the teeth (Hurlbutt, 2011). For patients with incipient non-cavitated lesions that have progressed into the outer surface of the dentine, sealant placement or minimal invasive restorations are advantageous to arrest the lesion (Heller *et al.* 1995).

Risk assessment is now viewed as the critically important step in the clinical decision process of managing dental caries (Van Hilsen *et al.* 2013). For teledentistry, caries risk assessment can effectively manage and triage patients for treatment planning, prevention, and establishing follow-up and recall times. The combination of teledentistry with the caries risk assessment strategy can be significant in providing a synergy of preventive and curative oral health care to children in critical access communities (Van Hilsen *et al.* 2013). Therefore, teledentistry could be strategically engineered into the oral health school screening systems to ensure continued oral health care and management of young children.

2.12 Ethical and Legal issues of teledentistry

The practices of both teledentistry and telemedicine remain untested by law. Issues such as accountability, jurisdiction, liability, privacy, consent and malpractice are crucial to consider though will vary among different countries (Mittal *et al.* 2011).

As teledentistry is rapidly evolving in the delivery of oral health care, it is vital that regulatory bodies specify the role of the teledentistry operators. Currently there is no law to clarify the role of the teledentist and their liability (Mittal *et al.* 2011). Furthermore, information on teledentistry licensure does not appear to be readily available today (Jampani *et al.* 2011). Legal and ethical guidelines need to be formulated to safeguard both the patient and the teledentistry operator.

There is growing concern regarding the safety, confidentiality and privacy of patient information as health records have moved from paper formats to electronic media (Cederberg *et al.* 2011), therefore there is a need for governance and regulation for health information systems.

The Health Professionals Council of South Africa (HPCSA), the legal health professional authority in South Africa defines telemedicine as “the exchange of information on health care at a distance for the purpose of facilitating, improving and enhancing clinical, educational and scientific health care and research, particularly to the under-served areas in the Republic of South Africa” (Kekana, Noe and Mkhize, 2010). As a regulatory body, the HPCSA is faced with a variety of ethical and legal challenges related to telemedicine. It is crucial for well-defined telemedicine legal and

ethical guidelines in South Africa to be designed and scheduled. Stanberry (2006) outlined the legal and ethical issues that are fundamental to telemedicine (Table 2).

Table 2: Legal and ethical issues in telemedicine

Issues	Content
Ethical fundamentals	Autonomy and consent, confidentiality and other aspects of the patient–professional relationship, non-maleficence and beneficence, justice and access.
Political fundamentals	National and cross-border reimbursement of patients and professionals, national programmes and strategies, funding and political direction.
Using and sharing health information	Consent to information sharing, confidentiality, privacy and data protection, information security management.
Responsibility, liability and good practice	Duty of care, registration and training, indemnity insurance, clinical governance and risk management.
Guidelines, protocols and best practice	Evolution, provenance and content of published guidelines, standards and protocols.
Cross-border practice	Registration and licensure, indemnity insurance, jurisdiction and choice of law, mobility of patients and professionals, health in the EU internal market.
Supplying telemedicine services	Directives on electronic commerce and distance selling, advertising of medical and pharmaceutical products, media and broadcasting regulations.
Standards and interoperability	“New approach” directives, standards bodies, obligations relating to procurement by public bodies.
Medical devices, product liability and safety	Medical devices regulations, Conformité Européenne (CE) marking, Food and Drug Administration (FDA) approval, directives on product liability and general product safety.
Intellectual property rights	Copyright, patents, trademarks, design rights, passing off and other infringements, exploitation.

However, resource constraints and other issues relevant to developing countries, like South Africa, may require the formulation of guidelines that do not necessarily conform with those of the developed world (Jack *et al.* 2008). As teledentistry is a subset of telemedicine, the same legal and ethical issues will apply. An eHealth Strategy has recently been promulgated for South Africa and includes recommendations for the establishment of regulations on privacy, confidentiality and security; a national standards compliance body; the development of a licensing policy and determination of effective risk mitigation strategies for eHealth projects (Department of Health, 2012). It is critical that there are adequate security systems in place to secure data and should any legal and ethical issues arise, accountability needs to be clearly defined. For example, data encryption, password protection and user access logs can help in deterring most of the people and in protecting patient confidentiality (Chhabra *et al.* 2011). However, if technical problems occur during data transmission that cause a misdiagnosis or medical error, then issues of responsibility and malpractice need to be considered (Shirolkar *et al.* 2011).

In Minnesota in the US as of April 2003, all members of a health care team and the teledentistry network were considered covered entities under Health Insurance Portability and Accountability Act and System Security with Teledentistry (HIPAA) privacy regulations (Friction *et al.* 2009). This is a regulatory body that ensures that the privacy, confidentiality, security, and secure back-up of data are maintained by meeting the HIPAA requirements and federal standards for system security (Friction *et al.* 2009). To ensure that the standards are met, a state-of-the-art computing facility is a requisite requirement for housing the databases of electronic dental records and teledentistry (Friction *et al.* 2009). Regulatory bodies like the HIPAA makes teledentistry user-friendly and assists with issues of security, confidentiality and privacy. However, even though there are a number of methods used to prevent unauthorized entry into databases (such as encryption of data, password protection, router filtering), there is always a possibility that these methods can be bypassed by hackers. In keeping with the tenets of ethical principles, it is imperative that patients in addition to agreeing to the traditional, standard consent form be advised of the inherent risk of improper diagnosis and/or treatment due to technological failures (Bhambal *et al.* 2010). Furthermore, patients must be informed that there is an added risk that the electronic information can be intercepted during transmission, despite security efforts (Bhambal *et al.* 2010). The consent form should contain the name of both the referring

and consulting practitioners to ensure adequate coverage for malpractice, and the consulting doctor should acquire a copy of the informed consent before any form of patient contact is established (Sukhabogi *et al.* 2014).

Technology globally plays a part in most aspects of our lives. For example, internet banking, e-filing of tax returns, medical and dental records, insurance policies/investments, employment and business information. All electronic information often containing personal and confidential details presents as an inherent risk for interception during transmission from one site to another. Hence, even though information and communications technology has made significant advances in all aspects of our life, including saving time and money, there remains a large challenging gap with regards to the secure transmission of electronic information. It is therefore imperative that in the interest of the patients and telehealth practitioners that legal and ethical guidelines in the practice of telemedicine and teledentistry are designed and scheduled for South Africa.

2.13 Challenges

As the digital era of teledentistry evolves, it raises a wide array of challenges. Legal and ethical issues surrounding teledentistry is a major concern. Ethical and legal principles does not change for telemedicine and remains the same as for conventional face-to-face consultation (Fleming *et al.* 2009) in some countries as telemedicine is still a fairly new concept. Problems occur primarily due to a lack of well-defined standards (Golder *et al.* 2000). The challenge presents on how to address situations when a teledentist provides long distance consultations to a patient from a different country or state. The teledentist will need assurance that they can treat patients who are located in another state/country without the possibility of violating licensure regulations (Bajaj *et al.* 2015). The latter appears to be a major impediment to the use of teledentistry across borders (Reddy, 2011). Legal issues such as licensure, jurisdiction, and malpractice, have not yet been definitively decided by legislative or judicial branches of various governments (Bajaj *et al.* 2015). In addition, licensure of teledentistry practice largely depends upon the country's definition of teledentistry and upon its interpretation and perception of the nature of the doctor-patient relationship therein (Bhambal *et al.* 2010). Other challenges concerning legal matters are privacy, antitrust statues and avoidance of malpractice and fraud (Wallwiener *et al.* 2009).

Concerns about the confidentiality of dental information arise from the transfer of medical histories and records as well as from general security issues of electronic information stored in computers (Bajaj *et al.* 2015). This presents as a challenge as practicing teledentists need to ensure that patient privacy is maintained at all times and not intercepted by unauthorized individuals. Therefore, patients need to be informed of the possible inherent risks of having their personal information intercepted during electronic transfers, despite major efforts to ensure security. This then presents as a deterrent, as patients become reluctant to participate in teledentistry with fears of having their confidentiality and privacy invaded. Hence, the need to address the security and confidentiality cannot be overemphasized as this could be one area that could be detrimental to telemedicine (Wallace *et al.* 1999) and teledentistry.

Reliability of technology and ICT users presents as a problem in teledentistry. In a study that focussed on store-and-forward in remote areas it was noted that it was essential for consultants to be not only reliable but also trustworthy (Bonnardot *et al.* 2009).

Friction *et al.* (2009) highlighted that a major challenge in a teledentistry visit (real-time) is the collaboration between the hub site and the remote site. Because the consultation is “remote” in nature, the dental teams at both sites must collaborate constantly for a smooth teleconsultation, and the challenge begins with making the concurrent appointment at both sites (Friction *et al.* 2009). In addition, the specialist in a real-time consult cannot perform a hands on examination and therefore will have to rely on the examination performed by the referral dental team.

The technology associated with teledentistry needs to be reliable to ensure efficient consultations and the correct transmission and reception of data. If a technical problem occurs during data transmission that may cause a misdiagnosis or medical error (Rana *et al.* 2015). For example, there was an incident where emails were being sent to the official telemedicine service, whose email address provided a response of “out of order” indicating that the information was not verified (Bonnardot *et al.* 2009). This jeopardized the service that was being provided. Likewise, in teledentistry, if the web-based images in the asynchronous method of consultations is emailed to a defunct address or incorrect address, then there will be a breakdown in electronic communication which leads to failure of the teledentistry service and possible breach in confidentiality if sent to an incorrect functional server.

In addition, the increasing costs of setting up telemedicine equipment were regarded by many advocates of telemedicine as a major obstacle (Khan *et al.* 2013). However, even though the initial financial layout for telemedicine and teledentistry is very high, future financial cost benefits and savings can be envisaged. Furthermore, if public hospitals/clinics already have computers, internet access, intraoral camera and smartphones, then half the financial burden is solved as existing infrastructure can be used in the telemedicine/teledentistry system. For example, in Rochester, New York, a teledentistry project complemented the existing telehealth centres in six elementary schools and seven child-care centres (Kopycka-Kedzierawski *et al.* 2006).

Teledentistry fundamentally enhances the delivery of oral health care, but not without its challenges. As the digital era advents and expands in the medical and dental arena, there is hope that the challenges associated with teledentistry will be resolved or minimised.

2.14 User satisfaction

Teledentistry has been shown to be a reliable and valid dental screening diagnostic tool (Boye *et al.* 2013a; Kopycka-Kedzierawski *et al.* 2007; Patterson *et al.* 1998). In a qualitative narrative review of studies about technology acceptance and user satisfaction, it was reported that there is limited information available on dental professionals' opinions on using telemedicine applications in dentistry or their satisfaction about newly implemented specific teledentistry systems (Elmokadem, 2013). The experiences of examiners diagnosing dental caries from the intraoral images in epidemiological surveys have been minimally reported in the literature (Boye *et al.* 2013b). However, it has been shown to be acceptable to children who are the main participants of the dental caries epidemiological surveys (Boye *et al.* 2012).

Although, in a systematic review of studies about patient satisfaction with telemedicine it was reported that patients generalise about their satisfaction with telemedicine, no explanations are given as to why users are satisfied with the service (Mair *et al.* 2000). Mair *et al.* (2000) reported that the underlying concept of satisfaction is often vague and the interpretation of the satisfaction findings unclear (Daniel *et al.* 2013) and by continuing to measure user satisfaction in the current manner, previous findings of acceptability of the technology will be confirmed, but will not increase the understanding of the underlying processes of teledentistry use (Daniel *et al.* 2013).

A study in Manchester, in the UK was carried out to determine the views of the examiners on the use of intraoral photographs for detecting dental caries for epidemiological studies (Boye *et al.* 2013b). A focus group discussion was carried out with 5 examiners three weeks after they completed the visual face-to-face examinations and the intraoral image assessments of the same children (Boye *et al.* 2013b). The main themes that emerged from the focus discussions were: viewing/examination conditions, the viewing/assessment process, utility, and improvements (Boye *et al.* 2013b). The examiners suggested that to improve the utility of the photographic method, further research is required to determine adequate removal of debris and moisture control prior to imaging for use in the field. Further views included that a standardised presentation of the photographs including the size and resolution is required, and there is a need for the examiners to be specifically trained on caries detection from the images.

The examiners in the study found it easier to make caries detection decisions on the intraoral images of primary teeth than that of permanent teeth and the fact that they could carry out the screening of the intraoral images at a convenient time and place was reported as an advantage (Boye *et al.* 2013b).

One of the possible problems in obtaining empirical evidence on user satisfaction is that tools are often untested, not standardized or terms used in the data collection tools are not adequately constructed. For example, a teledentistry systematic review revealed that the tools used to measure user satisfaction are for the most part poorly described and not standardised, and the underlying satisfaction concept is often vague making the interpretation of satisfaction findings unclear (Daniel *et al.* 2013). Whitten *et al.* (2005) suggests that a well-designed tool should include: the use of technology, future adoption and perceived risks and benefits.

Furthermore, the importance of the human factor in order to achieve successful implementation of the teledentistry system is important. In an eHealth environment it is important that an “inter-personal” human-to-human connection between the doctor and the patient be maintained or enhanced (Weiner, 2012). Focusing on the technological aspect without giving much attention to the social aspect might lead to the failure of implementation of the teledentistry system (Elmokadem, 2013). There are nine human factors (Table 3) that assist in user acceptance of telemedicine (Buck, 2009) and these human factors will essentially apply to user acceptance of teledentistry as well.

Table 3: Human factors that aid in user satisfaction of telemedicine

Human Factor	Description
Aim and usefulness	Aim of the telemedicine application must be clear, user must understand the products right to exist
Respect	The values of the doctor and patient must be respected
Control	Doctor and patient must not feel as if they are losing control over their actions
Retaining care providers status	Introducing telemedicine may change roles, this will affect the care providers' role but not their status
User profile	The process should be appropriate to the telemedicine users' expectation, skills and restrictions
Emotional condition of the patient	Accommodate the patient needs for safety, feelings of shame, fear or uncertainty
Levelling of communication	As telemedicine involves multiple role players with different skill levels, it is important to ensure the issue being dealt with is done so in a manner where terminology is easily understood
Traceability	Information about telemedicine should not only be available as a reminder to the doctor but also for professional verification and future clarity
Information selection	Only information pertinent to the telemedicine application should be made available to process

These human factors can be used as a guide and taken into consideration when designing data collection tools for user satisfaction research studies. However, these factors may not conform to all user satisfaction studies, hence; they should be applied when warranted. In the present study, only questionnaires were used to collect user satisfaction data, therefore not all of the human factors were applied.

2.15 Concordance

The definition of concord is “agreement or harmony” (Oxford English Dictionary, 2013) and concordance is defined as “a state in which things agree and do not conflict with each other” (Merriam-Webster Dictionary). Hence, diagnostic concordance refers to the agreement of different diagnostic systems (Langenbacher *et al.* 1996).

There is some evidence that shows the diagnostic accuracy of teledentistry. In New York, in an inner-city child care centre, the authors compared visual face-to-face dental screenings and dental screenings using intraoral images on 4-6 year olds. Fifty children were examined by a calibrated dental examiner. The results showed a 95% diagnostic concordance (agreement) implying that there was no statistically significant difference between both the screening methods (Kpycka-Kedzierawski *et al.* 2007).

Patterson *et al.* (1998) carried out a similar study earlier on that compared visual face-to-face dental screenings and dental screenings using intraoral images. A total of 137 children were examined by a calibrated oral hygienist using the visual face-to-face screening method on school children and a calibrated dental assistant recorded the DMFT. Thereafter only a random 35 children from the 137 were assessed using intraoral images. The results showed a diagnostic concordance that ranged from 89% to 100% (Patterson *et al.* 1998). In the United Kingdom 130 five year old and 140 ten to eleven year olds were visually examine by 5 calibrated examiners. The same children had intraoral images of their teeth taken which the same five examiners assessed for dental caries. The results from both the screening methods were compared and showed a diagnostic concordance that ranged from 87.8% to 95.8% in the 5 year olds and 58.5% to 71.7% in the 10-11 year olds (Boye *et al.* 2013a).

Teledentistry screening shows great potential in making oral health care accessible to rural and inaccessible areas. South Africa as a developing country striving for solutions to balance the inequalities that exist in the health sectors needs to adopt and embrace the use of teledentistry as a potential solution to the barriers that hinders the delivery of oral healthcare to all people in South Africa.

2.16 Conclusion

The literature review presents an overview of teledentistry, starting with the origin of teledentistry. From the literature review, it is evident that teledentistry has endless potentials to positively transform the delivery of oral health care, however there are crucial issues relating to ethical and legal issues, associated costs related to the technology used and reliability of the technology that is of concern. But, these issues are work in progress, like any new medical/dental concept that is initiated. Teledentistry is a fairly new subset of telemedicine that is being practiced extensively globally. An array of studies has been conducted globally to ascertain the feasibility and reliability of using teledentistry in the various subsets of teledentistry, many with favourable outcomes. However, teledentistry is under ongoing clinical investigations globally, and new knowledge is being discovered to revolutionize the way dentistry is practiced.



CHAPTER 3

AIMS AND OBJECTIVES

3.1 Hypothesis

Teledentistry screening for dental caries in children is as reliable as using the traditional dental screening method.

3.2 Aim

The aim of the study is to compare traditional dental screening versus teledentistry screening for dental caries in children

3.3 Objectives

1. To determine DMFT in 6-8 year old children using face-to-face traditional full mouth examinations
2. To determine DMFT in 6-8 year old children from full mouth intraoral images of 6-8 year old children
3. To measure the concordance between traditional dental screening versus teledentistry screening for dental caries.
4. To determine user satisfaction of the evaluators and the TAs with the teledentistry screening method.



CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1 Background

This study consists of two parts: the first part a concordance study and the second part the determination of user satisfaction with regard to the technology used. The users were the evaluators and teledentistry assistants (TAs).

4.2 PART ONE: CONCORDANCE STUDY

4.2.1 Background

The outcome of the concordance study was to determine the diagnostic concordance between traditional and teledentistry screening of dental caries in school children aged between 6-8 years old. The traditional method of dental screening usually involves a registered oral health worker who carries out a visual inspection of the child's mouth and teeth by using an intra-oral mirror, a portable chair and a light source. A registered dental assistant is often required to function as the recorder of the DMFT (Patterson *et al.* 1998). The DMFT record includes decayed (D), missing (M) and filled (F) teeth. The recording and calculation of the DMFT score is a globally used and accepted measurement of caries prevalence (Bratthall, 2000). The DMFT is recorded on paper at the face-to-face dental screening session, and each child has their own dental charting form or data capture sheet. In addition, infection control must be adhered to at all times.

On the other hand, teledentistry screening of dental caries involves the use of information and communications technologies (Kopycka-Kedzierawski *et.al.* 2007) including an intraoral camera to screen for dental caries.

4.2.2 Study Site

The study site was Magoda, a rural area in Richmond (Figure 4). The Richmond Municipality is a designated National Health Insurance pilot site, in the uMgungundlovu District of Kwa-Zulu-Natal, South Africa. Richmond is located on the southern part of the uMgungundlovu District Municipality and is approximately 38 kilometers south of Pietermaritzburg (the capital of the KwaZulu-Natal Province) (Richmond Municipality Development and Planning Unit, 2012).



Figure 4. Map of Richmond (uMgungundlovu District Municipality, KwaZulu-Natal, South Africa)

Richmond has a population of 65 793 with approximately 7 288 children in the age group 5 to 9 years (Statistics South Africa, 2011). The majority of the population resides in areas which are predominantly rural and are characterized by unavailability of basic services and facilities, and high unemployment levels (Richmond Municipality Development and Planning Unit, 2012).

It is estimated that there is at least 840 households have access to telephonic landlines, and a significantly larger number of households (13 433) have access to cellular phones (Statistics South Africa, 2011), indicating that the majority of the community relies on mobile connectivity.

According to the 2011 census households using electricity for heating, cooking and lighting are represented as follows: access for heating - 67.3%, access for cooking - 77.6% and access for lighting - 86.1%. Only 6363 households have access to flush/chemical toilets, and the majority of the households use pit latrines (8772), bucket latrines (75) and 500 households do not have access to toilets (Statistics SA, 2011).

Schoolchildren living in Magoda need to travel long distances to attend school, and most walk on corrugated, untarred roads due to the lack of public transport. Schools in Magoda do not have access to piped water, but rely on pumped water or water brought to the school by educators in buckets and drums.

The primary health care clinic is approximately 5 kilometers from the location and the dental clinic which is situated in the village as part of the Community Health Centre (CHC), which is approximately 10 kilometers from Magoda. At the public sector CHC there is one community service dentist and one dental assistant who provide dental care to all the people in Richmond. Currently, there is no private dental care facility in Richmond. In addition, there is only one emergency service vehicle that provides emergency care transport to the whole of the Richmond area, and for the transportation of referred patients to the District/Regional hospitals in Pietermaritzburg.

4.2.3 Study Population

The study population included all primary school children aged between 6-8 years attending schools in the Magoda area, Richmond, KZN. There are 27 schools in Richmond of which 6 are rural schools in Magoda. Of the 6 schools, 3 schools were selected to participate in the study by using the systematic sampling technique.

4.2.4 Study Sample

Of the selected three schools there were a total number (n) of 413 children aged between 6-8 years old: Magoda Primary (n=154), Ndabikhona Primary (n=150) and Nyambayi Primary (n=109).

4.2.5 Sample Size

There were 413 children eligible for the study. Of the 413, 250 children provided written informed consent. Of the 250 children, 233 children participated in the study. Of the 17 children who did not participate, 8 children had left and 9 children were absent on the day of the screening.

4.2.6 Pilot Study

The pilot study included the evaluators and the TAs. The information technologist was present at the pilot study to ensure proper use and function of the intraoral cameras and the ICTs used. All technical problems were addressed during the pilot study.

It was carried out to ensure that the methodology was adequate to meet the aims and objectives of the study and to test the adequacy of field training (Katzenellenbogen, 2007). The pilot study tested the following:-

- Duration of the intraoral imaging process per child
- Duration of the face-to-face dental screening per child
- Calibration of the TAs and the evaluators
- Effectiveness of the disposable plastic picks

The TAs used the intra-oral cameras to obtain images from 10 children and the evaluators carried out the face-to-face examinations on the same 10 children and obtained a DMFT score. After a one week wash out period, the blinded evaluators assessed the digital intraoral images of the same 10 children and scored a DMFT. After the pilot study, all necessary adjustments were implemented in the main study. The data from the pilot study was not used in the main research project.

4.2.7 Standardization and calibration

Intra-calibration and inter-calibration for the evaluators was carried out prior to the main study. The objectives of the standardization and calibration exercises were to:

- (i) Ensure uniform interpretation, understanding and application of the criteria for the various diseases and conditions that were observed and recorded.
- (ii) Ensure that each examiner could examine consistently to a standard.
- (iii) Minimize variations between different examiners.

4.2.7.1 Intra-examiner calibration

For the intra-examiner calibration consistency was determined by examining a randomly selected group of 10 patients twice, on successive days. By comparing the results of the two examinations, the examiner was able to obtain an estimate of the extent and nature of the diagnostic errors. If the level of agreement between the examinations did not meet the recommended minimum level, the examiner reviewed the interpretation criteria and additional calibration examinations were conducted until an acceptable consistency was achieved. Agreements were in the range of 85-90%.

4.2.7.2 Inter-examiner calibration

For the intra-oral DMFT examination there were two examiners (SB, AM). The examiners were calibrated and by consensus made the final diagnosis for each tooth. Consistency was determined by examining a randomly selected group of 10 patients twice, on successive days. By comparing the results of the two examinations, the examiners were able to obtain an estimate of the extent and nature of the diagnostic errors.

If the level of agreement between the examinations did not meet the recommended minimum level, the examiners reviewed the interpretation criteria and additional calibration examinations were conducted until an acceptable consistency is achieved. There was an almost perfect agreement between the evaluators at 97.08%.

4.2.8 Training

Teledentistry assistants received training on how to correctly and effectively use the intra-oral cameras (Kodak 1500 - Carestream) prior to the study to ensure standardization, to obtain quality images and eliminate bias. Three training sessions were conducted by an experienced technician. Training included hands-on demonstration of the imaging process followed by practical practice sessions on volunteers until the technique was mastered. Further training regarding the use of the accompanying software package was also provided. The TAs had on-going technical support to troubleshoot any difficulties during the entire data collection process.

4.2.9 Data Collection

Summary

Two registered dental clinicians were engaged as evaluators, designated as evaluators one and two. The evaluators performed the face-to-face dental screenings on all 6-8 year olds at selected rural primary schools using the traditional dental screening method and scored them for DMFT. Each evaluator screened a total of 233 children. The tools used in the traditional method of dental screening included the use of a headlamp, disposable tongue depressors, gauze, gloves, masks and disposable plastic picks (Figures 5 & 6).

Disposable plastic picks were used instead of periodontal probes to determine pit and fissure caries and to remove debris (Figure 7). In this way, cold sterilization was not required, which in turn saved us time and ensured that excellent infection control was maintained at all times. The Modified WHO Oral Health Assessment Form (1997) was used as the DMFT record sheet (Figure 8). At the same time of the face-to-face screenings, the same children had intraoral images of their teeth captured by the TAs.

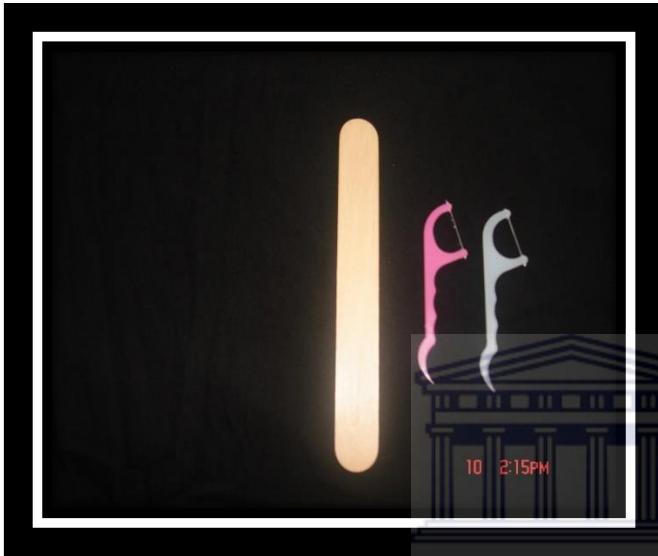


Figure 5. Disposable tongue depressor & plastic picks



Figure 6. Headlamp



Figure 7. Plastic pick used to detect pit & fissure caries

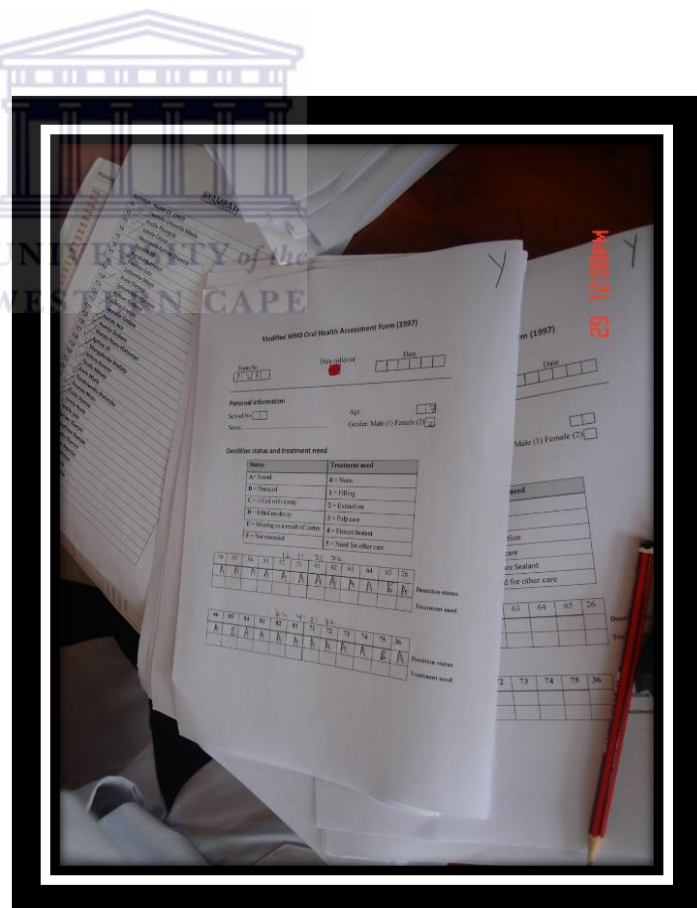


Figure 8. Modified WHO Assessment forms

Following Phase 1 of the data collection process, the evaluators had a ‘wash out’ period of two weeks and they then carried out assessments on the intraoral images of the same children and scored them for DMFT. The WHO Oral Health Assessment forms were used for the recordings. Both the TAs and the evaluators were trained and inter- and intra- examiner calibrated. All images were randomized and blinded. The randomization and blinding of images ensured that bias is minimal. The data was checked and the DMFT scores were verified. The data analysis involved determining assessment accuracies. The DMFT scores were compared not only across methods (i.e. traditional dental screening (Gold Standard) versus teledentistry screening of dental caries), but also across evaluators.

4.2.9.1 Details of Phase 1 data collection

In the first phase, two trained, standardised and calibrated evaluators carried out face-to-face intra-oral examinations (Figure 9) on all 6-8 year old children at the selected three rural primary schools. Each evaluator independently carried out the examination of the selected children and scored them for DMFT. This was recorded on a data capture sheet in a hard copy format. The Modified WHO Oral Health Assessment Form (1997) was used as the data capture sheet (Appendix E).

At the same time of the face-to-face examinations, two trained and calibrated teledentistry assistants captured digital images of the children’s teeth using an intraoral camera and a lap top (Figure 10). These images were web-based stored for each child. Six intraoral images of the upper and lower anterior teeth and the four posterior quadrants were taken for each child (Figure 11). However, during the imaging process, the TAs had captured more than the recommended six images so as to ensure that clear images of all the teeth in the oral cavity were represented.

4.2.9.2 Image capturing

The TAs used gauze to remove any debris from the dentition. A wooden disposable tongue depressor was used to retract the cheeks, lips and the tongue so to facilitate clear vision of the teeth. The intraoral camera was focused on the teeth, and the image was simultaneously viewed on a laptop (Figure 12). Once a clear image was obtained, the image was captured electronically on the laptop (Figure 13 & 14). The TAs had experience in determining image clarity during their training sessions to ensure that only clear images were stored. Images of poor quality were deleted and retaken if

needed. The imaging process was non-invasive, pain-free and there was little or no discomfort to the child. The imaging process took about 10 to 15 minutes per child. Although the teledentistry screening process was slow initially compared to the traditional screening method, with experience and familiarity with the technology system, the TAs made up the time.

An electronic file (eFile) was created for each child prior to the dental screening process. Each child was allocated a code that was unique to their identity. The codes used depicted the primary school that the children attended (Table 4). For example, if the child attended Magoda Primary, the coding system started at M1 to M73, depending on the number of 6-8 year olds at the school that presented an informed consent. The images were safely stored in the corresponding eFiles and web-based stored, to ensure that there is a proper tracking system. Security of data was maintained at all times with the use of protective passwords. Confidentiality and anonymity was maintained as each child was coded.



Figure 9. Evaluators carrying out the traditional dental screening method



Figure 10. Intra-oral camera and lap top used in the imaging process

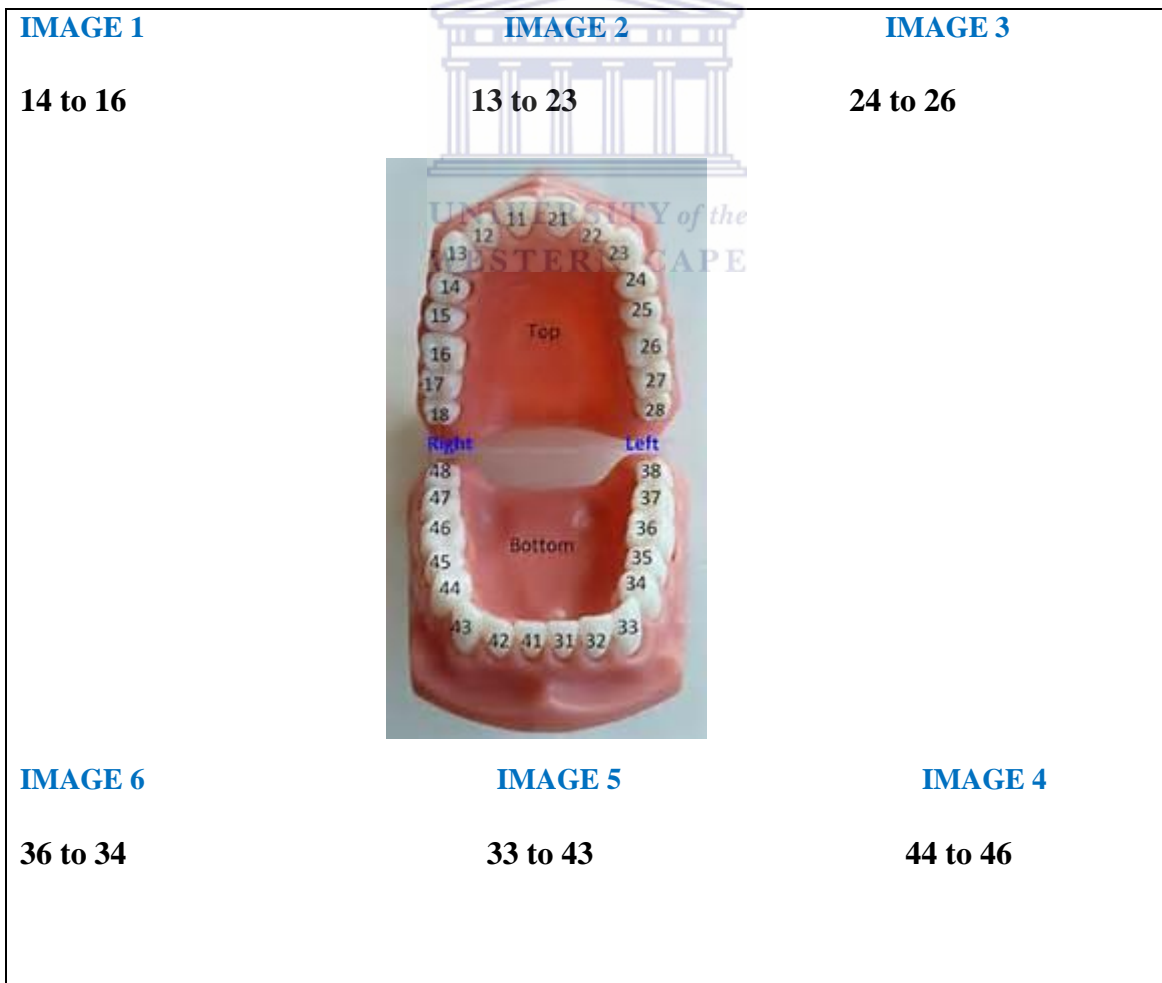


Figure 11. Diagrammatic view of the six images captured



Figure 12. TA carrying out the imaging process

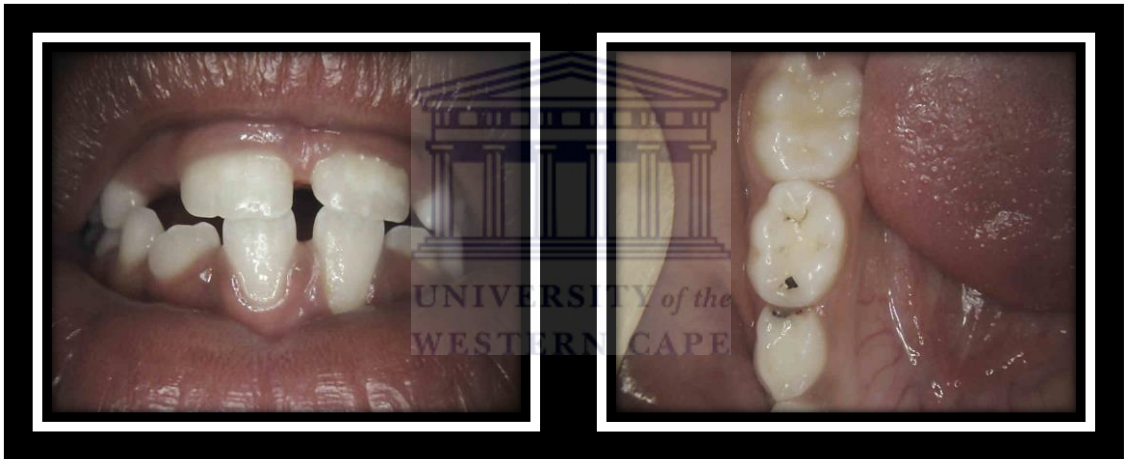


Figure 13: Examples of the images that were captured by the TAs



Figure 14: Examples of the images that were captured by the TAs

Table 4. Coding system for each child

IDENTIFICATION CODE	NAME OF CHILD	CODE
M10	Peter Zuma	M represents Magoda Primary
N20	Cindy Cele	N represents Ndabikhona primary
Y45	Harry Mtaloba	Y represents Nyambhayi primary

On completion of the traditional dental screening and the intraoral imaging process, all the children in grades 1, 2 and 3 of the three selected primary schools were given a gift packs (Figure 15) irrespective if the children participated or not. The packs consisted of toothpaste, a toothbrush and stickers. In addition, the school was given oral health education posters and a DVD on healthy diet and brushing techniques.



Figure 15. Gift packs being handed out to the children

4.2.9.3 Details of Phase 2 data collection

In the second phase, evaluators 1 and 2 took on the role as assessor 1 and 2 respectively. After a two week wash-out period, the electronically stored intraoral images were made available to the same two assessors on a secure computer. All identifying information was blinded to the assessors. The assessors independently viewed the images at different sites and scored them for DMFT on a data capture sheet in a hard copy format. The Modified WHO Oral Health Assessment Form (1997) was used to capture the data (DMFT) obtained from the images.

The image assessors were blinded by using a coding system (Table 2)). The data capture sheets were pre-coded prior to the assessments. To gain access to the images for each child, the assessors entered the code indicated on each record sheet. In addition, the WHO record sheets were also randomly placed (Figure 16). The sequence of the data capture sheets varied for both assessors and were not viewed in chronological order.

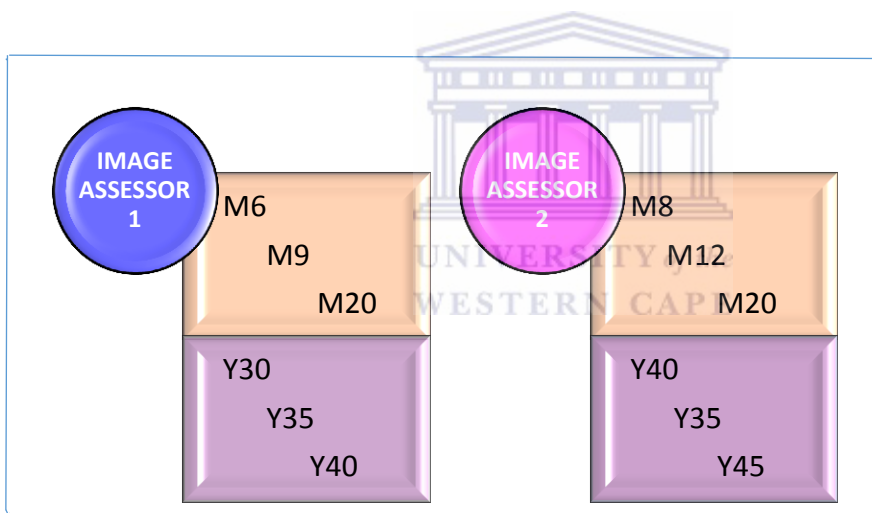


Figure 16. Example of the sequence of the Phase 2 assessments

4.2.10 Data Analysis

After data quality control, the data was then put on a data spread sheet using excel and encoded. Analysis compared the DMFT scores that were obtained from traditional dental screening and the DMFT assessments off the intraoral images so as to determine reliability. This comparison of the DMFT scores across methods determined intra-evaluator reliability, and comparison of the DMFT scores across the evaluators determined inter-evaluator reliability.

All data analysis was conducted in SPSS version 23.0 and stats version 13.0. Descriptive statistics were employed. This describes the organising and summarising of quantitative data. Univariate and bivariate analysis is most appropriate for descriptive statistics. Descriptive statistics is useful as it summarises results for an experiment, thereby also allowing for more constructive research after more detailed analysis. Descriptive data analysis aims to describe the data the investigating the distribution of scores on each variable, and by determining whether the scores on different variables are related to each other (Lind et al. 2004). This can also be done using various types of tables and graphs.

The data type was nominal (or categorical) as teeth were classified according to their condition, for example, as decayed, missing or sound.

Cross Tabulations were carried out and data resulting from observations made on two different related categorical variables (bivariate) and were summarised using a table, known as a two way frequency table or contingency table. The word contingency is used to determine whether there is an association between the variables (Willemse, 2009). These tables were generated when determining the kappa values.

4.2.11 PROCEDURES

4.2.11.1 Establishing contacts

Access to the participants of the study was made initially by letter to the participating school principals and parents (Appendix C). An introduction of the researcher, the basic aims and objectives of the study, what participating in the study would involve and how long the examination would take were explained. It was emphasized that strict confidentiality would be maintained at all times and that the results of the study would be presented in a manner that ensured anonymity. Once signed informed consent (Appendix D) was received for each child, arrangements were made for the clinical examinations to be carried out at a time convenient to the participants and schools.

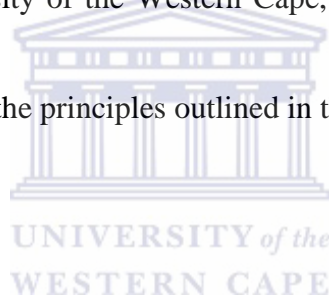
4.2.11.2 Ethical considerations

Gateway permission was obtained from the Department of education (DOE) prior to any contact made with the schools (Appendix A: Letter of Permission from DOE). Participation in this study was voluntary and participants were informed that they may withdraw from the study at any time without penalty. Study subjects were included in

the study after having been provided information about the study (Appendix C: Information Sheet) and was followed up by written informed consent (Appendix D: Consent Form). The study protocol was subjected to ethical review and approved by the Senate Research Ethics Committee at the University of the Western Cape (Appendix B: Ethics Clearance). Written informed consent was obtained for the photographic images that were taken.

The researcher ensured that:

- a) Informed consent was obtained from all subjects of the research.
- b) Strict confidentiality was maintained at all times.
- c) The rights and welfare of the subjects involved in the research was adequately considered and protected at all stages of the research.
- d) Storage and retrieval of information was the sole responsibility of the researcher.
- e) The research complied with the requirements of the Senate Research Ethics Policies of the University of the Western Cape, South Africa and the National Department of Health
- f) The research followed the principles outlined in the Helsinki Declaration.



4.3 PART TWO: USER SATISFACTION LEVELS

4.3.1 Study Design

For the second part of the study, structured questionnaires (Appendix F & G) were designed and administered to gauge the evaluators and TAs level of satisfaction with the use of teledentistry technologies for the screening of dental caries in children.

4.3.2 Instrument used

Questionnaires were designed based on the role of the evaluators and TAs in the teledentistry screening process. A closed format was used for the design of both questionnaires. A closed format was selected because it is easy and quick to fill in and it is easy to report on the results (Leung, 2001). The selected closed format style used was the Likert style scale. The Likert scale is a method of ascribing quantitative value to qualitative data, to make it amenable to statistical analysis (Business Dictionary.com, 2016). A numerical value is assigned to each potential choice and a mean figure for all the responses is computed at the end of the evaluation or survey (Business Dictionary.com, 2016). Likert scales usually have five potential choices (strongly agree, agree, neutral, disagree, strongly disagree) but sometimes go up to ten or more (Business Dictionary.com, 2016), but this study selected the five potential choices listed above. The final average score represents the overall attitude toward the subject matter.

Short and simple questions were asked. The questions asked were unidirectional to avoid any confusion during interpretation of the responses. In addition, the questions were designed using positives. For example, instead of asking the TAs or evaluators if they agree with the statement that the images were blur and unclear, the statement was phrased as 'the images were clear and very readable.' The use of the Likert scale ensured a concise response that was easy to read and disseminate.

A quantitative approach was adopted to ensure the collecting of hard and reliable data (Walliman, 2001). The questionnaires were administered by the researcher for both the TAs and the evaluators. Even though the questions were closed ended, with discussion the researcher was able to get more feedback on the feelings and experiences of the TAs and evaluators with regards to their selected responses in the questionnaires.

The TA questionnaire was divided into three themes and the evaluator questionnaire into four themes.

Teledentistry Assistants (TAs)

Theme 1: User satisfaction on technology

Different aspects of user satisfaction were covered: ease of use of the intraoral camera, visibility of the dentition in the oral cavity and ease of use of the software (eg. storage of the images on the eFiles, quality assessment etc).

Theme 2: Perception of children's attitudes & behaviour

TAs were asked to describe their perception of how the child handles the teledentistry experience. Were they excited/fearful, nervous/calm, comfortable/agitated?

Theme 3: Teledentistry as a screening option

As a new innovation was it an easy system to use? Were they satisfied with infection control?

Evaluators/ Image Assessors



Theme 1: User satisfaction on the technology

Different aspects of user satisfaction were covered: ease of using the software to access the images, clarity of the images for assessment purposes to determine DMFT, including interproximal caries.

Theme 2: Time and technology

Did ICT save time when compared to the traditional screening process?

Theme 3: Infection control and technology

To determine if the evaluators were of the opinion that dental screening via the use of ICTs was a sterile process or not.

Theme 4: Traditional dental screening versus teledentistry screening

Rating the method of screening, in their opinion, they would prefer. Furthermore, their screening method of choice for diagnosing interproximal caries was determined.

4.3.3 Data Analysis

Even though the participant number was small, the responses to the questionnaires were analysed and thematically described and reported on. The data type was ordinal because measurement was achieved by ranking (e.g. the use of a 1 to 5 rating scale from ‘strongly agree’ to ‘strongly disagree’) (Steyn et al. 1994).

4.3.4 Ethical considerations

The evaluators and TAs had given verbal consent to participate in the questionnaire process. The researcher ensured that questionnaire participants (Mouton, 2005):

- a) Had the right to refuse to answer any questions in the questionnaire.
- b) Had a right to refuse participation.
- c) Had a right to anonymity and confidentiality.
- d) Had a right to privacy

4.4 Summary

In this chapter, the study design and study population was discussed. It describes in detail the methods and codes used to elicit the measurements required both for the intra-oral examination concordance study and the satisfaction survey. The measure variables and the outcome variables used in this study were outlined. Analytical methods used and ethical considerations are also detailed.

CHAPTER 5

RESULTS

5.1 Introduction

This chapter presents the results and key findings of the present study. The chapter is described in two parts. Part 1 being the concordance study and Part 2 the user satisfaction levels of the evaluators and the TAs on the use of the ICTs used in the teledentistry screening process.

5.2 PART 1: CONCORDANCE STUDY

A total of 233 children had their teeth examined by two evaluators using two different methods of dental screening, namely the traditional dental screening method and the teledentistry screening method, to determine concordance and reliability between the two methods. The results of this part, reports on the concordance of traditional dental screening versus teledentistry screening of dental caries in children. The study sample consisted of 131 males and 102 females (Table 3). Overall, the ratio of males to female was 3:2 (56.2%:43.8%).

Figure 17 represents the overall age distribution of the participants by gender.

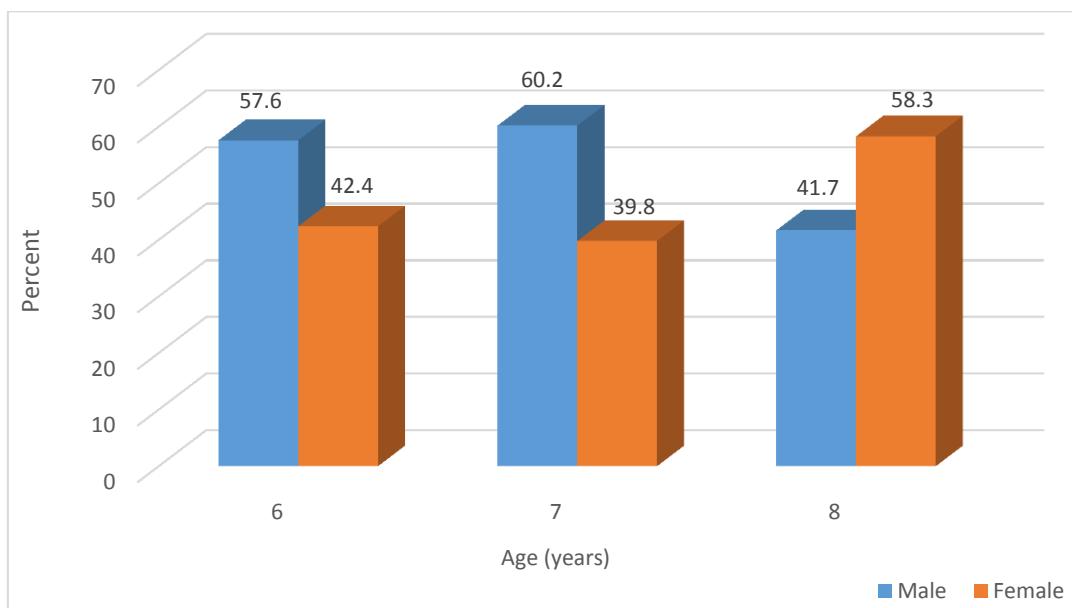


Figure 17: Age distribution by gender

Table 5. Gender Ratio

School 1, 2 and 3		Gender		Total
		Male	Female	
Total	Count	131	102	233
	%	56.2	43.8	100.0

The mean age for the total (233) number of children was 6.73 years. There were significantly more male participants aged 6 and 7 years old, and females dominated the 8 year old category (Figure 17). The mean and standard deviation for the age of the participants is shown in Table 6.

Table 6. Mean and standard deviation age of children

School	n	Mean Age	Std. Deviation
School 1	65	6.38	.550
School 2	77	6.77	.686
School 3	91	6.95	.751
Total	233	6.73	.713

Table 7 provides an indication of how the kappa scores were interpreted. The results from the rater comparisons are given in the various tables that follow (Tables 8-11).

Table 7. Interpreting kappa scores

Interpretation of Kappa		
Kappa Value		
<0.00	Poor	Less than chance agreement
0.01 to 0.20	Slight	Slight agreement
0.21 to 0.40	Fair	Fair agreement
0.41 to 0.60	Moderate	Moderate agreement
0.61 to 0.80	Substantial	Substantial agreement
0.81 to 0.99	Almost perfect	Almost perfect agreement

Source: Viera & Garret, (2005)

For each of the following Tables 8-11, the codes represent the following:

E1 = Evaluator 1 **E2** = Evaluator 2

CODE: 1 = Sound Teeth

2 = Decayed

3 = Filled with decay

4 = Filled with no decay

5 = Missing as a result of caries

6 = Not recorded

7 = unerupted

The cross-tabulations shown in Table 8 indicate the frequencies of DMFT choices made by the evaluators using the traditional dental screening method. For example, both evaluators rated the 1's simultaneously (3855 times). The diagonals show the (higher frequencies of the same ratings given by both the evaluators ie. that the ratings were the same. The high proportion at 1 rating (sound teeth) indicates that a higher percentage of children (69%) had sound teeth. Only 20% of the children had decayed teeth and 8% had missing and un-erupted teeth. Some frequencies showed a lack of concordance. For example, on **five** occasions, Evaluator 1 gave a rating of 1 while Evaluator 2 gave a rating of 7. Disagreement was the highest when rating sound (1) and decayed (2) teeth. On 102 occasions, E1 scored a rating of 2 whilst E2 scored a rating of 1. However, disagreements were few and Table 8a indicates a 96.73% accuracy achieved by both evaluators.

Table 8. Inter-rater comparisons for Traditional dental screening method

E1	E2				Total
	1	2	5	7	
1	3855	66	2	5	3928
2	102	1101	0	1	1204
5	4	0	220	1	225
7	2	0	0	234	236
Total	3963	1167	222	241	5593

Table 8a. Inter-rater Agreement and reliability for Traditional screening method

Agreement	Expected Agreement	Kappa	Std. Err.	Z	Prob > Z
96.73%	54.60%	0.9279	0.0103	89.98	0.0000

There is a similar and high level of agreement for each of the pair-wise comparisons (Table 9a). The same two evaluators (E1 and E2) were image assessors (IA1 and IA2) respectively when adopting the teledentistry screening method.

IA1 = Image assessor 1 **IA2** = Image assessor 2

Table 9. Inter-rater comparisons for Teledentistry screening method

IA1	IA2						Total
	1	2	4	5	6	7	
1	3819	53	1	2	0	4	3879
2	65	1160	0	2	0	0	1227
4	0	0	0	0	0	0	0
5	3	0	0	219	0	0	222
6	0	1	0	0	10	0	11
7	3	0	0	0	0	229	232
Total	3890	1214	1	223	10	233	5571

Table 9a. Inter-rater Agreement and Reliability for Teledentistry screening method

Agreement	Expected Agreement	Kappa	Std. Err.	Z	Prob > Z
97.59%	53.75%	0.9480	0.0103	91.77	0.0000

The cross-tabulation shown in Table 9 indicates the frequencies of DMFT choices made by the IA using the teledentistry screening method. For example, both IA rated the 1's simultaneously (3819 times). The diagonals show the higher frequencies of the same ratings given by both the IA

All other frequencies show some disagreement. For example, on 4 occasions, IA1 gave a rating of 1 whilst IA2 gave a rating of 7. The mismatches was the highest when rating sound (1) and decayed (2) teeth. On 65 occasions, IA1 scored a rating of 2 whilst IA2 scored a rating of 1. Disagreements again were few and Table 7a indicates a 97.59% accuracy achieved by the IA.

The cross tabulation seen in Tables 10 and 11 represents the two dental screening methods that were adopted by the evaluators to determine DMFT, and Tables 10a and 11a highlight the intra-rater agreement and reliability across screening methods.

Table 10. Intra-rater comparisons for E1 across dental screening methods

E1	IA1					Total
	1	2	5	6	7	
1	3863	50	1	5	2	3921
2	23	1177	2	2	0	1204
5	2	0	219	0	1	222
6	0	0	0	0	0	0
7	3	0	0	4	229	236
Total	3891	1227	222	11	232	5583

Table 10a. Intra-rater Agreement and Reliability for E1 across dental screening methods

Agreement	Expected Agreement	Kappa	Std. Err.	Z	Prob > Z
98.30%	54.02%	0.9630	0.0103	93.12	0.0000

The cross-tabulation Table 10 indicates the frequencies of DMFT assessments made by E1 comparing the traditional dental screening method and teledentistry screening method (IA1). For example, E1 rated the 1's simultaneously (3863 times) in both dental screening methods. On 23 occasions, E1 scored a rating of 2 whilst IA1 scored a rating of 1. There was an almost perfect agreement of the DMFT assessments obtained from both dental screening methods with a kappa value of 0.9630 (Table 10a).

Table 11. Intra-rater comparisons for E2 across dental screening methods

E2	IA2						Total
	1	2	4	5	6	7	
1	3779	142	1	7	4	4	3937
2	90	1071	0	4	2	0	1167
4	0	0	0	0	0	0	0
5	7	0	0	212	0	0	219
6	0	0	0	0	0	0	0
7	7	1	0	0	4	229	241
Total	3883	1214	1	223	10	233	5564

Table 11a. Intra-rater Agreement and Reliability for E2 across dental screening methods

Agreement	Expected Agreement	Kappa	Std. Err.	Z	Prob > Z
95.09%	54.30%	0.8926	0.0103	86.46	0.0000

The cross-tabulation Table 11 indicates the frequency of DMFT assessments made by E2 comparing the traditional dental screening method and teledentistry screening method (IA2). For example, E2 rated the 1's simultaneously (3779 times) in both dental screening methods. On 90 occasions, E2 scored a rating of 2 whilst IA2 scored a rating of 1. There was an almost perfect agreement of the DMFT assessments obtained from both dental screening methods with a kappa statistic of 0.8926 (Table 11a).

Tables 10a and 11a clearly shows a high level of agreement across the two methods of dental screening used by both E1 and E2 to assess the participating school children.

Tables 8a, 9a, 10a and 11a depict the inter-rater and intra-rater diagnostic concordance and reliability of the two dental screening methods adopted in this study ie. traditional dental screening and teledentistry screening. Both the inter-rater and intra-rater readings show high agreement with almost perfect agreement ($p < 0.001$). If each evaluator had made his determination randomly but with probabilities equal to the overall proportions, one would expect the two evaluators to agree on 54.6% of the classification. In fact, they agreed on a range between 95% - 98.30% of the classifications, or 92.79% of the way between random agreement and perfect agreement, implying that the hypothesis that they are making their determinations randomly.

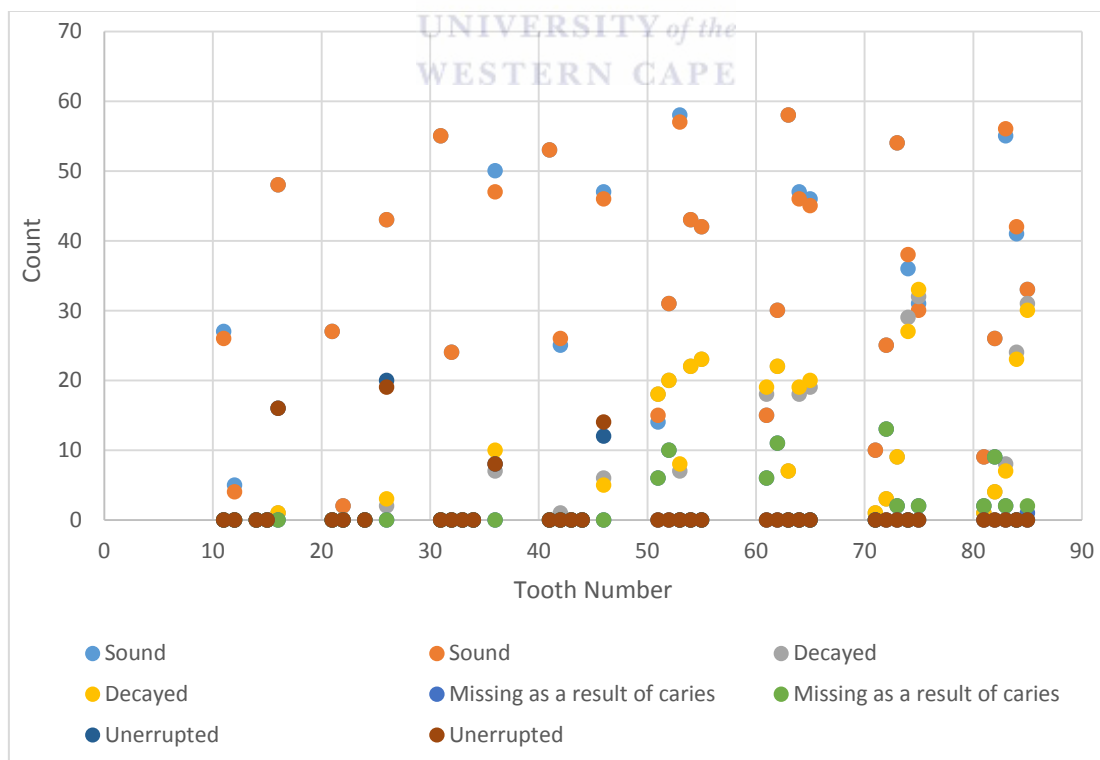


Figure 18: Scatterplot of traditional dental screening versus teledentistry DMFT assessments for school 1: Evaluator 1 (E1)

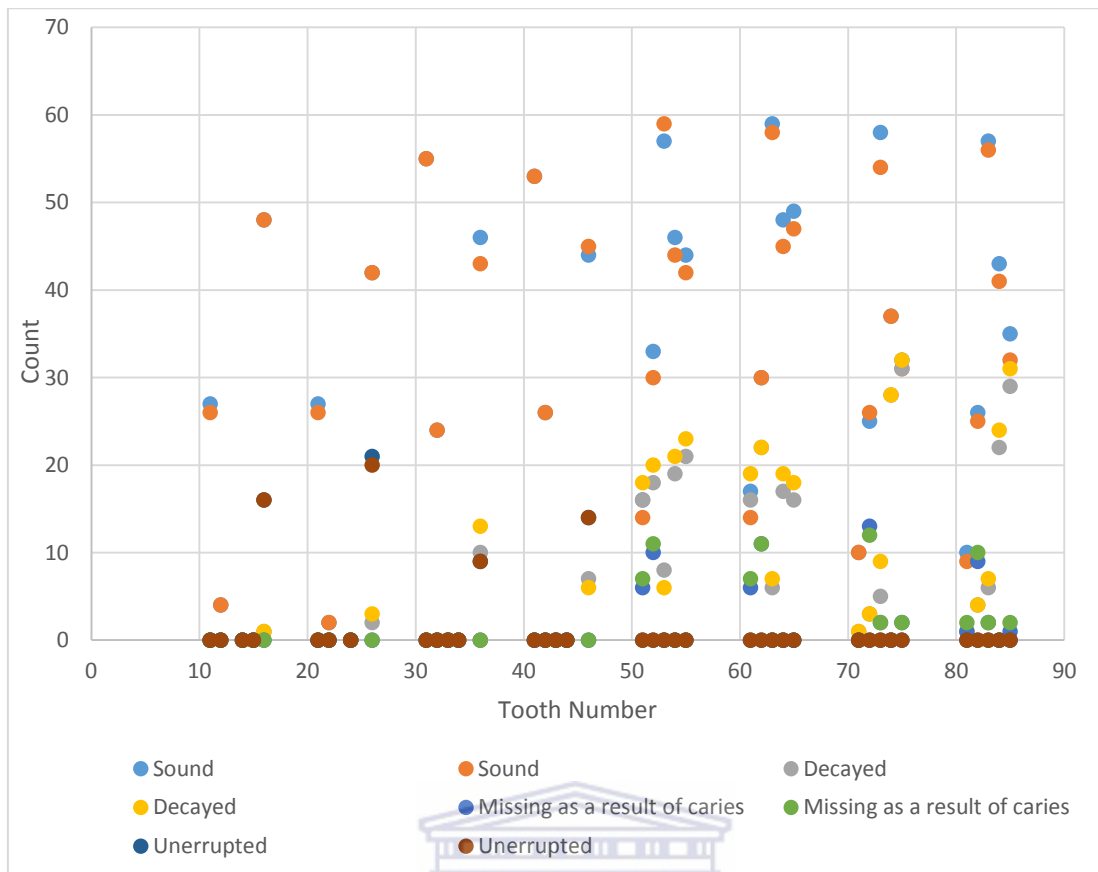


Figure 19: Scatterplot of traditional dental screening versus teledentistry DMFT assessments for school 1: Evaluator 2 (E2)

The scatterplots (Figures 18 and 19; 20 and 21; 22 and 23) illustrate the graphical comparisons per tooth of school 1, 2 and 3 respectively, of the DMFT assessments recorded by E1 and E2 (recorded as Traditional Dental Screening and Teledentistry Screening). Each child had between 20-24 teeth assessed for DMFT depending on their age category. For school 1, each evaluator examined 1563 teeth in total and scored a DMFT. Each evaluator scored each tooth as sound, decayed, missing or filled using the two dental screening methods. Therefore each tooth has 2 plots - each representing a score from E1 & IA1 (Figure 18) and E2 & IA2 (Figure 19). In most instances, it appears as though there are less than the expected dots observed due to the same DMFT or very similar DMFT values between the dental screening methods, thereby highlighting the high concordance between the traditional dental screening method and the teledentistry screening method. This is also supported by the high level of agreement as observed using the kappa score. They agreed on a range between 95% - 98.30% of the classifications, or 92.79% of the way between random agreement and perfect agreement ($p < 0.001$). Similarly, the scatter plots for schools 2 and 3 (Figures 20, 21, 22, 23) have like patterns as shown by the high kappa scores.

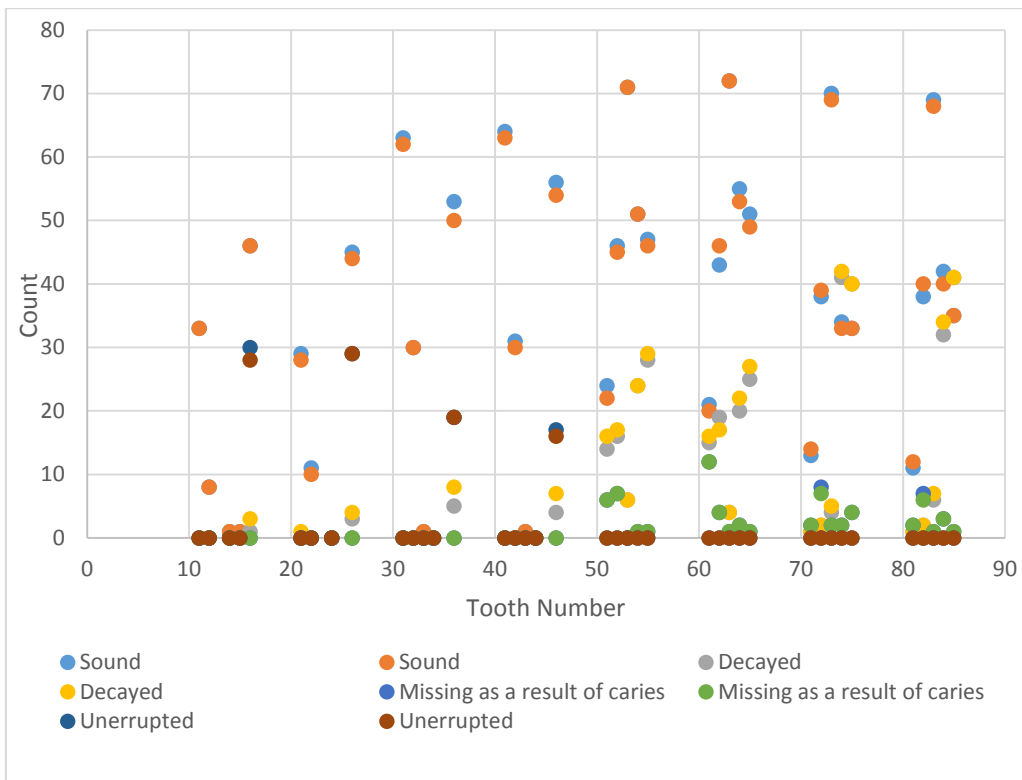


Figure 20: Scatterplot of traditional dental screening versus teledentistry DMFT assessments for school 2: Evaluator 1 (E1)

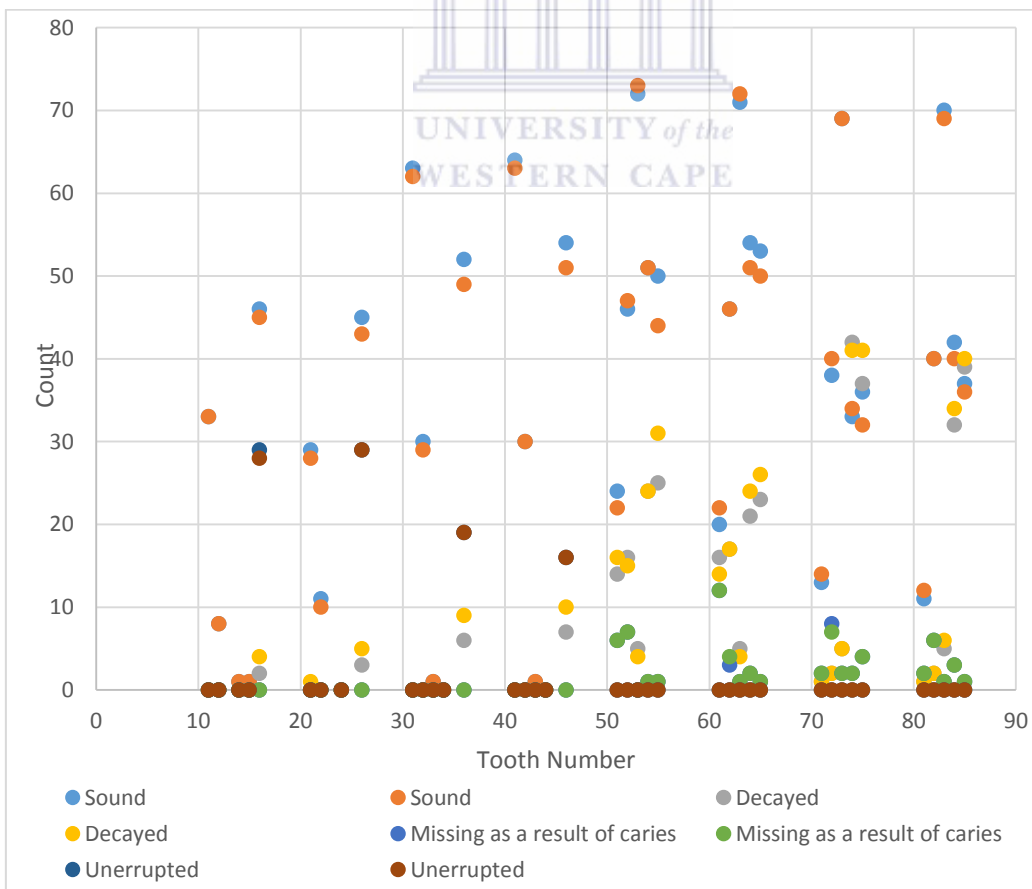


Figure 21: Scatterplot of traditional dental screening and teledentistry DMFT assessments for school 2: Evaluator 2 (E2)

For school 2, two evaluators scored a DMFT for 1853 teeth, which in essence should have 2 separate plots per tooth, thus totalling 3706 plots/dots that one should view per scatter plot (Figures 20 and 21) as there were two evaluators who used two different dental screening methods to score DMFT. However, in most instances there is less than the expected plots observed that indicates overlapping (the same DMFT values) or very similar DMFT values between the dental screening methods. This is also supported by the high level of agreement as observed in school 1.

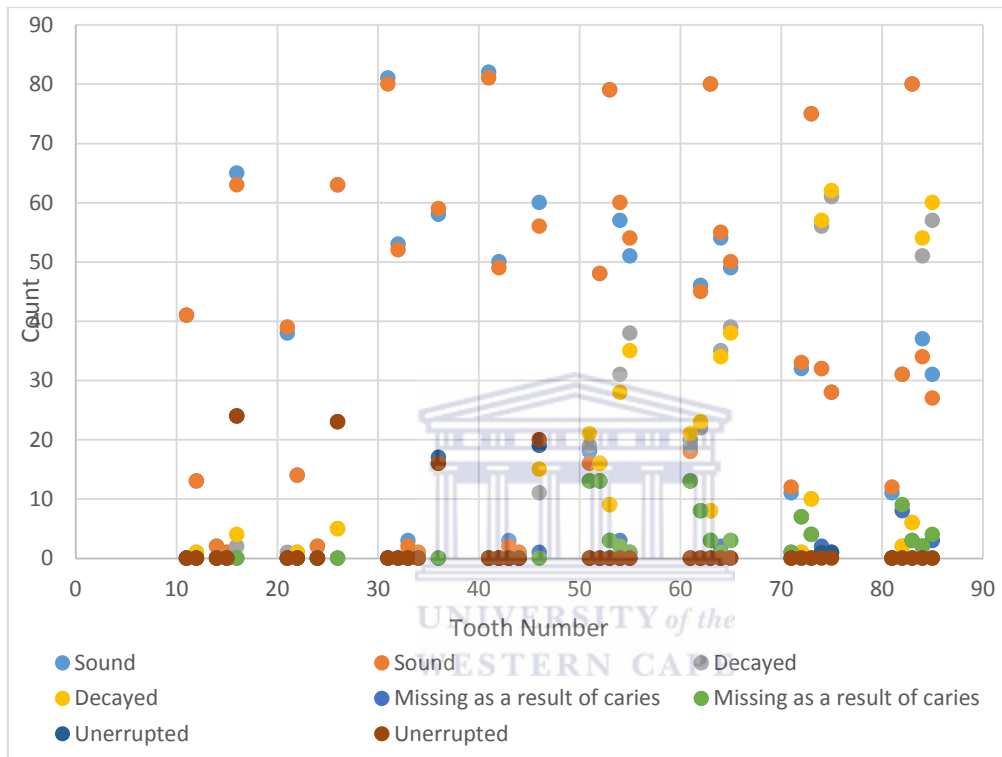


Figure 22: Scatterplot of traditional dental screening versus teledentistry DMFT assessments for school 3: Evaluator 1 (E1)

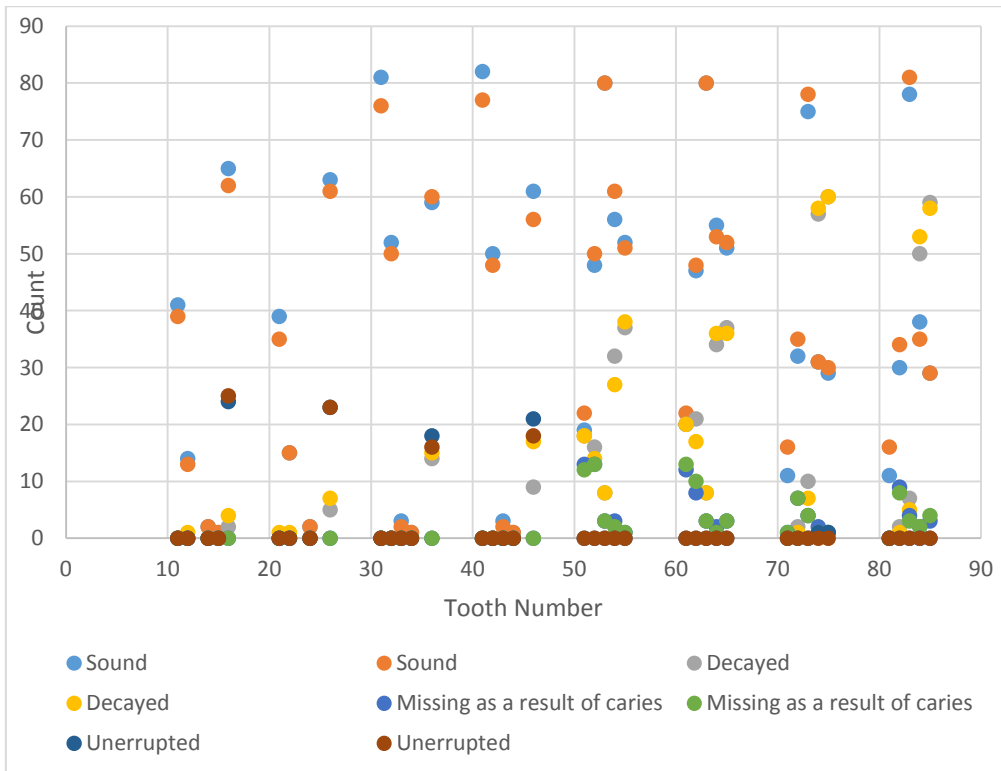


Figure 23: Scatterplot of traditional dental screening versus teledentistry DMFT assessments for school 3: Evaluator 2 (E2)

For school 3, two evaluators scored a DMFT for 2197 teeth, which in essence should have 2 separate plots per tooth totalling 4394 plots/dots that should be viewed per scatter plot (Figures 22 and 23) as there were two evaluators who used to different dental screening methods to score DMFT. However, in most instances there is less than the expected plots/dots observed as seen in school 1 and 2. Hence, the scatter plots for school 1, 2 and 3 depict similar patterns, highlighting the high kappa scores (ranged from 95% to 98.30%).

5. 3 PART TWO: USER SATISFACTION LEVELS

The study participants included the two evaluators (SB, AM) and the two TAs who were involved in the data collection process. Both evaluators were registered dental professionals and the TAs employees of the emergency services. The evaluators consisted of 1 male and 1 female, as did the TAs. The participants were presented with a closed format administered (by researcher) questionnaire designed for the specific role that they played in the study, so as to determine user satisfaction levels of the ICTs used in the teledentistry screening process. Table 12 illustrates the response rate of the evaluators. Table 13 and illustrates the response rate of the TAs.

Table 12: Response rate of the evaluators	Agree	Disagree
1. Accessing the intraoral images for screening was easy	2	
2. The quality of the images were clear and good	1	1
3. It was easy to score decayed teeth from the images	2	
4. It was easy to score filled teeth from the images	1	1
5. It was easy to score missing teeth from the images	2	
6. Interproximal caries was readable from the images	1	1
7. Interproximal caries was easy to detect from face-to-face examinations	2	
8. The screening process of the images went quick, thus saving time	2	
9. I prefer the traditional method of dental screening for dental caries	1	1
10. I prefer the teledentistry screening method for dental caries	1	1
11. Dental screening via teledentistry is a sterile process	2	
12. Dental screening via teledentistry is an innovative and easy system to use	2	
13. My opinion is that the teledentistry screening system will save clinical time by eliminating the visits to schools by the dental professionals	2	

Both of the evaluators agreed with 8 of the 13 statements (62%). The statements that were agreed up related mainly to theme 1 (user satisfaction on the technology) which included accessing the intraoral images for screening and the ease of scoring decayed and missing teeth off the images; theme 2 (time and technology) suggested the screening process of the images saved time because it was a quicker process as opposed to the traditional method of dental screening. The evaluators felt that assessing teeth off the images was faster and theme 4 (traditional dental screening versus teledentistry screening) which indicated teledentistry as being an innovative and easy system to use that will save clinical time for dental professionals. The evaluators felt that they could be treating patients in the clinic where they are in great demand, rather than going out

into the schools to carry out face-to-face dental screenings, instead trained TAs can capture intraoral images which can be later assessed by the diagnosing dentist. .

The statements they disagreed with related to the clarity of the images, scoring interproximal caries off the images, and the dental screening method of choice. However, even though one evaluator did not find the images to be clear and good, he/she still found it easy to score decayed and missing teeth off those images. Similarly, though one evaluator preferred the traditional method of screening, he/she was still in agreement that the teledentistry screening method is an innovative and easy system to use that will save clinical time for dental professionals.

	Agree	Disagree
1. The intraoral camera is easy to work with	1	1
2. Storing the captured images in electronic files (eFiles) is an easy process	1	1
3. The quality of the images was good and readable	2	
4. The children were comfortable during the imaging process	2	
5. The children were excited to see pictures of their teeth	2	
6. The screening process went quick, thus saving us time	2	
7. It was easy to delete unwanted images	1	1
8. The mouth did not need to be completely dry to capture clear images	1	1
9. Dental screening via teledentistry is a sterile process	2	
10. Dental screening via teledentistry is an innovative and easy system to use	2	
11. I could capture clear images irrespective of a poor lit environment		2

Both of the TAs agreed with 7 of the 11 statements (64%). They agreed upon statements related mainly to theme 2 (perception of children’s attitudes & behaviour) which suggested the children were comfortable during the imaging process and in addition they were excited to see pictures of their teeth. In addition, many of the children mentioned that they never had their teeth examined before; theme 3 (teledentistry as a screening option) where they found teledentistry to be an innovative and easy system to use. The TAs were in agreement that the use of the intraoral camera and the associated ICTs used for the screening of children’s teeth is an innovative system. In addition, the fact that the TAs had no dental background, contributed to their opinion of teledentistry being an innovative system. A system where people outside the dental fraternity can be trained in assisting in the delivery of oral health care.

Furthermore, they found teledentistry to be a sterile process and hence they were happy with infection control. In addition, both TAs disagreed with the statement that suggested clear images could be captured irrespective of poor lighting. The TAs felt that the headlamps used in the study assisted by providing more light in the oral cavity thereby improving vision for the imaging process. They both were in the opinion that the natural light and built in light on the intraoral camera was not sufficient for good intraoral visibility.

Discordant statements related mainly to theme 1 (user satisfaction on technology) which related to ease of using the intraoral camera, ease of storing the captured images into the eFiles and ease of deleting unwanted images. The TAs felt that maybe if they were working with the teledentistry system on a regular basis, the tasks would become easier with time.



CHAPTER 6

DISCUSSION

6.1 Introduction

Although teledentistry was initiated in 1994, it is still considered as a fairly new concept that has the potential to re-engineer the delivery of oral health care globally, thus enabling basic and specialized oral health care more accessible to remote communities. There is a large data base of literature that highlights teledentistry as a valuable tool in dentistry which is being practised extensively all over the world. It is a fast growing segment of dentistry exceptionally in the past five years and has shown promise in eliminating the gap between the underserved patient in rural areas and access to specialists (Arora *et al.* 2014). However, in Sub-Saharan Africa, no studies have been documented on teledentistry and in South Africa this technology has not yet found a place in every day dentistry or in the dental public sector.

This chapter discusses the findings of the present study. The study was divided into two parts. The first part of the chapter discusses the findings of the concordance study which investigated the diagnostic reliability and agreement of traditional dental screening versus teledentistry screening. This is followed by the second part that determined the user satisfaction levels of the evaluators and the TAs on the use of the ICTs in the teledentistry screening method. Finally the limitations of the study will be discussed and the chapter concludes with a summary of the key findings and a reflection on the limitations of this study.

6.2 Concordance study

The concordance study was carried out to determine the diagnostic reliability and agreement between traditional dental screening and teledentistry screening of DMFT in young children. Teledentistry and traditional diagnosis of five year olds and ten to eleven year old children in Manchester, United Kingdom, were compared for concordance. The results achieved an almost perfect diagnostic concordance (87.8% to 95.8%) in the 5 year olds and a substantial diagnostic concordance (58.5% to 71.7%) in the 10-11 year olds (Boye *et al.* 2013a).

In the present concordance study, traditional face-to-face DMFT scores and teledentistry DMFT scores were compared for diagnostic agreement and reliability using kappa statistics. There was a high frequency of agreement between traditional dental screening and teledentistry screening. Concordance between teledentistry and traditional dental screening radiography ranged from 95.09% to 98.30% for both evaluators in the present study. This implies that the use of teledentistry as a diagnostic tool for oral health services is effective in its current form.

The study sample consisted of 233 children between the ages of 6 to 8 years old with the mean age of 6.73 years. There were significantly more male participants in the age 6 and 7 category with the females dominating the age 8 category. However this did not impact on the concordance study of the two screening methods.

The inter-rater analysis compared DMFT assessments made by both evaluators (E1 and E2) using the traditional dental screening method and teledentistry screening method. The kappa statistics were found to be in almost perfect agreement (96.73%) for the traditional screening method. This was similar for the DMFT assessments made by the evaluators (IA1 and IA2) using the teledentistry screening method, where again the kappa statistics were in almost perfect agreement (97.59%).

The number of decayed teeth of the total sample scored using the traditional dental screening method was 20% and for the teledentistry screening it was 21% again suggesting that there was high agreement across methods. The fact that both evaluators had similar training, academic background and years of clinical experience, could have impacted positively on the results obtained and also suggest that they were competent to determine DMFT using both dental screening methods. However, decision support systems or diagnostic aids have been widely implemented to assist health professionals in making a diagnosis using the ICT platform. If there are standard assessment tool/diagnostic protocols, this will also allow for all dentists to utilise the teledentistry tool regardless of the level of experience. Other fields of telemedicine have utilised decision support systems successfully. One such example is the use of the cataract decision support system. One of the most beneficial aspects of this system included was that when technical measurements were being performed the decision support system yielded more consistent successful results regardless of the experience levels (Moore, 2005).

The intra-rater analysis compared DMFT assessments made by both evaluators across both the traditional dental and teledentistry screening methods. Kappa statistics revealed that both evaluators were in agreement between a range of 95%-98.30% of the classifications, or 92.79% of the way between random agreement and perfect agreement ($p < 0.001$). The high concordance level indicated that there was no statistical difference between the traditional dental screening method and the teledentistry screening method (intra-rater reliability), thus suggesting that the teledentistry screening method is a reliable alternative to the traditional dental screening method. Furthermore, this implies that intraoral images are a reliable tool to diagnose decayed missing and filled teeth in children.

Hence, teledentistry may have the potential to provide rural communities with the opportunity to have 'remote' consultations via the intraoral images that are electronically transferred without having to travel long distances to a clinic or hospital. This will reduce travel costs for the patient and improve the quality of care. A study carried out in Minneapolis showed high satisfaction levels of patients with the teledentistry service, with the greatest benefit being convenience and access to care (Chen *et al.* 2007). The study showed an average distance of only 13 miles for visiting the teledentistry clinic: On average less than two hours, compared to eighteen hours if the patient had to travel to Minneapolis (Chen *et al.* 2007).

For children requiring orthodontic interventions, images of the child's teeth can be forwarded to an orthodontist at a distant site who can then advise and guide a general dental practitioner on the treatment to be carried out. A feasibility study carried out by Berndt *et al.* (2008) suggests that interceptive orthodontic treatments provided by sufficiently prepared GDPs and supervised remotely by orthodontic specialists through teledentistry is a viable approach to reduce the severity of malocclusions in disadvantaged children when referral to an orthodontist is not feasible (Berndt *et al.* 2008). This is referred to as teleorthodontics. Therefore, intraoral images can be sent anywhere in the world via the internet for specialist consultations and advice and can be utilised for any of the subsets of teledentistry (Paediatric and Preventive dentistry, Tele Oral Medicine, Teleperiodontics, Tele Endodontics, Teleprosthodontics, Teleorthodontics). The distant diagnosis of paediatric dental problems, based on non-invasive imaging, was found to be appropriate for diagnosing dental problems and suggesting treatment options (Amavel *et al.* 2009).

A study on teleprosthodontics found in rural areas, through videoconferencing one can easily diagnose and plan a treatment for patients that require oral rehabilitation or prosthetic appliances (Panat *et al.* 2012) thereby affording underserved communities specialist services.

There was a high percentage of children with sound teeth and less than a quarter of children presented with decayed teeth. No children had filled teeth, indicating that they had not attended a dental clinic to have treatment. Many of the children reported that they had their teeth examined for the first time during the present study.

The most recent South African National Oral Health Survey (NOHS) revealed that 80 per cent of carious lesions in children go untreated (Van Wyk *et al.* 2004; DoH, 2003), which highlights South Africa's challenges of meeting its demanding dental needs for children, especially those living in remote and rural areas. This burden is compounded by the shortage of dental professionals that are required to service large populations. Contrary to the findings of the NOHS, the present study found a significantly higher proportion of children presenting with sound teeth, but this could be due to the small sample size and the localised study site.

In South Africa, it is estimated that in the public sector there are 2.31 dentists per 100,000 population (Health Systems Trust, 2012a) and 0.33 dental specialists per 100 000 population (Health Systems Trust, 2012b); implying a critical shortage of dental professional human resources in the public sector and a lack of access for people living in rural areas to dentist and specialist services. This scenario follows the rest of Sub-Saharan Africa where there is poor delivery of health care due to poor infrastructures and limited medical and dental professional human resources to deliver healthcare. Oral healthcare is an individual's right irrespective of their geographic location, and not a privilege. Teledentistry has been shown to improve access to general and specialised dental care for marginalised communities (Friction *et al.* 2009; Berndt *et al.* 2008; Kopycka-Kedzierawski *et al.* 2008; Kopycka-Kedzierawski, 2006; Chang *et al.* 2003). Furthermore, Scuffham *et al.* (2002) indicated that cost-savings are greatest in remote communities, where patients need to travel long distances to hospital for specialist consultations (Scuffham *et al.* 2002). Therefore, the Department of Health needs to invest in the teledentistry system to make oral health care more accessible to geographically challenged and underserved areas.

Dental hygienists and dental therapists will be able to provide quality care in collaboration with health care providers and specialists for consultation, referral, care and evaluation of care (Daniel *et al.* 2014). If the dental therapist is the only dental health provider in a rural setting, teledentistry may offer an opportunity whereby the dental therapist obtains specialist recommendations for patients without the need for them to travel for a face-to-face consultation.

Disagreement between the evaluators was minimal across the different methods used, and the majority of the mismatches were between the determination of decayed and sound teeth. This could be attributed to a few factors. Firstly, disposable plastic picks were used to detect pit and fissure caries in the traditional face-to-face examinations and while for the teledentistry screening method, evaluators had to rely on the images to determine pit and fissure caries. Secondly, dental caries (with an exception to pit & fissure caries) can be magnified with good lighting when viewing the intraoral teledentistry images thus improving vision and diagnosis of sound or decayed. It is also important to note that intraoral images are purposefully captured to provide the image assessors with the best quality of pictures to aid in the best possible diagnosis. Thirdly, interproximal caries is not easy to detect with either the traditional or teledentistry dental screening method unless it is obviously visible, such as a break in the surface enamel or the presence of large areas of shadowing.

The scatter plots presented in the Results chapter graphically depict the high concordance for both evaluators of the DMFT obtained between the traditional dental screening method and the teledentistry screening method carried out at the 3 schools. The high diagnostic concordance implies that there was no statistically significant differences between the dental screening methods and that the teledentistry screening method has been shown to be a comparable diagnostically reliable dental screening method. Internationally, Kopycka-Kedzierawski *et al.* (2007) carried out a feasibility and reliability study using teledentistry as a dental screening tool to screen preschool children for early childhood caries (ECC), and the authors concluded that there was no statistically significant difference between a visual examination and teledentistry screening, with a kappa agreement of 95% (Koycka-Kedzierawski *et al.* 2007), similar to the high kappa scores (95% to 98.30%) yielded in the present study. In addition, Patterson *et al.* (1998) carried out a similar study that compared the two screening methods, and again the results were consistent with the present study.

The percentage agreement between the traditional screening method and the teledentistry screening method ranged from 89% to 100% (Patterson *et al.* 1998). A teledentistry systematic review revealed that no statistical difference was found between teledentistry and clinical screening for dental caries (Daniel *et al.* 2013). The findings of the present study, together with international studies shows that teledentistry as a screening method is a reliable and feasible option, especially for the delivery of oral health care to the inaccessible and poorly resourced communities.

The significance of the findings of the present study is that teledentistry can be used as an invaluable alternate to the traditional dental screening face-to-face method especially when screening large populations of children in rural areas, particularly in Sub-Saharan Africa where poverty and the delivery of oral healthcare is a great challenge. South Africa is in an on-going process to try and bridge the gap and address the disparities within the health system. One of the key aims of the NHI is to re-engineer the way in which school-based primary health care services are provided, and here teledentistry has a significant role to play. In this regard, it may be a strategic opportunity to introduce teledentistry into the school-based primary health care policy, so as to improve oral health promotion and service delivery. Panat *et al* (2012) found teledentistry to be a good tool for screening dental caries in schoolchildren, and school going children can be divided into different categories of high risk or low risk patients. This risk triage can assist dental professionals in tailoring curative and preventive packages to assist communities in combating dental caries in schoolchildren. It is therefore anticipated that the present study will assist the Department of Health policy making decisions regarding the adoption and use of teledentistry as an innovative dental screening and diagnostic tool.

The importance of good oral health needs to be instilled in young children aged between 5-8 years so that they can carry the principles into adulthood, thereby reducing dental caries, early tooth loss and other oral diseases. This is a very important age group as the caries incidence can play a vital role in determining the caries risk assessment. Near-surface incipient lesions can be detected early so that caries can be arrested or reversed through topical therapies and improved oral hygiene and diet, as highlighted in Caries Management by Risk Assessment (CAMBRA) strategies (Ramos-Gomez, 2011). CAMBRA is an evidence-based approach to preventing or treating the cause of dental caries at the earliest stages rather than waiting for irreversible damage to the teeth (Hurlbutt, 2011).

Risk assessment is now viewed as the critically important step in the clinical decision-making process of managing dental caries (Van Hilsen *et al.* 2013). For teledentistry, caries risk assessment can effectively manage and triage patients for treatment planning, prevention, and establishing follow-up and recall times.

The combination of teledentistry with the caries risk assessment strategy can be significant in providing a synergy between preventive and curative oral health care to children in critical access communities (Van Hilsen *et al.* 2013). Therefore, teledentistry should be strategically engineered into the oral health school screening systems. The categorization of the caries risk factors will then allow for focused recommendations to minimise the risk of developing new carious lesions and/or the progression of existing lesions in the future (Pitts, 2011), thereby promoting oral health care and preventing further disease. This further highlights the potential value of the teledentistry screening method as it may be envisaged that the teledentistry screening system may be a more cost effective method to screen large populations of children.

The proposed introduction of the National Health Insurance (NHI) is to ensure that everyone has access to appropriate, efficient and quality health services regardless of their socio-economic status (DoH, 2011). It may be an option for the Department of Health to consider teledentistry for implementation into the NHI and the next National Oral Health Survey (NOHS). Appropriateness is one of the guiding principles of the NHI and refers to adopting new and innovative health service delivery models that focus on local needs (DoH, 2011). In addition, one of the objectives of the NHI is to strengthen the under-resourced and strained public sector so as to improve health systems performance (DoH, 2011). Teledentistry is an intervention that can enhance opportunities for the new primary healthcare model and has the capacity to take service delivery and accessibility to newer and improved levels.

The teledentistry screening method will eliminate the need for instrumentation (like mouth mirrors and probes). Furthermore, infection control will be improved as cold sterilization of the instruments will not be required. In addition, National Oral Health Surveys often require the deployment of a large number of calibrated dental professionals doing visual face-to-face examinations, and contrary to this, teledentistry screening can utilise trained and calibrated non-dental personnel (community health workers or nurses for example that are already based in the communities) to capture the intraoral images of the school children and the web-based stored images can then be

assessed by the dental professionals (community health dentists can be utilized for this role) at a distant site in their own time. Therefore, teledentistry screening can potentially greatly reduce the human resources required and may save travel time so that dental professionals make better use of their clinical training and expertise in the clinics.

The use of teledentistry screening for dental caries in young children has been shown to be cost-effective (Daniel *et al.* 2013) and although, the information and communications technology (ICTs) required for the teledentistry screening process may be expensive initially, the long term benefits of investing in the system are inherent. Furthermore, there are existing telemedicine sites in South Africa that teledentistry can ‘piggy-back’ on, and that in turn may reduce the ICT costs. Researchers in Rochester, New York, complemented their teledentistry project to the existing telehealth model in elementary and child-care centres that has been in establishment form May 2001. The telehealth assistants were trained to capture intraoral images which were then later electronically forwarded to the paediatric dentist at the diagnosing site. (Kopycka-Kedzierawski *et al.* 2006). Furthermore, integrating a dental component with the medical model may further improve the early intervention mechanism, and reduce disparities and increase access to care for the underserved (Kopycka-Kedzierawski *et al.* 2006), thereby promoting a holistic general healthcare approach.

The findings of high diagnostic concordance in the present study implies that teledentistry screening is reliable and has a significant role to play in the eHealth Strategy for SA (DoH, 2012). The eHealth Strategy is the ideal platform to incorporate teledentistry into the public healthcare system, thus improving the delivery of oral health care to the population especially the poorly resourced and disadvantaged communities in SA. The advantage will be that the interdisciplinary collaboration will avoid the compartmentalization of dental and medical care, thereby improving overall patient care. In addition, the eHealth Strategy was developed due to the poor outcome of the health information systems experienced in SA’s telemedicine initiative, hence; the success of the new eHealth strategy, and implementation is being closely monitored by the Ministry of Health and the National Health Council to ensure that the previous errors are not repeated (DoH, 2012). Therefore, this monitoring will ensure good management and implementation of teledentistry into the eHealth structure.

Furthermore, eHealth offers dentistry the advantage of mHealth (mobile health) which is one of the fastest growing subsets of eHealth. Mobile health makes full use of smart phones, tablets and personal health monitoring devices for the timely collection and transmission of personal health data for diagnostic, monitoring and educational purposes (Daniel *et al.* 2014). Hence, m-teledentistry has the potential to allow oral health care workers to engage parental/guardian assistance in maintaining good oral health for children. For example, the colour images of the carious teeth captured by TAs during the screening process can be forwarded to the parent's/guardians smart phones via multimedia messaging (mms), together with treatment recommendations. By parents getting an opportunity to view close up images of their children's teeth, this may motivate them to take their children to the dental clinics/hospitals to address their children's recommended treatment needs timeously. In addition, a possible alternative to using the intraoral camera for capturing images, is the use of smartphones.

A recent study in Australia was carried out using smartphone cameras to capture intraoral images to evaluate a cloud-based telemedicine application for screening for oral diseases (Estai *et al.* 2015). The intra-grader agreement indicated that the smartphone imaging and cloud-based screening system of oral diseases can be implemented to provide a valid and reliable alternative to traditional oral screening (Estai *et al.* 2015). However, this was a proof-of-concept trial and further field studies are necessary. This concept of using smartphone cameras to capture intraoral images and having the images stored and accessed via a cloud storage is work in progress for alternate technology options. South Africa is one of the countries with the highest proportion of mobile phone users per population, with 93 out of 100 people being subscribed to a mobile phone network (Mars *et al.* 2008), thereby suggesting that in SA, m-teledentistry has the potential to facilitate in dental diagnostics and the delivery of oral health care messages via cellular communications. However, this will largely depend on whether there is good mobile connectivity/reception and internet access available, especially in remote rural areas. Even though the cellular service is booming, the internet access remains low. Only 19 per 1000 Sub-Saharan inhabitants have access to internet, the lowest rate of any developing region (Asamoah-Odei *et al.*, 2007).

One of the strategic priorities to leverage eHealth to strengthen healthcare transformation in South Africa is the applications and tools to support healthcare delivery (Department of Health, 2012). Therefore, it is anticipated that this study will

play a pivotal role in highlighting the importance and value of ICT tools when used in the assessment and management of dental caries, thus underpinning the above mentioned strategic priority of the eHealth strategy of South Africa.

Teledentistry can be used in various modalities to improve the delivery of general and specialist oral health care. The teledentistry screening method used in the present study was the store-and-forward method where the images are web-based stored and later assessed at a remote site, however, the teledentistry real-time consulting method can also be utilized for patients that visit the dental clinics and require specialist consultations. Real-time teledentistry consultations usually includes a videoconference in which dental professionals and their patients, at different locations, may see, hear, and communicate with one another (Bhambal *et al.* 2010). With real-time consultations also known as synchronous teleconsultations, information is transferred immediately and there is a two-way interaction between the patient and the consulting specialist, which allows for immediate feedback from the specialist consultant. Hence, through the use of telecommunications and computer technologies, it is now possible to provide interactive access to specialist opinions that are not limited by the constraints of either space or time (Jain *et al.* 2013), thus making specialist care accessible to critical access areas and bridging the gap between demand and supply.

Specialist consultations via videoconferencing were well received in a study in Minnesota where the majority of patients felt comfortable have a doctor consultation through a videoconference service. Many patients reported that the teledentistry visit was “the same as in-surgery or in person”, “just through the TV” (Chen *et al.* 2007). Therefore, the integration of teledentistry into the NHI and eHealth strategy can improve the delivery of oral health care to SA’s underserved communities.

The present study has shown the reliability of teledentistry as a dental screening tool. Once initiated, teledentistry has the potential grow and develop within its own versatility and various adaptations. For example, it can be used for a variety of online dental information and education purposes, for electronic consumer medical and health information, dentist-laboratory communication, patient consultations, specialist referrals and for remote patient monitoring or home-health care. All of which has great potential to enhance dental education and the delivery of oral health care in SA.

Teledentistry improves the integration of dentistry into the overall health care delivery system (Jain *et al.* 2013). For example, if a patient presents with oral HIV lesions, the

general dental practitioner can liaise with the patient's general medical practitioner to determine a holistic treatment plan. In addition, many interventions for chronic diseases such as diabetes, hypertension, tobacco cessation, and obesity management have been found to be more successful when supported by coordinated, inter-disciplinary and collaborative care among several types of healthcare providers (Schleyer *et al.* 2012).

In summary, the following advantages of the teledentistry screening method were obtained by the present study:-

- It saved the time by having assistants capture the images of the children's teeth
- The intraoral images could be accessed and assessed at a distant site in the clinicians own time.
- The intraoral images can be reviewed and reassessed to verify diagnosis without inconveniencing the child.
- The process was non-invasive and the children were comfortable during the imaging process.
- As the intraoral images are web-based stored in eFiles, children that are referred for treatment can be easily followed up.
- Intraoral images can be emailed to distant sites for specialist and further treatment advice if necessary.

6.3 User Satisfaction Levels

User-friendliness can enhance the successful adoption and adaptation of the teledentistry system. A study in Minnesota used teledentistry to help increase access to specialist dental care to the underserved population (Chen *et al.* 2007). A provider satisfaction survey of the study showed that all providers felt comfortable during the teleconference. Majority of the providers reported that not much technical skill was required to conduct the teledentistry consults, even though none of the providers had any previous experience with the teledentistry system. Consistently, the patients also expressed high satisfaction levels with the teledentistry service, with patients continuing to use the teledentistry system (Chen *et al.* 2007). The user-friendliness of the ICTs used in the Minnesota study encouraged health care practitioners and patients to use teledentistry thereby improving access to oral health care.

Closed format self-administered questionnaires using the Likert scale were completed by the evaluators and the TAs to determine user satisfaction levels of the ICTs used in the teledentistry screening process. There were two evaluators (1 male and 1 female) and two TAs (1 male and 1 female). The response outcome will be discussed in two parts thematically.

6.3.1 Evaluator response

The evaluators agreed that it was easy to access the images for scoring a DMFT and that the eFiles were operator-friendly. Although, the eFiling system can be expensive, it is an initial investment, but can be used to record data for many years unlike the regular investment required for the on-going purchase of paper records (Chandra *et al.* 2012). In highly developed health care systems like those in Israel, the United States, and Europe, most aspects of the health care and consumer health experience are becoming supported by a wide array of technology such as electronic and personal health records (EHRs and PHRs) (Weiner 2012). The EHRs is the main patient information access centre that can be tapped in to by the authorised clinician/s when required. An advantage is that all information and images stored in the EHRs or PHRs can be archived, retrieved and updated when necessary. Furthermore, the fact that EHRs are paperless records, it will decrease carbon footprints and assist in combating global warming.

An advantage in the present study is that the intraoral images can be accessed and reassessed if required, however, with the traditional face-to-face method, you only get a few minutes to quickly examine the teeth for DMFT. Examiners can also spend more time examining the images as opposed to the face-to-face method. Face-to-face examinations need to be quick as children tend to get restless and time is a factor as maximum children need to be examined within specified school hours.

Both of the evaluators reported that it was easy to score decayed and missing teeth from the images. However, rigorous training of the TAs is required to ensure that high quality images are captured. In general, the diagnosis of interproximal caries from both intraoral images and face-to-face visual examination is difficult unless there is a visible break in the surface enamel or there is distinct shadowing present, and if suspected can be verified with bitewing radiographs.

A study in Manchester, UK was carried out to determine the views of the examiners on the use of intraoral photographs for detecting dental caries for epidemiological studies (Boye *et al.* 2013b). The examiners suggested that to improve the utility of the photographic method, further research is required to determine adequate removal of debris and moisture control prior to imaging for use in the field. Further views included that a standardised presentation of the photographs including the size and resolution is required, and there is a need for the examiners to be specifically trained on caries detection from the images. The examiners in the study found it easier to make caries detection decisions on the intraoral images of primary teeth than that of permanent teeth and the fact that they could carry out the screening of the intraoral images at a convenient time and place was reported as an advantage (Boye *et al.* 2013b).

Despite the fact that one of the evaluators preferred the traditional screening method, there was agreement from both evaluators that teledentistry is an innovative and easy system to use and that it saved time. Travel time is saved and instead of dental professionals going to schools to carry out traditional dental screening, they can spend more time treating and managing patients in the clinic. Dental professionals' clinical time can be saved by training non-dental personnel to capture intraoral images that can be screened by the dental professionals in their own time. This is advantageous where there is a shortage of dental professionals to service rural communities who have poor access to oral health care.

It has been reported that in South Africa, more than 80% of oral health care workers (includes dentists, dental therapists, hygienists and dental technicians) are employed in the private sector (Van Wyk *et al.* 2004) where the demand is low in comparison to the public sector. To reduce the burden of human resource shortages in the public sector, the use of teledentistry as a school screening tool has been recommended.

It was reported that there is limited information available on dental professionals' opinions on using telemedicine applications in dentistry or their satisfaction about newly implemented specific teledentistry systems (Elmokadem, 2013). Therefore, it is recommended that more evidence based studies on user satisfaction levels is required so as to eliminate or minimise user friendliness as a barrier to the use of teledentistry.

6.3.2 Teledentistry Assistants (TAs)

The TAs agreed that teledentistry is an innovative and easy system to use, and that they did not require a dental background to efficiently capture the intraoral images. This means that non-dental workers including community healthcare workers or community nurses can be trained to assist with the imaging processes for teledentistry screening. While there were mixed responses regarding the use of the technology, many of the issues can be resolved through rigorous training. With continued and long term use of the technology operators can then gain more confidence and efficiency.

Poor lighting was highlighted as a reason for not being able to obtain good images in some instances. Even though the intraoral cameras have built-in lighting that illuminates the area of focus, individual head lamps were used to improve the lighting of the entire oral cavity during the imaging process. Furthermore, the intraoral camera can be focused, and the teeth can then be viewed on the laptop screen to capture the final image.

Teledentistry has been found to reduce fear and anxiety when compared to clinical examinations in real time (Mihailovic *et al.* 2011). The TAs reported that the children showed no discomfort during the imaging process and were excited to view the images of their mouth and teeth on the laptop monitors. Teledentistry can be seen as a fun and innovative method of reducing the fear and stress of dental examinations in young children.

Good infection control was maintained during the imaging process, since disposable plastic sleeves for the intraoral camera and disposable tongue depressors were used.

For traditional screening examinations cold sterilization is used for probes and mouth mirrors. The use of disposal covers and instruments saves time during the imaging process, as the waiting period associated with the cold sterilization technique is eliminated.

Overall, both the evaluators and the TAs in this study found the teledentistry screening method to be an innovative system that saves time and is easy to use, thus suggesting they were satisfied with the use of the teledentistry system. A teledentistry systematic review found an overall satisfaction rating regarding the use of teledentistry as very high from both patients and therapists, regardless of the patient population, setting or study design (Daniel *et al.* 2013). However, the current study focused more on user

satisfaction of the technology and not so much on the human factors. A better understanding of user satisfaction levels is required and future studies in teledentistry needs to focus on this aspect thus making teledentistry a more attractive dental screening and diagnostic system to use. Teledentistry screening has the potential to revolutionize the delivery of oral health care in South Africa, especially in poorly resourced and underserved areas that are geographically challenged.

6.4 Limitations of the study

- The user satisfaction questionnaires were closed ended, hence no explanations were given as to why evaluators and TAs were satisfied or dissatisfied with use of the teledentistry process.
- User satisfaction levels focused more on the technology aspect and not much on the human factors.



CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

Even though dental caries is a preventable disease, it remains a serious public health problem. In South Africa the most recent National Oral Health Survey (NOHS) reported at least 80% of dental caries in children is untreated (Van Wyk *et al.* 2004; Department of Health, 2003). To reduce the dental caries burden in children, the use of teledentistry as a screening tool for school children is recommended and it has the potential to improve access and delivery to oral health care to children in rural areas. But, can teledentistry be shown to be a reliable dental screening tool in South Africa's health system and rural settings?

The concordance study data output suggest that teledentistry screening is a feasible method. The diagnostic concordance in this study yielded an almost perfect result which is very similar to global findings, suggesting there were no statistically significant differences between the traditional dental screening method (visual examination) and the teledentistry screening method. This indicates that teledentistry can be used as a reliable alternate dental screening method which is used to determine DMFT in young children.

This research study further revealed valuable data on user satisfaction levels of the evaluators and TAs, and has an impact on the utilisation of the teledentistry screening system. To ensure adoption and adaptation of the screening process all users must be satisfied with the ICTs used in the teledentistry system. User friendliness can impact negatively on the adoption of teledentistry.

In addition, this study has provided evidence to enhance the proposed eHealth patient-centred strategy for South Africa (DoH, 2012-2016) to eliminate the oral health disparities that exist in South Africa with the implementation of teledentistry.

Patterson *et al.* (1998) complemented their teledentistry screening study to the existing telehealth centre at The University of Alberta. The researchers concluded that for teledentistry screenings to be cost-effective, it would likely be necessary for the telehealth infrastructure to be already present. Alberta Health is currently considering expanding the telehealth equipment to more sites within that province, which will allow a "piggyback" effect for completing dental consultation and screening services without

having to purchase or install equipment solely for that purpose. With the introduction of the NHI, it may be an opportune time for teledentistry to be integrated into the eHealth Strategy for South Africa. As there are already existing NHI pilot sites and telemedicine sites in South Africa, teledentistry can easily be initiated incrementally via these sites, consequently possibly reducing costs for the Department of Health and improving access to oral health care to underserved communities, and increasing equity and thereby reducing the oral disease burdens in children.

The key findings of this study highlights the reliability of utilising teledentistry as a dental screening and diagnostic tool which can be valuable in the delivery of oral health care in South Africa. However, the following important aspects need to be taken into consideration:-

- The implementation models for teledentistry should ensure comprehensive training for both TAs and the end users. This should include training with use of the teledentistry equipment and clinical training to ensure calibration. This is pertinent to ensure that high quality images that are easily stored and retrieved are produced for the evaluators.
- Key policies are required in eHealth and teledentistry to ensure that there is an establishment of a regulatory body that governs issues that relate to confidentiality, privacy, security, consent, compliance, accountability, malpractice and liability. It is crucial that legal and ethical guidelines be formulated to safeguard both the patient and the teledentistry operator.
- The development, implementation, monitoring and evaluation of the teledentistry system will require a multi-skilled team. The expertise of the various team members will include dental professionals, health informatics and IT specialists, health management, policymakers and community health workers or community health nurses. Inter-collaboration of the multi-skilled team is essential for teledentistry to be successful in SA.

Further research should be carried out to determine the:

- Costs associated with traditional dental screening versus teledentistry screening.
- Feasibility of teledentistry in other subset fields (Tele Oral Medicine, Teleorthodontics, Teleprosthodontics, Tele Endodontics and Teleperiodontics) in South African settings.
- Long-term impact of the ICTs in teledentistry on the management of dental caries in young children.
- Concordance with adults

South Africa is a developing country and so is the rest of Sub-Saharan Africa, and as such needs to integrate new technologies into the medical and dental sectors that will improve service delivery to marginalised communities – as highlighted by the present study, teledentistry has the potential to enable this.

Technology is evolving and being integrated into all aspects of daily life such as electronic banking, e-Tolls, smart phones and tablets, emails, eHealth, social networks, online shopping and eLearning (online, schools and tertiary institutes), thus making life easier in a fast-paced world. Therefore, health professionals and all stake holders need to identify the fundamental importance of implementing teledentistry into South Africa's current eHealth strategy thereby redesigning the delivery of oral health care to the countries poorly accessed areas.

However, at the same time, the minimizing of telephonic and face-to-face communications can impact negatively on us as individuals as people require face-to-face communication and interaction to survive. Technology must therefore be seen as an adjunct that enhances medical and dental care so as to improve the mode of delivery to the geographically diverse communities and not to eliminate face-to-face patient interactions completely.

In addition, even though information and communications technology has made significant advances in all aspects of our life, including saving time and money, there remains a large challenging gap with regards to the secure transmission of electronic information.

However, the eHealth Strategy has recently been promulgated for South Africa and includes recommendations for the establishment of regulations on privacy, confidentiality and security; a national standards compliance body; the development of a licensing policy and determination of effective risk mitigation strategies for eHealth projects (Department of Health, 2012). It is therefore critical that these recommendations are met to ensure that there are adequate security systems in place to secure data, thus protecting patient confidentiality and preventing patient-practitioner medicolegal complications. The benefits of teledentistry far outweigh the negative aspects. Therefore, once the challenges are addressed, teledentistry has the potential to take the delivery of oral health care to newer and improved heights.



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APPENDICES

APPENDIX A: LETTER OF PERMISSION FROM DOE



education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Nomangisi Ngubane

Tel: 033 392 1004

Ref.:2/4/8/1/15

Mrs S Bissessur
286 Spencer Road
Clare Estate
DURBAN
4091

Dear Mrs Bissessur

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **“THE IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGY ON THE MANAGEMENT OF DENTAL CARIES IN KWAZULU-NATAL”**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 31 January 2015 to 31 December 2015.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Connie Kehologile at the contact numbers below.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report / dissertation / thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education (Umlazi District).

Nkosinathi S.P. Sishi, PhD
Head of Department: Education
Date: 05 November 2014

KWAZULU-NATAL DEPARTMENT OF EDUCATION

POSTAL: Private Bag X 9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa ...dedicated to service and performance
PHYSICAL: 247 Burger Street, Anton Lembede House, Pietermaritzburg, 3201. Tel. 033 392 1004 **beyond the call of duty**
EMAIL ADDRESS: kehologile.connie@kzndoe.gov.za / Nomangisi.Ngubane@kzndoe.gov.za
CALL CENTRE: 0860 596 363; Fax: 033 392 1203 WEBSITE: WWW.kzneducation.gov.za

APPENDIX B: ETHICAL CLEARANCE



Office of the Deputy Dean Postgraduate Studies and Research

Faculty of Dentistry & WHO Collaborating Centre for Oral Health



UNIVERSITY OF THE WESTERN CAPE

Private Bag X1, Tygerberg 7505

Cape Town

Date: 16th March 2015

Dear Ms Bissessur

STUDY TITLE: A comparative analysis of traditional dental screening versus teledentistry screening

PROJECT REGISTRATION NUMBER: 15/2/8

ETHICS: **Approved**

At a meeting of the Senate Research Committee held on Friday 17th August 2012 the above project was approved. This project is therefore now registered and you can proceed with the study. Please quote the above-mentioned project title and registration number in all further correspondence. Please carefully read the Standards and Guidance for Researchers below before carrying out your study.

Patients participating in a research project at the Tygerberg and Mitchells Plain Oral Health Centres will not be treated free of charge as the Provincial Administration of the Western Cape does not support research financially. Due to the heavy workload auxiliary staff of the Oral Health Centres cannot offer assistance with research projects.

Yours sincerely

Professor Sudeshni Naidoo

Faculty of Dentistry

University of Western Cape



APPENDIX C

INFORMATION SHEET

RESEARCH TITLE: A Comparative Analysis of Traditional Dental Screening versus Teledentistry Screening



What is the study about?

This research project is conducted by Ms Sabeshni Bissessur and Professor Sudeshni Naidoo (Supervisor) at the Faculty of Dentistry, University of the Western Cape.

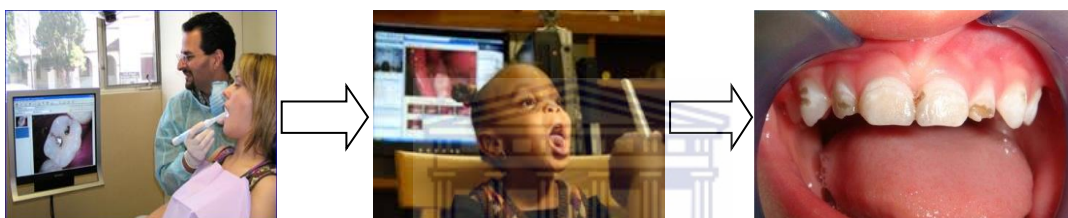
The purpose of the research project is to determine if computer technologies (for example cellular phones, emails and cameras) can improve access of dental health care to young children (6-8 year olds). The findings of this study will be useful in helping the government to improve dental care for children in South Africa.



Camera for the teeth

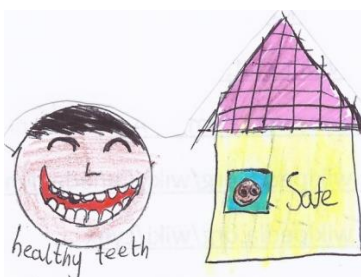
If my child participates, what is his/her role?

Your child will have his/her teeth examined at by using an intraoral camera, which is a camera used for your mouth, and this will be a free service for your child. Six photos of your child's teeth will be taken, and this is not painful at all and may even be fun and exciting for your child to see photos of his/her teeth. The procedure will take about 15-25 minutes for each child. These photos will then be sent to a dentist who will examine the photos and see if your child needs any dental treatment. You as the parent/guardian will be informed by a text message on your smart phone, or, if you do not have a smart phone, a written notice will be sent to you together with a picture of your child's teeth. Names of the closest dental clinics will also be sent to you so that you may take your child for the treatment he/she needs. After three months, we will once more take pictures of your child's teeth and your child's involvement in the study is then over.



Are there any risks?

There are no known risks associated with participation in this research project and no harm will come to your child.



Is my child's information safe?

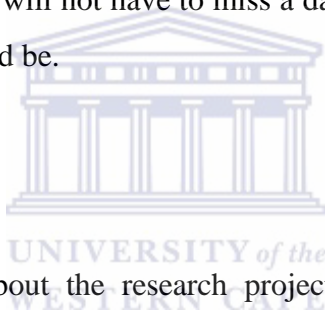
All information on your child will be strictly confidential and will only be viewed by the researcher. All information will be kept confidential and will be stored in password protected computer files.

You as a participant

Your participation in this research project is completely voluntary. You will be required to give written permission for your child's participation by signing a consent form. You may also choose to not participate at all. If you do allow your child to take part in this research project, you may withdraw your child and stop participating at any time. You and your child will not be penalised in any way if you do so.

Benefits of the study

Your child will have his/her teeth examined by using a pain free method at no cost to you. All dental treatment that is required for your child will be sent to you together with a picture of your child's teeth and a guide as to which clinics you can attend. Your child does not have to miss a day at school to travel to a clinic to have his/her teeth examined, and you as the parent/guardian will not have to miss a day at work. You will be referred to a dental clinic for care if need be.



For questions

If you have any questions about the research project, please contact the principle investigators:-

Sabeshni Bissessur

Professor Sudeshni Naidoo

Tel: 031 2624471

Tel: 021 9373095

Mobile: 0829586706

Email: sabeshb@vodamail.co.za OR Email: suenaidoo@uwc.ac.za

APPENDIX D

INFORMED CONSENT

I am a PhD student in the Department of Community Oral Health at the Faculty of Dentistry, University of the Western Cape. Decayed (rotten) teeth are a problem in young children and we need to try and use new improved ways to help treat and prevent this disease of the teeth. There are large populations of children that may not have a chance to have their teeth examined at a young age and this is why we are trying to use a new, easy, pain free method that will allow all children to have dental check-ups at their school. An intraoral camera will be used to take photos of your child's teeth, and this is pain free. Photos of your child's teeth will be taken twice, in the first month of the study and at three months (the last month of the study).

The dental examination will take about 15-25 minutes. There are no known risks in taking part. All information gathered in the study will be treated as strictly confidential. No one will have access to this information except the researcher and her team. Neither your name nor anything that identifies you will be used in any reports of this study. All information collected will be maintained and stored in such a way so as to keep it as confidential as possible. Your participation is voluntary and you may withdraw from the study at any time without any penalties.

By signing this consent form, you as the parent/guardian are also stating that you have explained the dental check-up process to your child and that he/she is happy to take part in the study. Furthermore, that you have also explained to your child that he/she is allowed to leave the study at any point, without any penalties.

If you would like your child to take part in the study, please sign the bottom of this letter. If you would like to know anything more about the study, please contact Ms Sabeshni Bissessur on telephone number at work 031-2624471.

Thank you in advance for your co-operation.

Yours sincerely

Sabeshni Bissessur

I understand what will be required of my child to take part in the study. I agree to participate in the research being undertaken by Ms Sabeshni Bissessur. I understand that at any time my child may withdraw from this study without giving a reason and without it affecting me or my child's management in the future.

Name of parent/guardian:.....

Name of child:.....

Signature:..... **(Witness):**.....

APPENDIX E

Modified WHO Oral Health Assessment Form (1997)

Form No

--	--	--	--

Data collector

--

Date

--	--	--	--	--	--

Personal information

School No

--	--

Age

--	--

Name:

Gender: Male (1) Female (2)

--

Dentition status and treatment need

Status	Treatment need
A = Sound	0 = None
B = Decayed	1 = Filling
C = Filled with decay	2 = Extraction
D = Filled no decay	3 = Pulp care
E = Missing as a result of caries	4 = Fissure Sealant
F = Not recorded	5 = Need for other care

16	55	54	53	52	51	61	62	63	64	65	26

Dentition status

46	85	84	83	82	81	71	72	73	74	75	36

Dentition status

APPENDIX F

QUESTIONNAIRE FOR TELEDENTISTRY ASSISTANTS

*****Please make a cross (X) in your selected box*****

User satisfaction towards the imaging process in teledentistry	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
1. The intraoral camera is easy to work with.					
2. Storing the captured images in electronic files (e-files) is an easy process.					
3. The quality of the images was good and readable.					
4. The children were comfortable during the imaging process.					
5. The children were excited to see pictures of their teeth.					
6. The screening process went quick, thus saving us time.					
7. It was easy to delete unwanted images.					
8. The mouth did not need to be completely dry to capture clear images					
9. Dental screening via teledentistry is a sterile process.					
10. Dental screening via teledentistry is an innovative and easy system to use.					
11. I could capture clear images irrespective of a poor lit environment.					

APPENDIX G

QUESTIONNAIRE FOR THE EVALUATORS

*****Please make a cross (X) in your selected box*****

User satisfaction levels of the evaluators with the teledentistry screening system	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
1. Accessing the intraoral images for screening was easy.					
2. The quality of the images were clear and good.					
3. It was easy to score decayed teeth from the images.					
4. It was easy to score filled teeth from the images.					
5. It was easy to score missing teeth from the images.					
6. Interproximal caries was readable from the images.					
7. Interproximal caries was easy to detect from face-to-face examinations.					
8. The screening process of the images went quick, thus saving time.					
9. I prefer the traditional method of dental screening for dental caries					
10. I prefer the teledentistry screening method for dental caries					
11. Dental screening via teledentistry is a sterile process.					
12. Dental screening via teledentistry is an innovative and easy system to use.					
13. My opinion is that the teledentistry screening system will save clinical time by eliminating the visits to schools by the dental professionals.					