ROOT CANAL TREATMENT OUTCOMES AT THE UNIVERSITY OF PRETORIA ORAL HEALTH CENTRE.

By

Vanessa Mostert

21238058

DISSERTATION

Submitted in partial fulfilment of the requirements for the degree of MSc in the Department of Dental Management Sciences, School of Dentistry, Faculty of Health Sciences, University of Pretoria.

Supervisor: Dr T.C. Postma

Co-supervisor: Dr C.H. Jonker

MARCH 2015

ACKNOWLEDGEMENTS

I thank God for giving me the ability to attempt this master's degree. Without Him I would not have had the strength or ability to complete it.

I want to express my sincere appreciation to the following people for their contributions to this dissertation:

- A special thanks to my supervisor, Dr TC Postma for his unwavering dedication, insight and guidance. His hunger for teaching and eagerness to help every student is inspiring. I am especially grateful for the personal attention I received.
- My co-supervisor, Dr Jonker for his example of spirituality and devotion.
- My mother who never gave up on me even when I struggled academically.
- My husband for his love and continued support.
- My children for the sacrifice that they have made by having a mother with such long working hours when they needed me most.
- My friend, Samantha and my sisters for their friendship and encouragement.
- The staff at the DMS department for allowing me the time out to research.
- The statistician, Prof Bekker for his contribution.
- Sincere thanks to Dr Uys for his time and effort to examine the radiographs.

DECLARATION

I declare that the topic “Root canal treatment outcomes at the University of Pretoria Oral Health Centre” is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

I declare that this work has never been submitted before for any other degree at any other institution.

April 2015

Vanessa Mostert

Staff and student number:

21238058

ABSTRACT

Aim: The University of Pretoria Oral Health Centre (UPOHC) is inundated by patients who demand emergency pulpectomies. The demand for service however exceeds the capacity to treat, which may be problematic in terms of treatment outcomes. The aim of this study is therefore to measure the outcome of emergency pulpectomies at the UPOHC.

Method: The electronic and paper records of 498 randomly selected teeth that received an emergency pulpectomy at the UPOHC from 1July 2012 until 30 June 2013 were examined to determine the outcome of the treatment. The completion rate over time was calculated in combination with the percentage of teeth that was eventually extracted or referred for extraction. In the case where the root canal treatment (RCT) reached the obturation phase, the post-operative radiographs were analysed in terms of the technical quality of the obturation.

Results: Forty-five percent of the sample size of 498 teeth for which an emergency pulpectomy was performed returned to have the RCT completed. Of these, 43% were inadequately obturated. Eight percent of teeth observed referred for extraction. Seven percent of teeth had the initial phase of treatment repeated while 40% were never seen again after the initial pulpectomy. A total of 46.96% of the teeth were still incomplete after 16.56 months.

Conclusion: The results of the study indicate that the UPOHC has a limited capacity to complete RCTs. A strategy is needed to expand the region's

resources and to incorporate a preventative dental focus. However, this will require an intervention in the functioning of the dental health system with regard to government funding in order to achieve success in both service delivery and education. An audit of the current undergraduate endodontic curriculum is perhaps necessary to improve students' skills and efficiency in the service learning environment.

TABLE OF CONTENTS

ABBREVIATIONS

RCT	Root Canal Treatment
RCTs	Root Canal Treatments
UPOHC	University of Pretoria Oral Health Centre
CCS	Compulsory Community Service

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

LIST OF APPENDICES

KEYWORDS

University of Pretoria Oral Health Centre:

This is the hospital premises of the University of Pretoria where students are trained and graduate as dentists or oral hygienists. Dentists are also trained at postgraduate and specialist levels.

Root Canal Treatment:

Root canal treatment is also referred to as endodontics. It is the series of procedures performed in the root canal system of a tooth with a diseased or damaged pulp. The nerve is removed from the coronal and radicular pulp of the tooth to eliminate bacteria where after the prepared space is replaced with an obturation material in order to seal off the tooth from bacterial invasion.

Pulpectomy:

It is the removal of damaged or infected pulpal tissue. A pulpectomy is the initial step of root canal treatment.

Obturation:

The point at which the root canal space has been densely filled and sealed with a hermetic sealing material.

Chapter 1:

Introduction

Root canal treatment (RCT) is an expensive, time-consuming dental procedure.[1] The University of Pretoria Oral Health Centre (UPOHC) is the only public health facility that provides RCT to the public on a fairly large scale in the Tshwane District. The reality is, however, that the majority of South Africans cannot afford private dental care and seek government services to sustain their oral health needs.[2] Inevitably the UPOHC is inundated by large numbers of patients demanding procedures such as RCT.

During 2013, internal statistics from the UPOHC show that more than 17 500 patients presented at the centre for initial screening for a variety of problems. Over and above this extensive service load, the UPOHC is also responsible to contribute to the training of oral health care personnel in South Africa by housing the School of Dentistry, University of Pretoria. The main purpose of the School of Dentistry, University of Pretoria is to train dental, oral hygiene and dental postgraduate students, making it difficult to balance this high demand for treatment with academic responsibilities. Although the academic staff members at the UPOHC render emergency dental care (including emergency pulpectomies) and routine dental treatment, RCT is generally completed by senior dental students in their fourth and fifth year of study. Due to the time-consuming nature of the procedure and the students' lack of skill and experience (especially in the early phases of

their training), students only complete a limited number of root canal treatments. Students are required to complete five RCTs on teeth with one and two canals during their fourth year of study.[3] This quota accounts for approximately two hundred and fifty pulpectomies per annum (there is about 50 students in a cohort of students). During the fifth year of study the students are required to complete five RCTs on molars accounting for another 250 patients.[3] The total of completed root canal treatments by the students are therefore approximately 500 in any given year. The result is that the UPOHC is confronted with the following dilemma on a daily basis: should the tooth be saved by means of root canal treatment or does the tooth require an extraction with or without tooth replacement in the future.[4]

There is a lack of management information regarding RCT outcomes at the UPOHC which could inform service delivery and educational policies and protocols. Emergency pulpectomies are currently provided on demand to walk-in patients without taking into consideration the institution's capacity to complete the root canal treatments after the initial treatment. A need therefore exists to gauge the institution's capacity to complete RCTs against the demand for RCT. It is also necessary to explore the clinical outcomes of emergency pulpectomies in terms of the quality of the completed RCTs because failed RCTs will result in retreatment and certain wastage of resources.

The only known study published on the attendance for RCT completion following an emergency pulpectomy, was conducted by Lynch *et al*. (2010) at the University Dental School in Cork, Ireland.[5] The study revealed that 39% of the patients had returned for the root canal completion.[5] The quality of the root canal treatment however was not evaluated in this study.

Several studies[6-10] have been conducted on the acceptability of the root canal obturations by measuring the technical quality of post-operative radiographs. The criteria used for acceptable technical quality in all these studies were root fillings ≤ 2mm from the radiographic apex, consistent density and uniform taper. Peak *et al.* also included the absence of a periapical lesion and pathology.[10] The results of these studies showed an acceptable technical quality of 44%, 61.35%, 84.1%, 47.4% and 57% respectively. Four of the studies assessed the quality of RCT, specifically completed by undergraduate students.[6-9]

In South Africa there has been no research in this area with regard to both the attendance of patients for completion of RCT as well as the technical quality of root canal fillings.

Having motivated the rationale of the study in the section above, the following section continues with a detailed literature review.

Chapter 2:

Literature review

RCT (endodontics) involves essential stages to ensure a predictable end result (outcome). These stages include the removal of the necrotic or irreversibly inflamed pulp (extirpation) from the coronal and radicular pulp space, mechanical cleaning (debridement) and shaping with chemical irrigation of the canals to remove infected tissue. The final stage involves the filling (obturation) of the root canal system to create a tight seal, preventing re-infection.[8] This type of treatment obviously requires specialised materials and equipment and is a very time-consuming process, which inevitably impacts on the resources of a public health care system.

Each of the above-mentioned stages will be systematically addressed in the literature review below from a clinical perspective, following a brief description of why RCT is often necessary. The review will be concluded with an overview of the impact of specialised services, such as RCT, on health service delivery in an academic and public health context.

The need for pulp extirpation

Dental caries, tooth wear, periodontal disease and trauma are some of the most common causes of pulpal inflammation and/or necrosis.[11,12] Pain often occurs when

these dental diseases and/or conditions are neglected and are allowed to spread (bacteria dwell in the dentinal tubules) and infect or involve the pulp over time.[13] This neglect may be due to anxiety related to visiting the dentist. Dental anxiety is highly prevalent and the main cause of anxiety is fear of pain which is a major hindrance to the pursuit of dental treatment.[14] Evading dental care because of anxiety is evident in many patients with neglected oral health.[14] Other reasons why patients postpone treatment especially in second and third world countries, include diminished dental education and lack finances for transport and treatment. Bedos *et al*. concluded that patients prolong suffering from dental pain because of their perception that dental treatment is a painful experience.[15] The findings of Bedos *et al*. and others provide an explanation why so many patients seek dental care when the decay has already reached the pulp (when they are in discomfort).[15,16]

Extirpation of the pulp

The pulp of a compromised tooth is usually extirpated during routine RCT or as part of emergency treatment. The extirpation of a pulp as part of routine RCT is far less common compared to the extirpation of the pulp during emergency treatment. An emergency pulpectomy is the procedure of choice to relieve tooth ache caused by pulpal inflammation or necrosis.

Studies have shown that between 4% and 45% of patients presenting with dental emergencies are treated by means of a pulpectomy.[17-19] It should be noted that emergency pulpectomy is also the treatment of choice at the UPOHC to obtain pain relief for patients who choose to retain their compromised teeth.

The aim of an emergency pulpectomy and the ensuing RCT is to reduce, and if possible, eliminate the infected tissue and microorganism count in root canal systems.[20] The purpose of reducing bacterial and infected tissue concentration is to prevent apical infection and the spread of disease. Incomplete root canal treatment often leads to recurrent pain which will re-appear approximately six months after the initial phase of treatment.[21]

An emergency pulpectomy usually includes the following steps:

- Preparing an access cavity to remove the roof of the pulp chamber in order to obtain direct entry into the root canal opening.[22]
- Identifying the canal orifices.[22] Once the orifices have been located, straight-line access needs to be achieved in order to create an unimpeded passageway for subsequent endodontic instrumentation.[23, 24]
- Extirpation of the infected pulpal tissue from the root canal system.
- Debridement (cleaning the canals using hand or rotary files and irrigants/chemical solutions).
- Placing a medicament with an anti-inflammatory action such as Ledermix®.
- Sealing the tooth with a temporary filling.
- Provide patient with the information on the whole process of full RCT.

Although emergency pulpectomy is very effective in relieving pain it is not a long-term solution. Following the pulpectomy phase, the root canal treatment is only effective if the treatment is completed by proper mechanical and chemical debridement and all the canals are obturated to length.[25] Literature, however, does

not state the period in which obturation should take place following initial pulpectomy (extirpation of the infected or inflamed pulp tissue).

Debridement and medicaments

The mechanical and chemical debridement of an affected tooth can be started during the emergency pulpectomy procedure or as part of routine root canal treatment. Regardless of the context in which the procedures are performed, the principles generally remain the same. Once most of the coronal dentine and pulpal tissue has been removed during straight-line access and coronal flaring, the apex locator is often used to determine working length.[26] The canal is then enlarged and tapered apically using hand or rotary files. The step-back technique of flaring to create a taper is commonly used and aims to diminish procedural errors such as ledging, transportation and apical perforation which will influence the final outcome after obturation.[27] The canal is constantly being flushed to remove debris and dissolve pulpal tissue with irrigants such as sodium hypochlorite. A medicament such as Ledermix® or calcium hydroxide is placed in the root canal after the preparation phase, until the obturation phase is carried out in the next visit.[22]

A recent publication observed that placing calcium hydroxide before the second visit in the two-visit root canal therapy improved the microbial status of the root canal compared to the single visit procedure.[28] Calcium hydroxide's solubility in water is low and its pH of 12.5-12.8 is high. It releases hydroxy ions creating a high alkaline habitat in which micro-organisms cannot survive.[13] A study by Sjögren *et al.* supports this statement that an inter-appointment dressing is necessary to eliminate all infection from the root canal.[29]

The UPOHC generally uses the protocol of placing Ledermix® into the canals presenting as pulpitis or inflamed vital tissue as a sedative during the emergency pulpectomy stage. Ledermix® contains an antibiotic (demethylchlortetracycline) which eliminates bacterial growth and a steroid (triamcinolone) which reduces the inflammatory response.[22] The protocol is that the students use Ledermix® for vital teeth and calcium hydroxide in teeth with a necrotic pulp. Calcium hydroxide which is a bacteriostatic dressing is described by Tasdemir *et al.* as the most commonly used intracanal medicament.[30] The material is biocompatible and active against most of the endodontic pathogens.[13,30]

Physical circumstances and clinical diagnosis often dictate the number of visits required for RCT. A few studies have investigated the difference between single- or multiple-visit RCT. These studies do not particularly favour single- or multiple-visit RCT with respect to reduction of infection or healed periapical lesions.[31-36] The majority of these mentioned studies proposed that there is no correlation between longevity of RCT or reduced infection in single and multiple RCT visits.

It should be noted that most root canal treatment failures develop when initial treatment procedures, mainly technical in nature, have not succeeded to adequately eliminate pathogenic factors.[37]

The technical quality of endodontic therapy largely influences the outcome of the root canal treatment and the preservation of teeth.[38] It is of utmost importance that the quality of the treatment complies with international standards.[5,39] The elimination of pathogenic factors through debridement is subsequently followed by the obturation of the root canal system.

Root Canal Obturation

The purpose of obturation of a root canal system is to fill the entire prepared canal system in order to seal the canal from leaking both coronally and apically.[40] This is done to prevent re-infection by blocking the entrance of bacteria, within the saliva, into the tooth. Another reason is to isolate the remaining microorganisms from surviving by obtaining nutrients in the periradicular tissue fluids.[22,41] Obturation follows only once the canal has been adequately prepared. The most widely taught obturation technique is to place gutta-percha with the use of the lateral condensation technique.[41] The lateral condensation technique is carried out by adding accessory gutta-percha points (generally size 15 or 20) snugly into the canal once a master cone (MGP) has been placed at the correct working length. The smaller points are compacted against the canal walls until there are no voids in the entire canal. Gutta-percha is the root canal filling of choice and is the material most commonly used.[22]

A detailed description of what is considered to be good technical quality in terms of RCT obturation will be provided in paragraph 4.5 in Chapter 4 of the dissertation.

Up to this point in time RCT was generally addressed from a scientific perspective. Reality is however, a different situation! RCT often needs to be carried out in hectic real life situations, for example in overcrowded public health facilities. It is therefore necessary to understand the context of RCT in a service delivery environment that is already saturated.

RCT in a Service Delivery Context

Many studies have been conducted to analyse the effectiveness of the obturation methods and consequently the survival rate of endodontically treated teeth.[42-45]

Skupien *et al.* proved with their success rate of 98% over a 4.48 year observation period, that root canal treatment is definitely beneficial and worthwhile.[42] Nagasiri *et al.* investigated the survival of teeth, with no coronal coverage, that was placed on a waiting list for fixed prosthodontics after the RCT was performed.[43] They found that after a period of 5 years, 54% of the endodontically treated teeth survived which showed that a proper coronal restoration like a crown is essential for certain root canal treated teeth.[43] In another study at a German dental school, Stoll *et al.* attributed the 74% survival rate to the fact that, at a training hospital the difficult root canal treatment cases are delegated to the dentists.[44] The study by Dammaschke *et al.* on teeth endontically treated by students of the Westfälische Wilhelms-Universiät, Münster, Germany reported a survival rate of 85% after 10 years.[45] They concluded that root canal therapy is a long lasting means of conserving teeth even when the root canal is carried out by students.[45]

A study by Lynch *et al.* at the Cork University Dental School and Hospital in 2010 investigated the number of root canal treatments that were started and remained incomplete within a certain period of time.[5] This particular study examined the subsequent attendance for the completion phase of the root canal treatment in 574 patients who received initial emergency pulpectomy.[5] The results showed that 39% of patients returned for the final phase of endodontic treatment (obturation), 11% returned to have the tooth removed and 50% failed to return for the completion phase of the RCT. The above findings show that more than 60% of RCTs were incomplete. The study concluded that it is important to select patients correctly for the completion phase of endodontic treatment. Additionally, patients should be counselled and informed before RCT commences, ensuring that manpower and

resources are utilized effectively. Lynch *et al.*'s view is significant in the fact that the result of his study questions the appropriateness of carrying out the initial step of RCT in certain cases.[5]

As mentioned in Chapter 1, no similar studies could be found for the local context to inform local policy. It is however well known that there is a shortfall of human resources to supply not only the medical[46] but also dental needs of the South African population.[47] After the 1994 political changes in South Africa, public oral health facilities offered free dental services which resulted in an increased workload and strain on existing limited resources. This policy caused a rise in the number of patients seeking treatment regardless of the fact that personnel capacity remained unchanged.[48] The unemployment figures in South Africa continue to rise and peak to 4.6 million during the period between 2008 and 2013.[49] Approximately13·5% of South African families live in informal settlements mirroring the socioeconomic inequality in South Africa.[50] When patients of lower socioeconomic status are in pain, they have no option but to seek dental treatment from public services. This is particularly relevant to specialised treatment such as endodontics, crown and bridge work, dentures, orthodontics and removal of impacted wisdom teeth. The demand for the above mentioned treatment options simply exceeds the capacity to provide the services.[51]

Retreatment of previously endodontically treated teeth is even more costly if at all achievable.[10] Certain root canal failures such as broken file segments is sometimes impossible to reverse and as Souter et al. and others have suggested it should not be attempted routinely.[52,53] The technique described by Souter et al. utilizes

modified Glates Glidden burs, ultrasonic scalers and an operating microscope, which is costly and time-consuming.[53] With rapid escalation in health care costs due to the development of modern high-priced technologies developing countries are often forced to resort to cheaper alternatives, such as the extraction of teeth.[54]

In South Africa and also in the rest of the world, only a small portion of the general health budget is allocated to oral health.[55]

The South African government employs a limited number of qualified dentists in the public services and fail to retain many of them due to emigration.[56,57] South Africa has a relatively low ratio of dentists per 1 000 population (dentists 0.085 per 1 000 population). As a result, many areas have sub-optimal access to specialized dental services such as RCT.

Chapter 2 highlighted RCT from a clinical perspective and summarized existing research published on the outcome of RCT and the outcome of RCT in dental training environments. Chapter 3 will subsequently continue with an elaboration of the aim and objectives of the current study.

Chapter 3:

Aim and Objectives

This health services research project is the first phase in a long-term project that will monitor treatment outcomes at the UPOHC. The aim of this study was to determine the outcome of endodontic care in order to inform service delivery/education protocols and policies at the training hospital. This project focuses on the short-term outcome of RCTs started at the UPOHC.

The objective of the study was to analyse the records of patients who received emergency pulpectomies in order to-

- compare the institution's capacity to complete RCTs with the demand for RCTs.
- assess whether the teeth that received emergency pulpectomies (initial phase of RCT) were followed up with complete root canal therapy.
- assess how many teeth that received a pulpectomy were extracted.
- assess the quality of those root canal treated cases that reached the obturation phase.
- make recommendations for the patient management and educational systems in terms of RCT protocols.

Having established the aims and objectives of the study, Chapter 4 will continue to describe the methods employed during this study.

Chapter 4:

Methods

This chapter describes the design and setting of the study. The chapter also elaborates on the sample selection and measurements utilised during the study. It describes the criteria used in technically assessing the quality of the root canal treated teeth and how the outcome of the emergency pulpectomies were analysed.

4.1 Study design

The design is an observational retrospective cross-sectional study consisting of two phases.

During the first phase an analysis of the electronic and paper records of patients that had an emergency pulpectomy (1 July 2012 until 30 June 2013) at the UPOHC were conducted.

The technical quality of the root canal filling in those cases where the root canal treatment reached the obturation phase were assessed by means of examining the post-operative radiograph during the second phase of the study.

4.2 Setting

The files as well as digital records from the computer software program, Good X Dental Studio were accessed in the Section: Patient Management[‡] in the Department of Dental Management Sciences at UPOHC.

4.3 Sample selection

Teeth that received an emergency pulpectomy was identified on the database using dental procedure code "8132" as the parameter.

Of the 1050 that were identified 500 teeth were randomly selected for further study. This selection was done by the Biostatistics Unit, Medical Research Council through computer generated randomization.

4.4 Measurements

Following an analysis of the patient's paper-based file, the outcome of the pulpectomy was recorded by selecting one of the appropriate categories as indicated by the flow diagram, Figure 1 on Page 16. The identified teeth were categorized either as "presented for further treatment" or "no further treatment after the initial pulpectomy". Teeth that came back for follow-up were categorized as

[‡] The Patient Management Section hosts the Service Rendering Unit where the majority of emergency patients are treated. It is also the first contact point for all new patients presenting at the Hospital as well as those referred from government clinics and private practices.

"received another pulpectomy", "referred for extraction" or "obturated". Teeth that were referred for extraction were classified as "removed" or untreated".

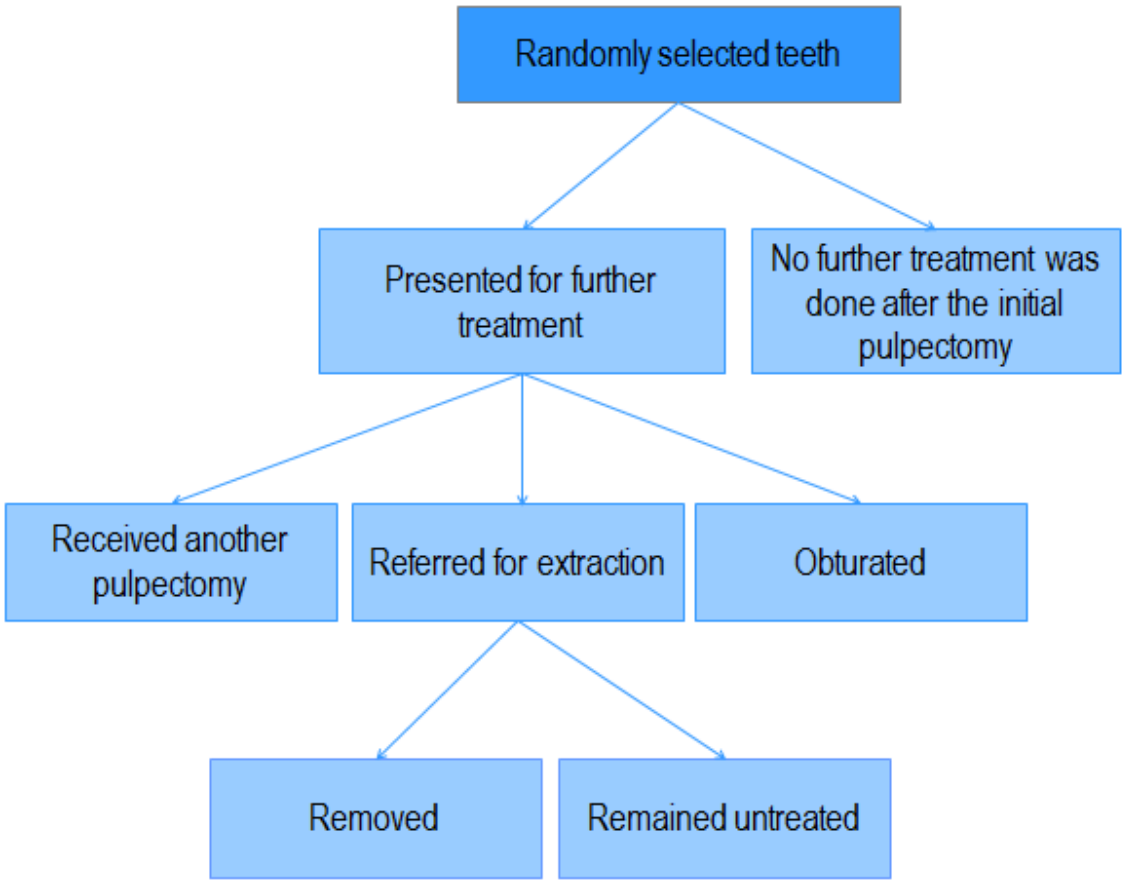


Figure 1: Outcomes measurement

4.5 Technical quality assessments

The post-operative radiographs were accessed on the Kodak (version 6.12.17.0) software programme in RVG (Radiovisiography) format. RVG is high-resolution digital images which can be manipulated once captured allowing more detail to be viewed than the traditional radiographs.[58,59] The dose exposure in the digital radiographs is lower and the images appear instantly which reduces the clinical time. In the cases where the RCT reached the obturation phase, a decision was made whether the RCT was completed adequately or inadequately based on technical quality as viewed on post-operative periapical radiographs.[6]

All radiographs were identified by the case number only. No details of the cases were supplied so as to make sure that this was a blind trial with no bias. The dentist nominated to evaluate the technical quality of the RCT radiographs had the following CV:

- Fourteen years clinical experience.
- Had supervised students in endodontics at the UPOHC for 6 years.
- Obtained a Diploma in Endodontology.
- Obtained a Master's degree in Radiology.

The dentist mentioned above was requested to evaluate the Radiographs using the parameters/criteria indicated in Table 1 below. The radiographs were examined and categorized using the criteria proposed by Román-Richon *et al.*[6]; the same variables/parameters were also used in other studies.[7,60-62]

Table 1: Criteria used to assess the technically quality
Adequately completed
Density: No voids and no moth eaten appearance prevails.[7,63] Length: The root canal filling material within the canal is to an acceptable working length of 0.5--2mm from radiological apex.[64,65]
Inadequately completed
Density: The root canal filling material was inadequately condensed (voids are present in the obturation).[7] Length: The root canal filling material is more than 2mm short of the radiological apex (under-filled)[6] or has extruded past the radiological apex (over-filled).[7,8,66] One or more canals were missed during extirpation and debridement. The restoration that was placed after obturation (which was either underfilled or had voids) is inadequate causing loss of coronal seal. Other reasons such as a fractured file or root perforation.

4.6 Data Analysis

Descriptive statistics generated in Microsoft Excel® Ver. 2003 (Microsoft Corporation USA) were used to describe the following outcome of emergency pulpectomies at the UPOHC:

- The ratio of obturated teeth following emergency pulpectomy.
- The ratio of emergency pulpectomies that have been repeated.
- The ratio of teeth referred for extraction after the emergency pulpectomy.
- The ratio of teeth that were adequately and inadequately obturated (according to international standards).

Kaplan-Meier methodology (using STATA version 11) was employed to describe the time to event and data was recorded. In order to use the Kaplan-Meier survival analysis, the failure date (date follow-up occurred) was recorded onto a data set to give a purposeful result.

4.7 Ethical considerations

A proposal for the project was submitted and approved by the University of Pretoria, Faculty of Health Sciences Research Ethics Committee on 25 June 2014 (Appendix A).

The relevant authority, namely the Dean/Manager of the University of Pretoria, School of Dentistry gave consent (Appendix B) for the study to be conducted at the UPOHC; and the patient files – including digital radiographic material – to be retrospectively accessed.

All personal data is being kept confidential and patient anonymity is respected.

The findings of this study using the above mentioned methodology, is described in Chapter 5.

Chapter 5:

Results

The data was obtained from 500 initial cases of RCT randomly selected over a 12 month period (1 July 2012 until 30 June 2013) and thereafter follow-up was done on outcomes until 1 July 2014. Thus the total period for evaluating outcomes was from 1 July 2012 until 1 July 2014 (24 months). The statistics (code 8132) was drawn from pulpectomies performed between 1 July 2012 and 31 June 2013 (12 month period). The records (paper and electronic) of the cases were drawn just after 1 July 2014 to evaluate the outcome of treatment performed up until 1 July 2014.

Of the five hundred teeth, two case records could not be used for the study. One was a mock entry on the electronic system and the other was a duplicate entry. Of the 498 remaining teeth (Figure 2), 301 were presented for further treatment. A further 197 teeth had no further treatment. Of the 301 that were presented for further treatment 35 received another pulpectomy, 42 were referred for extraction and 224 were obturated at the UPOHC. Thirty six of the teeth that were referred for extraction were removed while six remained untreated.

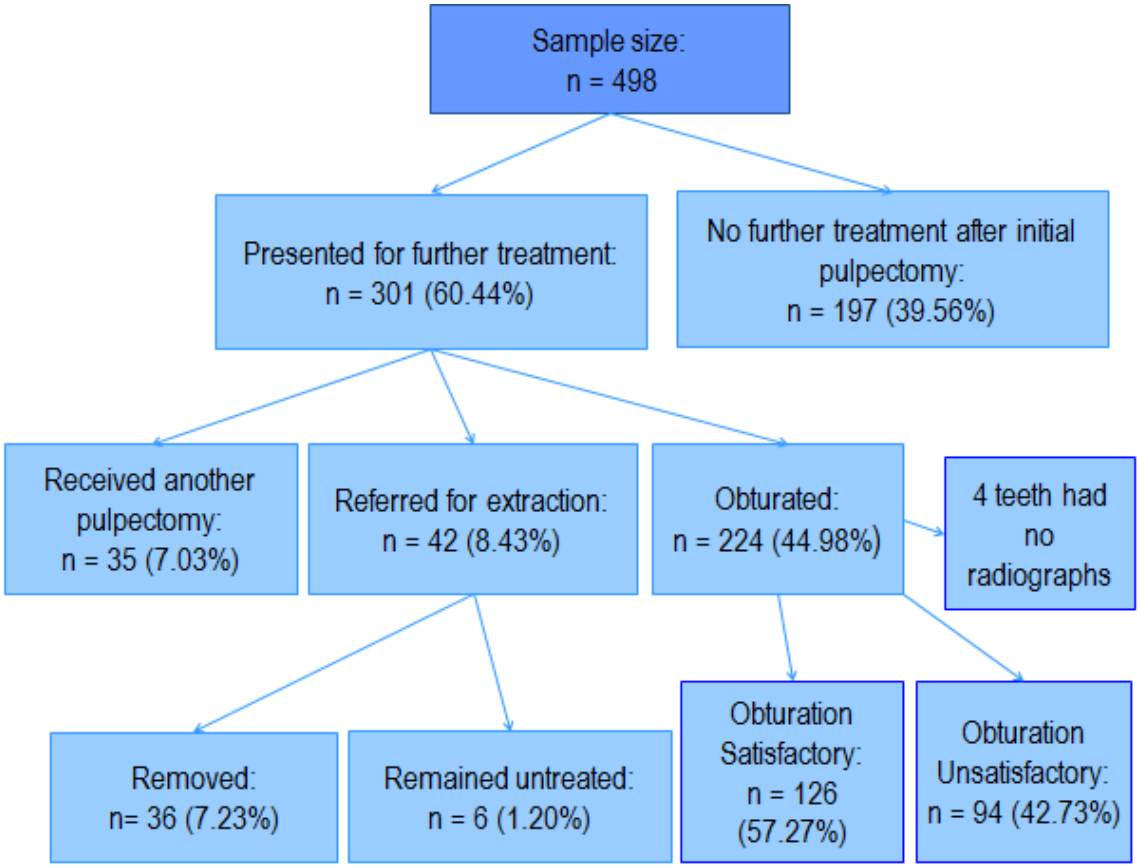


Figure 2: Outcomes measurement of success.

In addition, a differentiation was made in those teeth that were completed by dentists and teeth completed by students. The calculation of data showed that the dental students completed 120 (54%) of the 224 cases and the dentists completed 104 (46%) cases. (Table 2 below).

Table 2. Frequency table for distribution of completed RCTs (n=224)

Treatment Procedure	n	%
RCT was completed by a student	120	53.57
RCT was completed by a dentist	104	46.43
Total RCTs completed	224	100.00

There was however no radiographs available for one tooth completed by a student and for three teeth completed by the dentists. The technical quality for those teeth could not be assessed. Thus the totals add up to 220 instead of 224 (Table 3) for the technical quality assessment.

Table 3 below also lists the observed technical quality of the obturation per provider type (student or dentists).

Table 3. Frequency table for outcome of RCT completed by students versus dentists (n=220)

	RCTs completed by students		RCTs completed by dentists		Total	
	n	%	n	%	n	%
Satisfactory	71	59.66	55	54.46	126	57.27
Unsatisfactory	48	40.34	46	45.54	94	42.73
Total	119	100.00	101	100.00	220	100.00

Chi^2- test, not significant.

Analysis of the data pertaining to the students showed that they completed 59.66% of the 119 assessed teeth “satisfactorily” and 40.34% “unsatisfactorily”. The dentists on the other hand, completed 54.46% of the 101 teeth “satisfactorily”; they treated 45.54% “unsatisfactorily”. These differences were not statistically significant Chi^2- test. See Table 3 above.

Table 4, on page 23, contains the overall results for the technical quality assessment of the completed RCTs. The outcome is described as “satisfactory”,

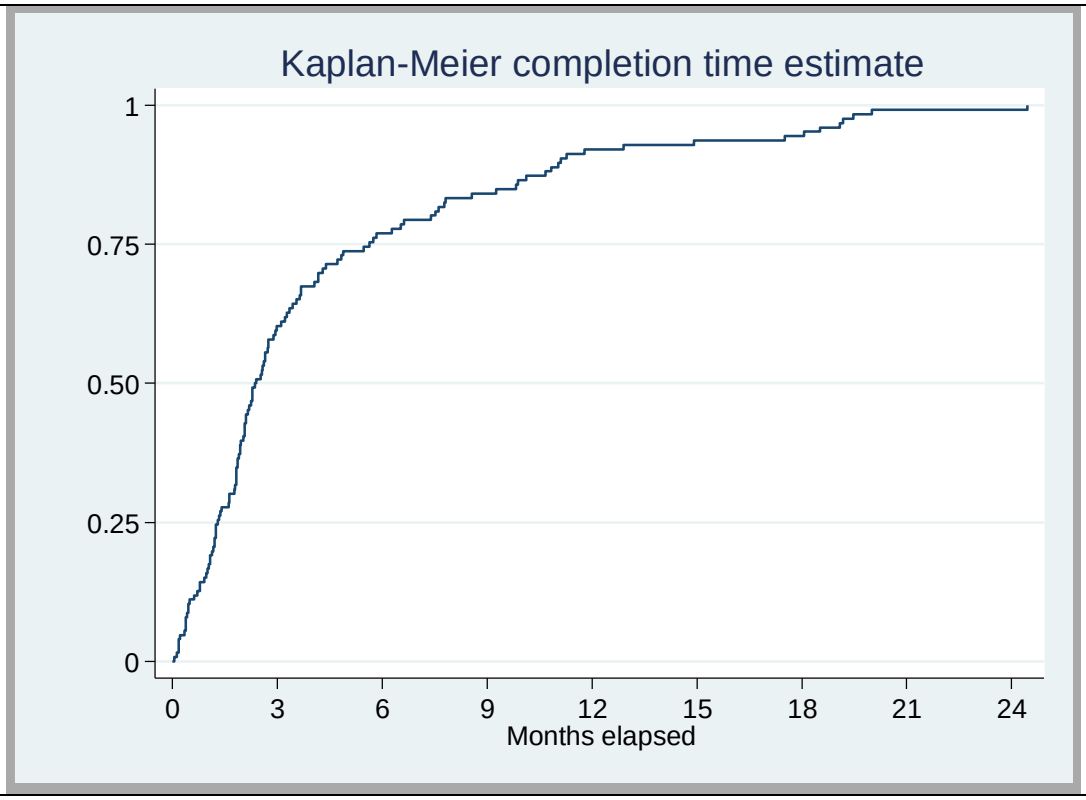
"unsatisfactory" or "incomplete". Results from data showed 46.96% (n=232) of cases were still incomplete after 16.56 months (SD 6.19) after initial treatment. Those obturations assessed to be satisfactory accounted for 25.51% of all cases. These teeth were adequately completed within an average of 4.47months (SD 5.06) after the initial phase of endodontic treatment. Moreover, 27.53% of obturated teeth were assessed as unsatisfactory. These teeth were either referred for extraction or inadequately obturated within an average of 6.22 (SD 6.20) months.

Table 4. Frequency table for results of study sample (n=494*)

	n	%	Mean Duration (months)	SD
Uncompleted: Only the pulpectomy was done or the pulpectomy was repeated	232	46.96	16.56	6.20
Technical quality Satisfactory: RCT was adequately completed	126	25.51	4.47	5.06
Technical quality Unsatisfactory: RCT was inadequately completed, the tooth was extracted or referred for an extraction (no follow up appointment will be made on the latter).	136	27.53	6.22	5.82

* There were no radiographs for four teeth (thus the totals add up to 494 instead of 498 teeth).

The graph that follows on page 24 illustrates the duration in which the 126 root canal treatments were adequately completed from the point at which the pulpectomy was carried out.



Graph 1: Period of time elapsed from emergency pulpectomy to satisfactory root canal completion.

The graph indicates that 50% of the teeth that were adequately completed were completed within three months since initial treatment, 75% within six months and the remaining 25% of teeth were completed between six and 24 months.

The teeth that were inadequately completed by either dentists or dental students were classified according to the evaluation of the postoperative radiographs (Table 5, page 25). The canals of 57 teeth were under-filled and 11 teeth were over-filled. Sixteen obturated teeth had voids in the obturation and in 11 obturated teeth a missed canal was diagnosed. In five obturated teeth an endodontic instrument was fractured off. A proper coronal seal lacked in five of the teeth which were either underfilled or had voids in the obturation. A root was perforated in a

further two cases. Appendix D (page 52- 54) illustrates some digital radiographic examples, of the underfilled and overfilled canals (Figures 3 and 4 respectively). Appendix D also provides visual examples of voids in the obturation (Figure 5), missed canals (Figures 6 and 7), fractured files (Figure 8), loss of coronal seal (Figure 9) and a root perforation (Figure 10).

Table 5. Frequency and reasons for inadequately obturated (filled) canals

Treatment Procedure	n
RCT underfilled (short of radiological apex) (Figure 2)	57
RCT overfilled (past the radiological apex) (Figure 3)	11
Voids in the obturation (Figure 4)	16
Missed canal/s (Figure 5,6)	11
Fractured file (Figure 7)	5
Loss of coronal seal (Figure 8)	5
Root perforated (Figure 9)	2
Canal not optimally prepared (inadequate size)	1
Teeth that have two reasons for inadequacy*	13

*A total (n) could not be supplied as in some cases there were two or three reasons for inadequacy.

This Chapter summarized the findings of the study, which will be discussed in detail in Chapter 6.

Chapter 6:

Discussion

This study examined the capacity of the UPOHC to obturate the root canals of teeth that were initially treated at the institution with emergency pulpectomies and observed the technical quality of the RCTs that were completed. This chapter contains an analysis of the results and make recommendations to advance both education and service delivery.

The capacity of the UPOHC to complete RCTs

The research reported in the current study show that 45% (n=224) of the 498 RCTs that were started were finished (obturated) during the period examined (Figure 2, page 21). This is more or less congruent with the figures reported in a study by Lynch (2010) at Cork University in Ireland.[5]

Dentists employed at the School of Dentistry, UPOHC generally do not complete RCT due to their academic and research commitments. These dentists however, perform the pulpectomies, after which the patient is placed on a waiting list for completion of treatment by students.

In August 2012 the Department of Dental Management Sciences appointed a few part-time dentists to relieve the service load, which included an 18 month waiting list for endodontic treatment. One of these part-time dentists was employed with

the purpose to complete RCTs. This is evident in the data analysis of the number of completions done by a dentist (104 out of the 224 completed RCT cases). It however creates a distorted result with regards to RCT outcomes at the UPOHC. Due to financial constraints, the employment of all of these dentists could not be continuously sustained. Moreover, the time-consuming endodontic procedures led to an even bigger backlog in terms of emergency care and other curative work at the UPOHC. This particular dentist who concentrated on RCT, no longer completes RCTs due to a high load of other emergency patients. If the RCTs completed by the part-time dentist in the study period was not taken into consideration, the result for patients whose RCT's were completed could probably have been as low as 25%. This 25% is probably the UPOHC's actual capacity to treat. It should be noted that some dentists completed walk-in patients, which would otherwise have been placed on the waiting list.

The low completion rate in the current study raises the question of the appropriateness of suggesting and performing a pulpectomy as a treatment option in so many instances in the local oral health care system.[4] This statement is supported by the Kaplan Meier time estimate. The results indeed showed that the chance for satisfactory obturation diminishes quickly after 6 months from initial treatment and becomes virtually zero after 18 months (Graph 1 on page 24). Clearly the demand for RCT exceeds the UPOHC' capacity to provide the treatment, which indicates challenges in terms of the supply of human resources.

According to Lalloo (2007) the South African Department of Health prepared a document: "A National Human Resources Plan for Health" recommending that the

number of dentists produced every year must be reduced from 200 to 120 and, the number of dental therapists needs to be increased from 25 to 600 *per annum*.[67] The rationale for these recommendations is that the salary scales of dental therapists are lower than the salary scales of dentists and the training period of therapists are shorter, which will reduce the cost of basic dental care. The DMFT (decayed/missing/filled teeth) score could drop if there is more intervention earlier (oral hygiene instructions and restorations by therapists) before treatment reaches the root canal stage. It is suggested that dental therapists should focus on basic restorative dentistry, basic extractions and preventive care, which would aid dentists to concentrate on more complex treatment options like RCTs and crown- and bridge work, which therapist are not permitted to do.[67] These proposals have not been implemented to date.

Another strategy introduced by the South African Department of Health to reduce the insufficiency in human resources is the implementation of a one year compulsory community service (CCS).[68] These newly qualified dentists, that are fresh out of Dental school are inexperienced in the area of endodontics. Most of them are employed in designated rural areas where patients mainly seek extraction of teeth. According to Holtshousen, over 80% of dentists who completed their CCS in 2003 in the South African province of Gauteng alone, had done primarily extractions.[69,48] Holtshousen goes on to say that these newly qualified clinicians felt that their skills were not being optimally applied and that they had suppressed their abilities to do specialised clinical procedures (such as crown and bridge work) taught to them as undergraduates. The author felt that if mandatory community service for dental therapists existed, dentists could entrust simple restorations and

extractions to the therapist while focusing on the more specialized dental treatment. It would add value to their career if the dentists carrying out their CCS year could complete some of the RCTs at the School of Dentistry during the periods when the rural clinics are not functioning at peak capacity. The aim of the CCS program was for these young professionals to expand their skills and attain knowledge during this period and simultaneously provide a service to the public. A potential solution for the current predicament could be to place a community service dentist at the UPOHC to eliminate or shorten waiting lists. Another solution could be to introduce CCS for dental therapists so that they can perform basic dental procedures, allowing dentists to spend more clinical time on patients requiring RCT and other specialized dental work. Of course, such measures will require capital investment by the Government into the supply of facilities, dental equipment and additional support staff.

A further consideration might be to increase efficiency during service delivery involving students by placing students in the emergency service unit more often than they are currently doing. The focus here should be to also educate patients so that dental caries can be prevented or at least the prevalence decreased.

At the UPOHC students spend a lot of time on preparing/disinfecting the surgery (cubicle) for their patients and on locating materials. The output of these students could certainly be increased if they could be provided with dental assistants. Possible solutions may include the training of junior dental students to assist during clinical teaching and learning, and greater collaboration with Universities of

Technology. Dental assistant students, who are trained at the Universities of Technology could for example be placed in the clinical wards during the student clinical sessions so that productivity can be enhanced. It should be noted that such collaboration used to exist in the past but has not been explored recently, probably due to logistical problems and the needs of the Universities of Technology themselves.

If more qualified chair side assistants could be employed then these personnel could help the dental students to prepare their surgeries before and after treatments. Dental assistants could help ensure that infection control protocols are in place, gather and prepare dental materials to be used during the session, and process instruments once the treatment has been carried out. Such measures will not only increase the productivity of the students, but may even provide both the dental and dental assistant students more time to apply their skills and competencies, which may have an additional educational benefit. A similar recommendation was made in the United Kingdom. The General Dental Council recommended that for all dental procedures students work with a dental nurse (referred to as dental assistants in South Africa).[70] The implementation of any of the above-mentioned suggestions and/or recommendations should be part of an integrated human resource plan for the region and will require innovative approaches in the undergraduate curricula presented at the School of Dentistry, University of Pretoria and the University of Technology. This will require political will and leadership.

In the current study 8.43% (7.23 plus 1.20% - Figure 2) of teeth that was treated with an emergency pulpectomy, was extracted or was referred for extraction after the pulpectomy. Caplan *et al.* documented that teeth treated with endodontics have significantly lower survival times in comparison to their matched non-endodontically treated controls.[71] Endodontically treated teeth could be lost for reasons such as periodontitis, tooth fracture due to weakened coronal tooth structure or damage during endodontic treatment.[71] Jones *et al.* stated that preserving teeth improves the quality of life.[72] Thus, receiving of RCT as compared to having the tooth extracted is a useful gauge of the quality of oral care.[54,72] The real reasons for the extraction in 7.23% of teeth after the emergency pulpectomy at the UPOHC remain unknown. It could be speculated that due to complications that reduced the prognosis of the outcome some patients may have become despondent with continuous pain or repeated dental visits for the same tooth. When a patient is referred for an extraction at the UPOHC the chances of the extraction taking place on that day is very slim. Most often the patients are requested to return on another day due to the great demand for extractions at the UPOHC. The waiting lists that exist for the completion of the RCT is evident in the 46.6% of teeth which after one year, had no further treatment or for which the pulpectomy had to be repeated. The pulpectomy could have been repeated because the patient experienced re-occurring pain or due to loss of coronal seal because the temporary restoration had fractured or had been dislodged. Waiting lists are a trait of worldwide tax-funded health care systems.[73,74] An attempt has been made by the Department of Odontology (The Endodontic subsection) in 2014 to reduce the waiting list. A full time staff member was appointed to review the

teeth of patients on the waiting list to eliminate those teeth that can no longer be saved or teeth that were too difficult for students to complete. The effectiveness and sustainability of this intervention has however not been determined to date as that dentist has left the University of Pretoria.

As a solution to a similar problem, Lynch *et al.* (2010) recommended that patients should be properly selected and counselled beforehand to prevent improper use of manpower and resources.[5] Ideally, treatment options should be conveyed to patients in an impartial manner when both RCT and tooth extraction are feasible choices, so that their preferred decision is well informed.[75] Patients must be informed of the follow-up procedures that will be required to complete the treatment. They should also be counselled with regards to the importance of maintaining good oral hygiene. The recommendation to pre-counsel patients need to be applied to the current situation, although a lack in human resource capacity to complete the RCTs may have mainly contributed to the low completion rate in the current study. It should be noted that virtually all vacant dental posts at the UPOHC have been filled during the study period. There is also limited office space and insufficient treatment chairs available to accommodate more oral health care personnel. Furthermore, all patients who are placed on the waiting lists to complete the RCTs are systematically contacted for appointments with the students as soon as appointments become available.

Up to this point the discussion chapter focussed on the institution's ability to complete RCTs and possible solutions to remedy the situation. It is, however,

important to remember that it is of no value to complete RCTs if the clinical quality is poor. The control of the quality of the outcomes is therefore essential.

Technical quality of RCTs at the UPOHC

The results on technical quality from the current study showed that 57.27% (Figure 2, page 21) of completed cases were of acceptable quality (using the criteria described in Table 1 on page 17). This percentage appears to be lower than those found in other studies[61-63] which focussed on the quality of the root canal fillings done by undergraduate students. Lynch *et al.* reported in 2006 that 70% of the RCTs performed had acceptable root fillings using the same criteria as used in this research.[76] A similar study, by Chakravarthy and Moorthy found that 61.35% of the RCT's completed by undergraduate students in the Department of Conservative Dentistry and Endodontics, Penang International Dental College, Malaysia were adequate.[6] The latter is more or less the same compared to the results of this study where acceptable technical quality was achieved by dentists and students. It should be noted that in some instances different methodologies may have been applied and the expertise of the examiners of the technical quality may have differed, which limits the comparability of these studies.

Chakravarthy and Moorthy's study suggested that auditing the root canal fillings plays an essential role in quality assurance in dental schools. The authors offer valuable insights such as the need for regular review of the endodontic curriculum, to lengthen the time spent in preclinical and clinical training, to increase staff-student supervision ratio and to incorporate student self-assessment exercises.[7] In

another study by Hayes *et al.* a mere 13% of RCTs were adequately obturated using the same criteria used in the current study.[38] This particular study by Hayes *et al.* stated that the poor results reflected the dental students' lack of experience, inadequate supervision and assessments methods.

Endodontics is indeed a difficult skill[77,78] and the clinician's competence is the overriding factor determining the success of the outcome of root canal treated teeth.[78] Duvivier *et al.* emphasized the need for deliberate repetition of practical exercises in order to acquire the necessary clinical skills.[79] Simulation in undergraduate studies is common practice.[80] As part of the current curriculum at the UPOHC, the dental students in their third year of study practice RCT on extracted teeth in the skills laboratory. They are allowed to treat endodontic patients in their fourth year of study only once they have passed the preclinical practical exam. Although these students start at an early stage in their studies to identify the root canal system more extensive training can be planned. Scaffolding is an approach to enhance a student's self-governed learning skills.[81] At every level of study the students should have adequate assistance in the initial phases of endodontic training and then gradually be weaned off instruction as they master the endodontic milestones independently.[82] This means gradually reducing the support and progressively expanding the student's responsibility.[82] The experience gained in increments whether good or bad from the second year of study already will produce a more confident and skilled clinician.

In view of these findings it is recommended that an increase in student clinical quotas for endodontics be considered at the UPOHC. The quotas could be

increased if more digital radiographic machines could be installed as time is wasted queuing to have radiographs taken during the endodontic treatment sessions. Endodontics could already be introduced more extensively in the preclinical third year of study. Included in this preclinical year should be the practical application of modern technology such as the rotary instrumentation and the electronic determination of working lengths.[63,83] The technique for obturation of root canal treated teeth currently being taught to undergraduate dental students at the University of Pretoria is cold lateral condensation. They make use of gutta-percha which Hammad *et al.* documented as showing the minimum amount of voids during root section.[84] The final year students are however, additionally taught to use the ProTaper system which consists of rotary nickel-titanium files. An earlier introduction of the use of rotary instruments (particularly the use of rotary instruments on extracted teeth in the laboratory) may improve the acceptable outcome of completed root canal treatments (57% of patients whose root canal reached obturation stage). This application of the use of rotary instruments in clinical wards must be preceded by thorough practice on extracted teeth.

Hayes' statement about supervision and assessment methods is confirmed in another study by Lynch *et al.* (2006) stating that teaching of undergraduate students should be done by specialist endodontists rather than academic consultants who have an interest in endodontics.[38,76] It is therefore recommended that dentists supervising the endodontic clinical student sessions at the UPOHC should preferably have postgraduate qualifications in the endodontic field of study.[8,52] Seminars should be presented to supervisors that do not have postgraduate qualifications.[63] This could contribute to their Continuing Professional

Development (CPD) points required by the Health Professions Council of South Africa. It should also be considered to increase the supervisor-student ratio for endodontic sessions as also recommended in Chakravarthy's study.[7]

The results from Table 3 (page 22) indicate that both satisfactory and unsatisfactory RCTs completed by qualified dentists and undergraduate students differ with only 5.2%. It is conceivable that qualified dentists should have a higher success rate compared to students. The staff of the UPOHC however work under severe time constraints, which may influence the quality of the clinical work.[41,85] In addition the more complicated RCT cases are most often assigned to the dentists to complete. A valuable insight by Hayes *et al.* stated that there should be focussed on the quality of treatment rather than quantity.[38] Dentists at the UPOHC should allocate more time to complete each RCT rather than aiming for quantity (compromising quality). However, this will impact on the delivery of other essential dental services.

The discussion above addressed the reasons for the RCT outcomes at the UPOHC and made recommendations on how it can be overcome. It should however be noted that the findings of the current study should be viewed bearing in mind the limitations of the research design. The limitation of the study is that two-dimensional radiographs (conventional digital intra oral digital) were used to assess the technical quality of the completed root treatment instead of a three-dimensional radiograph (a CBCT scan/cone beam) which would have been ideal in viewing every aspect of the tooth. It is financially costly to perform a CBCT scan on every

endodontic patient at this institution and the high radiation dosage produced with the CBCT imaging makes it unethical to perform routine scans.[86]

Also as with most retrospective studies, data quality depended largely on the quality of the existing records documented[87] including legible handwriting on the hospital files. Sometimes students or dentists failed to capture the entire treatment visit or tooth numbers for treatment procedures were omitted.

The dentist nominated to view the postoperative radiographs could have deducted that RCTs were completed by students in cases where the dentist failed to use a rubber dam which may be noted on the digital radiographs. Students are not allowed to complete RCTs without the use of a rubber dam whereas dentists at times do not make use of it. This may have introduced some biased in the assessor's decision making.

Another limitation in this study is that the reason why patients did not return for the completion of the RCT is unknown. As mentioned earlier a solution to a similar problem Lynch *et al*. (2010) recommended that patients should be properly selected and counselled (with regard to completing their treatment) prior to the pulpectomy.[5]

Chapter 7:

Conclusion

It is evident from the current study that the demand for RCT exceeds the capacity of the UPOHC to complete the RCT's. The centre has an inability to adequately follow up on RCTs that were initiated while only a minority of teeth on which a pulpectomy was performed were extracted during the study period. Just over half (57.27%) of the cases that were obturated were of adequate quality. This indicates that a need exists for intervention in the functioning of the dental health system in order to increase productivity. It is suggested that a primary health care approach with a preventative focus combined with an integrated human resource plan for the region be investigated as part of the planned National Health Insurance (NHI). An assessment of the availability of the necessary dental treatment facilities is vital for proper planning. This should be complimented with a review of the undergraduate endodontic curriculum to improve students' skills and efficiency in the service learning environment.

References

1. Bender IB. Reversible and irreversible painful pulpitides: diagnosis and treatment. Aust Endod J 2000; 26(1):10-4.
2. Naidoo S, Chikte UM, Moola H, Steyn K. Perceptions of oral health: the South African Demographic and Health Survey of 1998. SADJ 2001; 56(11):505-10.
3. Department of Odontology, School of Dentistry, Faculty of Health Sciences' Study Guide. 2014.
4. Torabinejad M, Anderson P, Bader J, Brown LJ, Chen LH, Goodacre CJ, et al. Outcomes of root canal treatment and restoration, implant–supported single crowns, fixed partial dentures, and extraction without replacement: a systemic review. J Prosthet Dent 2007; 98(4):285-311.
5. Lynch CD, Burke FM, Ríordáin RN, Hannigan A. Endodontic treatment completion following emergency pulpectomy. Community Dent Health 2010; 27(2):114-7.
6. Román-Richon S, Faus-Matoses V, Alegre-Domingo T, Faus-Llácer VJ. Radiographic technical quality of root canal treatment performed ex vivo by dental students at Valencia University Medical and Dental School, Spain. Med Oral Patol Oral Cir Bucal 2014; 19(1):93-7.
7. Chakravarthy PK, Moorthy JK. Radiographic assessment of quality root fillings done by the undergraduate students in a Malaysian Dental School. Saudi Endod J 2013; 3(2):77-81.

8. Kelbauskas E, Andriukaitiene, Nedzelskiene I. Quality of root canal filling performed by undergraduate students of Odontology at Kaunas University of Medicine in Lithuania. Stomatologija, Baltic Dent Maxillofac J 2009; 11(3):92-6.
9. Barrieshi-Nusair KM, Al-Omari MA, Al-Hiyasat AS. Radiographic technical quality of root canal treatment performed by dental students at the Dental Teaching Center in Jordan. J Dent 2004; 32(4):301–7.
10. Peak JD, Hayes SJ, Bryant ST, Dummer PMH. The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). Br Dent J 2001; 190(3):140-4.
11. Piattelli A, Traini T. Diagnosis and managing pulpitis: reversible or irreversible? PPAD 2007; 19(4):254-6.
12. Meng HX. Periodontic-Endodontic Lesions. Ann Periodontol 1999; 4(1):84-9.
13. Athanassiadis B, Abbott PV, Walsh LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. Aust Dent J 2007; 52(s1):S64-S82.
14. Cohen SM, Fiske J, Newton JT. Behavioural dentistry: The impact of dental anxiety on daily living. Br Dent J 2000; 189(7):385–90.
15. Bedos C, Brodeur JM, Levine A, Richard L, Boucheron L, Mereus W. Perception of dental illness among persons receiving public assistance in Montreal. Am J Public Health 2005; 95(8):1340.
16. Anderson R, Thomas DW. 'Toothache stories': a qualitative investigation of why and how people seek emergency dental care. Community Dent Health 2003; 20(2):106-11.
17. Gibson GB, Blasberg B, Hill SJ. A prospective Survey of hospital ambulatory dental emergencies. Part 1: Patient and emergency characteristics. Spec Care Dentist 1993; 13(2):61-5.

18. Kells BE, Hussey DL. Audit of the casual patient attendance at the restorative clinic. J Ir Dent Assoc 1994; 40(4):94-7.
19. McCartan B, Freeman L, Harrison A. Patterns of attendance and treatment at an emergency dental clinic. J Ir Dent Assoc 1996; 42(2):27-28.
20. Swarupa CH, Sajjan GS, Sashi Kanth YV. An in vitro stereomicroscopic comparative evaluation of a combination of apex locator and endodontic motor with an integrated endodontic motor. J Conserv Dent 2013; 16(5):458–61.
21. Nixdorf DR, Moana-Filho EJ, Law AS, McGuire LA, Hodges JS, John MT. Frequency of persistent tooth pain after root canal therapy: a systemic review and meta-analysis. J Endod 2010; 36(2):224-30.
22. Manogue M, Patel S, Walker R. The Principles of Endodontics. New York: Oxford University Press; 2005.
23. La Turno SAL, Zillich RM. Straight-line endodontic access to anterior teeth. Oral Surg Oral Med Oral Path 1985; 59(4):418-9.
24. Christie WH, Thompson GK. The importance of endodontic access in locating maxillary and mandibular molar canals. J Can Dent Assoc 1994; 60(6):527-32.
25. Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I, Nakagaki H, Nakamura H. Success rate of endodontic treatment of teeth with vital and nonvital pulps. A meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol and Endod 2004; 97(1):95-9.
26. Schroeder KP, Walton RE, Rivera EM. Straight-line Access and Coronal Flaring: Effect on Canal Length. J Endod 2000; 28(6):474-6.
27. Walton RE. Current concepts of canal preparation. Dent Clin N Am 1992; 36(2):309-26.

28. Vera J, Siqueira Jr JF, Ricucci D, Loghin S, Fernández N, Flores B, Cruz AG. One- versus two-visit endodontic Treatment of teeth with apical periodontitis: a histobacteriologic study. J Endod 2012; 38(8):1040–52.

29. Sjörgen U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J 1997; 30(5):297-304.

30. Taşdemir T, Celik D, Er K, Yildirim T, Ceyhanli KT, Yeşilyurt C. Efficacy of several techniques for the removal of calcium hydroxide medicament from root canals. Int Endod J 2011; 44(6):505-9.

31. Paredes-Vieyra J, Enriquez FJJ. Success rate of single-versus two-visit root canal treatment of teeth with apical periodontitis: a randomized controlled trial. J Endod 2012; 38(9):1164–9.

32. Su Y, Wang C, Ye L. Healing rate and post-obturation pain of single-versus multiple-visit endodontic treatment for infected root canals: a systematic review. J Endod 2011; 37(2):125–32.

33. Penesis VA, Fitzgerald PI, Fayad MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. J Endod 2008; 34(3):251–7.

34. Peters LB, Wesselink PR. Periapical healing of endodontically treated teeth in one and two visits obturated in the presence or absence of detectable microorganisms. Int Endod J 2002; 35(8):660–7.

35. Weiger R, Rosendahl R, Löst C. Influence of calcium hydroxide intracanal dressings on the prognosis of teeth with endodontically induced periapical lesions. Int Endod J 2000; 33(3):219–26.

36. Trope M, Delano EO, Örstavik D. Endodontic treatment of teeth with apical periodontitis: single vs. multivisit treatment. J Endod 1999; 25(5):345–50.

37. Nair PNR. Pathogenesis of apical periodontitis and the causes of endodontic failures. Crit Rev Belge Med 2004; 15(6):348-81.

38. Hayes SJ, Gibson M, Hammond M, Bryant ST, Dummer PMH. An audit of root canal treatment performed by undergraduate students. Int Endod J 2001; 34(7):501–5.

39. European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. J Endod 2006; 39(12):921-30.

40. Chong BS. Harty's Endodontics in Clinical Practice. 6th ed. Edinburgh: Elsevier Ltd; 2010.

41. Carrotte P. Endodontics: Part 8 Filling the root system. Bri Dent J 2004; 197(11):667–72.

42. Skupien JA, Opdam N, Winnen R, Bronkhorst E, Kreulen C, Pereira-Cenci T, Huysmans MC. A practice-based study on the survival of restored endodontically treated teeth. J Endod 2013; 39(11):1335-40.

43. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: A retrospective cohort study. J Prosthet Dent 2005; 93(2):164–70.

44. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root-canal fillings: a 10-year retrospective study. J Endod 2005; 31(11):783-90.

45. Dammaschke T, Steven D, Kaup M, Heinrich K, Ott R. Long-term survival of root-canal-treated teeth: A retrospective study over 10 years. J Endod 2003; 29(10):638-43.

46. Essack SY. Models for increasing the health workforce. SAMJ 2012; 102(11):830-2.

47. Van Wyk PJ, Louw AJ, Du Plessis JB. Caries status and treatment needs in South Africa: report of the 1999-2002 national children's oral health survey. SADJ 2004; 59(6):238-42.

48. Bhayat A, Yengopal V, Rudolph MJ. Attitudes of South African Dental Therapy Students towards Compulsory Community Service. J Dent Edu 2008; 72(10):1134-41.

49. StatsSA. Quarterly Labour Force Survey statistical release PO211. 2013 Available from: https://www.statssa.gov.za/publications/P0211/P02111stQuarter2013.pdf (accessed 24 March 2014)

50. Oldewage-Theron WH, Slabbert TJC. Impact of food and nutrition interventions on poverty in an informal settlement in the Vaal Region of South Africa. Proceedings of the Nutrition Society 2008; 67(1):91-7.

51. Rotstein DL, Alter DA. Where does the waiting begin? A short review of the dynamics and organization of modern waiting lists. Soc Sci Med 2006; 62(12):3157-60.

52. Ruddle CJ. Nonsurgical Retreatment. J Endod 2004; 30(12):827–45.

53. Souter NJ, Messer HH. Complications Associated with Fractured File Removal Using an Ultrasonic Technique. J Endod 2005; 31(6):450-2.

54. Asgary S, Eghbal MJ, Ghoddusi J. Two-year results of vital pulp therapy in permanent molars with irreversible pulpitis: an ongoing multicenter randomized clinical trial. Clin Oral Investig 2014; 18(2):635-41.

55. Unal GC, Kaya BU, Tac AG, Kececi AD. Survey of attitudes, materials and methods preferred in root canal therapy dental practice in Turkey: Part1. Ent J Dent 2012; 6(4):376–84.

56. Strachan B, Zabow T, van der Spuy ZM. "More doctors and dentists are needed in South Africa: Original article." SAMJ 2011; 101(8):523-8.

57. Lalloo UG, Bobat RA, Pillay S, Wassenaar D. A Strategy for developing future academic leaders for South Africa in a resources–contained environment. Acad Med 2014; 89(8):S55-9.

58. Nair MK, Nair UP. Digital and Advanced Imaging in Endodontics: A Review. J Endod 2007; 33(1):1-6.

59. Van der Stelt. Filmless imaging: The uses of digital radiography in dental practice. J Am Dent Assoc 2005; 136(10):1379-87.

60. Barrieshi-Nusair KM, Al-Omari MA, Al-Hiyasat AS. Radiographic technical quality of root canal treatment performed by dental students at the Dental Teaching Center in Jordan. J Dent 2004; 32(4):301–7.

61. Er O, Sagsen B, Maden M, Cinar S, Kahraman Y. Radiographic technical quality of root fillings performed by dental students in Turkey. Int Endod J 2006; 39(11):867–72.

62. Moussa-Badran S, Roy B, Bessart du Parc AS, Bruyant M, Lefevre B, Maurin JC. Technical quality of root fillings performed by dental students at the dental teaching centre in Reims, France. Int Endod J 2008; 41(8):679–84.

63. Khabbaz MG, Protogerou E, Douka E. Radiographic quality of root fillings performed by undergraduate students. Int Endod J 2010 June; 43(6):499–508

64. Lopes L. Endodontic considerations for General Dentists. Inside Dent 2007; 3(6).

65. Schaeffer MA, White RR, Walton RE. Determining the optimal obturation length: a meta-analysis of literature. J Endod 2005; 31(4):271-4.

66. Saunders WP, Saunders EM, Sadiq J, Cruickshank E. Technical standard of root canal treatment in an adult Scottish sub-population. Br Dent J 1997; 182(10):382-6.

67. Lalloo R. "A national human resources plan for oral health: is it feasible?" SADJ 2007; 62(8):360,362-4.

68. Reid S. J. Compulsory community service for doctors in South Africa-evaluation of the first year. S Afr Med J 2001; 91(4):329-35.

69. Holtshousen WSJ. Service rendering statistics of compulsory community service dentists in Gauteng. Presentation at the 2004 Meeting of the South African chapter of the International Association for Dental Research, in Pretoria.

70. Stewardson DA, Palenik CJ, McHugh ES, Burke FJT. Occupational exposures occurring in students in a UK dental school. Eur J Dent Educ 2002; 6(3):104–13.

71. Caplin DJ, Cai J, Yin G, White BA. Root canal filled versus non-root canal filled teeth: a retrospective comparison of survival times. J Public Health Dent 2005; 65(2)90-6.

72. Jones JA, Boehmer U, Berlowitz DR, Christiansen CL, Pitman A, Kressin NR. Tooth Retention as an indicator of quality dental care: development of a risk adjustment model. Med Care 2003; 41(8):937-49.

73. Siciliani L, Hurst J. Tackling excessive waiting times for elective surgery: a comparative analysis of policies in 12 OECD countries. Health Policy 2005; 72(2):201-15.

74. Derrett S, Cousins K, Gauld R. A messy reality: an analysis of New Zealand's elective surgery scoring system via media sources, 2000-2006. Int J Health Plann Manage 2013; 28(1):48-62.

75. Azarpazhooh A, Dao T, Figueiredo R, Krahn M, Friedman S. A survey of patients' preferences for the treatment of teeth with apical periodontitis. J Endod 2013; 39(12):1534-41.

76. Lynch CD and Burke FM. Quality of root fillings performed by undergraduate dental students on single-rooted teeth. European J Dent Edu 2006; 10(2):67-72.

77. Walton T. Guest Editorial: Too Many Cooks and Not Enough Chefs! Int J Prosthodont 2006; 19(6):532.

78. Ashkenaz PJ. One-visit endodontics. Dent Clin North Am 1984; 28(4):853-63.

79. Duvivier RJ, van Dalen J, Muijtjens AM, Moulaert VR, van der Vleuten CP, Scherpbier AJ. The role of deliberate practice in the acquisition of clinical skills. BMC Med Educ 2011; 11(1):101.

80. Bradley P, Postlethwaite K. Simulation in clinical learning. Medical Education 2003; 37(s1):1-5.

81. Kicken W, Brand-Gruwel S, van Merriënboer JJ. Scaffolding advice on task selection: A safe path toward self-directed learning in on-demand education. J Voc Educ and Training 2008; 60(3):223-39.

82. Larkin MJ. Providing support for student independence through scaffolded instruction. Teaching Exceptional Children 2001; 34(1):30-4.

83. Dummer PMH. Comparison of undergraduate endodontic teaching programmes in the United Kingdom and in some dental schools in Europe and the United States. Int Endod J 1991; 24(4):169-77.

84. Hammad M, Qualtrough A, Silikas N. Evaluation of Root Canal Obturation: A Three-dimensional *In Vitro* Study. J Endod 2009; 35(4):541–4.

85. Elemam RF, Pretty I. Comparison of the success Rate of Endodontic Treatment and Implant Treatment. ISRN Dent 2011:1-8.

86. Low KMT, Dula K, Bürgin W, von Arx T. Comparison of Periapical Radiography and Limited Cone-Beam Tomography in Posterior Maxillary Teeth Referred for Apical Surgery. J Endod 2008; 34(5):557-62.

87. Caplin DJ, White A. Clinical factors related to noncompletion of root canal therapy. J Public Health Dent 2001; 61(1):6-13.

Appendix A

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 22/04/2017.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

26/06/2014

Approval Certificate
New Application

Ethics Reference No.: 200/2014

Title: Root canal treatment outcomes at the University of Pretoria Oral Health Centre.

Dear Dr VC Mostert

The **New Application** as supported by documents specified in your cover letter for your research received on the 30/05/2014, was approved, by the Faculty of Health Sciences Research Ethics Committee on the 25/06/2014.

Please note the following about your ethics approval:
- Ethics Approval is valid for 2 years
- Please remember to use your protocol number (**200/2014**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:
- The ethics approval is conditional on the receipt of 6 monthly written Progress Reports, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers; MBChB; MMed (Int); MPharMed.
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

♦ Tel:012-3541330 ♦ Fax:012-3541367 Fax2Email: 0866515924 ♦ E-Mail: fhsethics@up.ac.za
♦ Web: //www.healthethics-up.co.za ♦ H W Snyman Bld (South) Level 2-34 ♦ Private Bag x 323, Arcadia, Pta, S.A., 0007

Appendix B

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Denkleiers • Leading Minds • Dikgopolo tša Dihlalefi

P. O. Box 1266
Pretoria 0001
Republic of South Africa
Tel 012-319-2911 Fax 012-323-7616
http://www.up.ac.za
Faculty of Health Sciences
School of Dentistry

Enquiries: Dr V.C. Mostert

Telephone: 012-319 2439/2370

TO WHOM IT MAY CONCERN

CONSENT TO CONDUCT AN INVESTIGATION AND ANALYSING THE PAPER AND ELECTRONIC RECORDS OF PATIENTS HAVING RECEIVED EMERGENCY ENDODONTIC TREATMENT DURING THE PERIOD: 01/07/2012-31/06/2013.

In terms of the requirements of the Promotion of Access to Information Act. 2 of 2000, I, Prof AJ Ligthelm, Dean/Manager of the School of Dentistry, hereby give permission to Dr VC Mostert to conduct the study titled "Root canal treatment outcomes at the University of Pretoria Oral Health Centre" at the School of Dentistry as described in the attached protocol. Permission is granted on the condition that ethical approval is acquired.

PROF AJ LIGTHELM
DEAN / MANAGER
Date: 30/5/2024

Appendix C

Date: 8 / 5 /2014

LETTER OF CLEARANCE FROM THE BIOSTATISTICIAN

This letter is to confirm that the student(s),

with the Name(s) DR VANESSA MOSTERT

Studying at the University of PRETORIA

discussed the Project with the title _____

_____

_____

_____ with me.

I hereby confirm that I am aware of the project and also undertake to assist with the Statistical analysis of the data generated from the project.

The analytical tool that will be used will be Descriptive statistics & Kaplan-Meier methodology. Sample size 500 – randomly selected from ±1000 eligible patients to achieve the objective(s) of the study.

Name PJ BECKER

Signature _____

Date 8/5/14

MEDICAL RESEARCH COUNCIL
Biostatistics Unit
Private Bag X385
Pretoria
0001
Tel: 012 339 8523 / Fax: 012 339 8582

Appendix D

RADIOGRAPHIC EXAMPLES OF INADEQUATELY OBTURATED RCTs

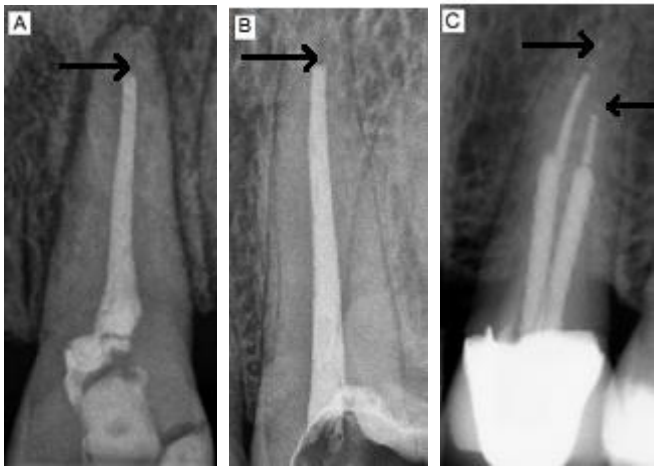


Figure 3: Exhibits canal filled short of radiographic apex (underfilled)

3 A: Shows an off centre access cavity preparation with a root canal obturation that is short of the radiographic apex.

3 B: Shows a root canal obturation that is short of the radiographic apex probably due to the fit of an incorrect master size GP point. Note the presence of the canal beyond the obturation material.

3 C: Shows a root canal obturation that is short of the radiographic apex in both canals. Note the presence of root canal sealer in the apical parts of the root canals that were not obturated adequately.

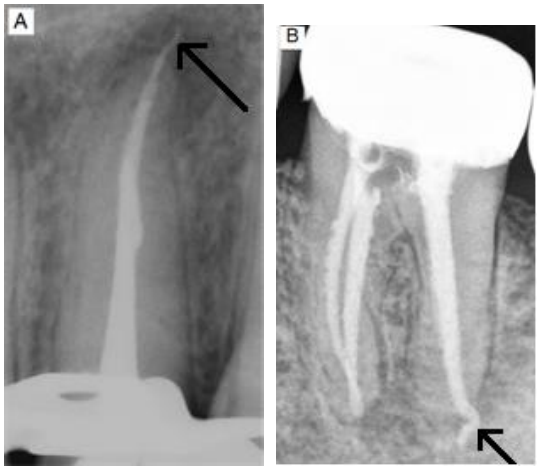


Figure 4: Exhibits canal filled past radiographic apex (overfilled)

4 A: Shows over extension of gutta-percha done probably due to overpreparation.

4 B: Shows an overfil of obturation material in the distal root canal system.

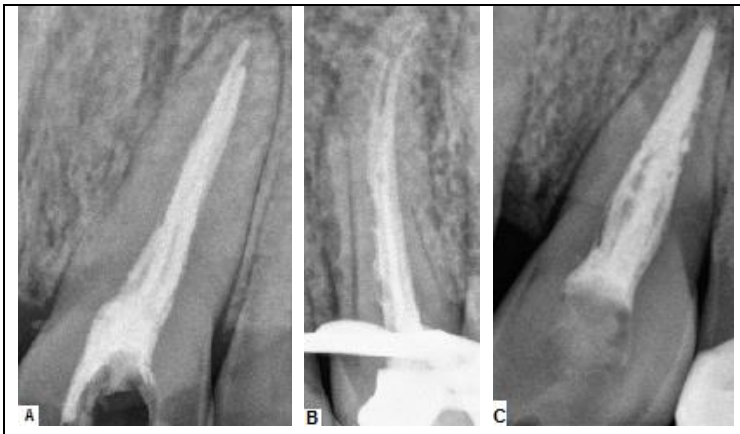


Figure 5: Exhibits Voids (density inadequate) in the obturation.

5 A-C:

Shows inadequate root canal obturation. Note the poor condensation of the gutta-percha and voids in the obturation material. This is probably due to using a poor lateral condensation technique.

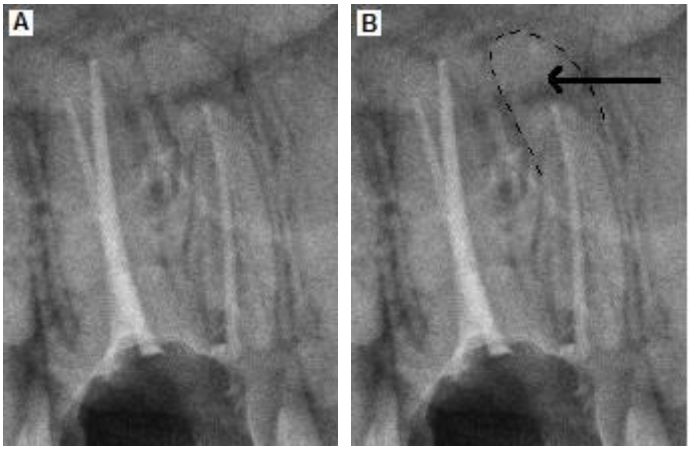


Figure 6: Exhibits a missed canal

6 A: Shows a mesial canal that was missed when preparing and obturating the canals of the17.

6 B: In this radiograph, identical to A, the missed canal is indicated.

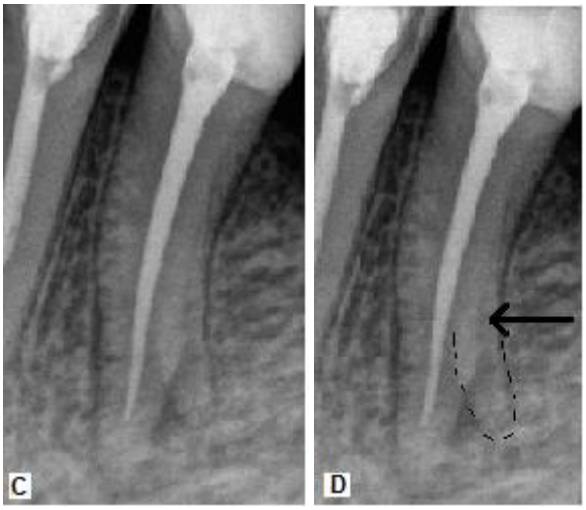


Figure 7 : Exhibits a missed canal

7 C: Shows the mesial canal missed in a mandibular first premolar.

7 D: In this radiograph, identical to C, the missed canal is indicated.

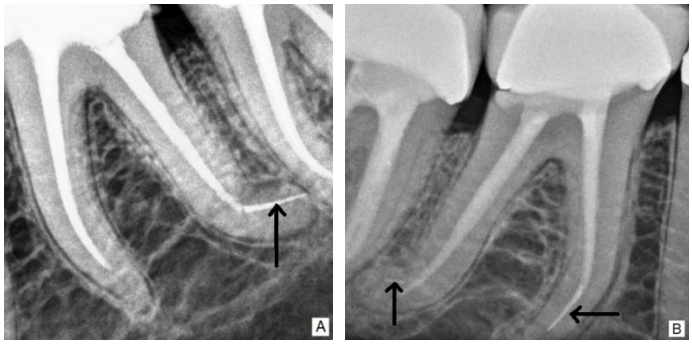


Figure 8: Exhibits fractured instruments.

8 A: Shows a fractured instrument in the apical curvature of the distal canal of the 36. The mesial canal is obturated short of the working length.

8 B: Shows fractured instruments in the apical areas of both mesial and distal root canal systems. There is also loss of coronal seal at the distal interproximal area of the crown (46) in B.

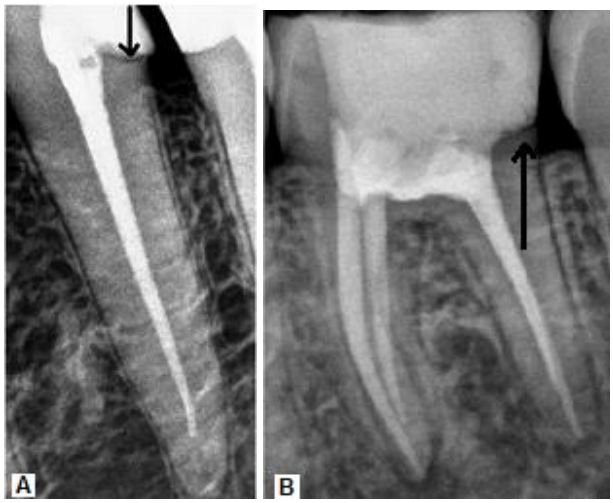


Figure 9: Exhibits loss of coronal seal.

9 A: The arrow indicates loss of coronal seal. The canal is also underfilled.

9 B: The arrow indicates loss of coronal seal at the distal interproximal area of the crown.

Figure 10: Root Perforation

Figure 10: Shows a root perforation that occurred during root canal preparation but was only evident after obturation.