THE EFFICACY OF ROTARY AND MANUAL INSTRUMENTS IN ROOT CANAL DEBRIDEMENT.

A Mini-Thesis Submitted in Partial Fulfilment for the MChD degree in Prosthodontics at the Faculty of Dentistry, University of the Western Cape

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KEY WORDS

Scanning electron microscope

Nickel-titanium rotary instruments

K-file®

ProTaper®

Smear layer

Debris

Canal transportation

SUMMARY

It has been shown that the use of both manual and rotary instruments result in the formation of a smear layer and debris during root canal treatment. The amount that is formed depends on the type of instrumentation used as well as the force applied.

Aim: The purposes of this study were

1. To use the scanning electron microscope to compare the cleanliness of the root canal walls following rotary and manual debridement methods
2. To assess the transportation of the apical part of the root canal orifice when using different instrumentation techniques.

Materials and Methods:

Endodontic treatment was performed on extracted maxillary central incisors following extirpation and debridement using the Protaper® nickel titanium files and K-files. The teeth were randomly divided into three groups.

Endodontic therapy performed simulated the clinical procedures, in which the teeth were extirpated using a barbed broach to remove the necrotic pulp. Pre-operative periapical radiographs were used to determine the working length. Root canals were debrided using the two filing methods, with copious irrigation using Sodium hypochlorite solution in a disposable syringe with a 27gauge needle.

A follow up radiograph with a master apical file in position was used to verify complete debridement in the apical third of the canal.

The teeth were then sectioned vertically using a diamond bur to create an initial groove and then split apart using a flat plastic instrument to separate the sections and to avoid contamination of the sections. These sectioned portions were then studied under a scanning electron microscope. The smear layer as well as the amount of debris was evaluated.

Results:

The assessment of residual debris and smear layer formed, were assigned numbers and tabulated. All three areas of the root canal were compared against each other. The sectioned apical third of the root canal was also studied for the presence or absence of apical transportation.

Conclusion:

From the present study, it was found that both the nickel-titanium rotary files and stainless steel hand files produced some smear layer and there was some residual debris left in uninstrumented areas of the root canal. However, it was shown that there was more smear layer formation when using nickel-titanium rotary files compared to that formed using hand files.

When assessed for the presence of apical transportation, it was found that both types of instrumentation resulted in some degree of transportation, however, with rotary files, the canals remained largely centralized with transportation clearly visible in hand instrumented canals

DECLARATION

I hereby declare that *the efficacy of rotary and manual instruments in root canal debridement* is my own work, that it has not been submitted before for any degree or examination in any University, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Madlabane Duduzile

Signed……………………………….

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DEDICATION

This work is dedicated to:

- My daughters Gugulethu and Ongiwe for their love and support, for allowing me to sacrifice them during my four years of study

- My long-term partner and the father of my children for his encouragement, during my study period and for allowing me to pursue my chosen field

- My supervisor for his guidance, encouragement and support ensuring that this project was a success.

- My mother for her love and support always

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF GRAPHS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

The introduction of rotary instruments has made it easier for clinicians to perform root canal therapy without too much operator fatigue, because it has been shown that shorter treatment times are required to complete the debridement procedure in the preparation of the canal walls (Suffridge, Hartwell, Walker 2003, citing Beeson *et al* (2000).

However in recent years, Nickel-titanium instruments such as Profile® and ProTaper (Dentsply Maillerfer), were developed and have been constantly improved for use in endodontic therapy in order to continue to reduce the known operator fatigue associated with conventional endodontics, thereby resulting in the further reduction in treatment times (Ahlquist *et al* 2001).

However, since fatigue was conclusively proven (Ahlquist *et al* 2001), to be reduced with rotary instrumentation, the present study excluded fatigue as a variable and concentrated on the amount of debris and smear layer formed during root canal debridement. The predictability of root canal preparation was found to be influenced by the design of the instrument (Al-Omari, Dummer, Newcombe, Doller 1992) and the alloy content of the newer instruments (Gulabivala, Jardine 1995) however, the tactile skills of the operator still remains an important aspect in the final shape of the debrided canals (Walia *et al* 1988).

The role of canal preparation, namely, shaping, has undergone a paradigm shift, as noted by Gulabivala and Jardine (1995), from one fulfilling the prime debriding function to one that is regarded more as access to the complex canal system and its contents for the irrigant.

Beeson *et al* (2000) showed that using rotary nickel-titanium files for canal instrumentation resulted in a significant reduction in chair time and operator fatigue when compared with the use of hand K-file instruments only.

According to Hata (1998) and Davies, Brayton, Goldman (1972) who compared rotational techniques with circumferential filing techniques, it was concluded that the rotational techniques left major areas of the root canal walls uninstrumented. The use of the push-pull filing technique was the one method that was encouraged by Davies, Brayton, Goldman 1972.

However, other researchers found no significant differences between rotational and circumferential filing techniques, as seen experimentally in extracted teeth (Walton 1976) or in clinical studies (McComb, Smith 1975).

In this study all rotary instruments were used in a crown- down movement and manual filing was done using the standard three quarter turn and pulling action for debridement, incorporating the circumferential filing technique.

CHAPTER 2

LITERATURE REVIEW

2.1 Historical background

Civjan, Huget and DeSimon were the first to implement the use of nickel titanium in endodontic rotary instruments in 1975. However, it was only in 1988 that Walia, Bantley and Gerstein established the feasibility of producing such nickel titanium instruments, which exhibited significantly greater elasticity and superior resistance to torsional fracture.

Despite the higher strength and flexibility, instrument separation can still occur with nickel titanium (NiTi) instruments, especially after extended use (Shen, Cheung, *et al* 2006), necessitating that the number of times that these instruments are used be related to the type and position of the teeth within the quadrant. Unfortunately, many of these fractures occur unexpectedly and without any prior visible signs of permanent deformation. Cyclic, static torsional and dynamic torsional fatigue are said to be the most common causes of rotary NiTi instrument fracture (Yao, Schwartz, Beeson 2006)

2.2 Significance of the smear layer in endodontics

It has been shown in a study performed by Torabinejad, Handysides, Khademi *et al* (2002), that current methods of cleaning and shaping root canals do produce a significant amount of smear layer that covers the instrumented walls. This smear layer has been found to contain both inorganic and organic substances that include fragments of odontoblastic processes, micro-organisms, and necrotic debris.

Some components of the formed smear layer can be forced into the dentinal tubules to varying distances as a result of capillary action generated between the smear layer material and the dentinal tubules (Torabinejad, Handysides, Khademi, *et al* 2002)

It has also been demonstrated that manual instrumentation can be more effective compared to mechanical instrumentation when creating a well-shaped root canal (Hulsmann, Stryga 1993). As both manual and mechanical shaping produce a smear layer and debris (Hulsmann, Stryga 1993), it is important to recommend an instrumentation technique for endodontic treatment that produces the minimal amount of smear layer and debris in order to seal the dentinal tubules but at the same time not to interfere with the sealing ability of the root canal sealer so that an optimum hermetic seal of the root canals is possible especially in the apical third of the canal.

According to Walia *et al* (1988), it was found that the advent of Nickel-titanium instruments not only provided greater flexibility during instrumentation, but also raised the possibility of automated instrumentation, that could conceivably reduce the need for highly developed tactile skills and bring about advanced endodontic practice within the compass of a broader proportion of general dental practitioners.

The design and metallurgic properties of files has been found to be of critical importance in an attempt at efficiently removing surface debris from the root canal, according to Elmsallati, Wadachi, Ebrahim *et al* 2006.They found such files to have optimum cutting efficiency, which is affected by various factors such as cross-sectional shape, flute design and flexibility.

Currently, nickel titanium rotary instruments are being used widely and are gaining popularity because of the inherent advantages such as decreased canal transportation and ledging, and shorter working time, owing to their flexibility and ease of use (Walia *et al* 1988), thus increasing the possible predictability of the final results.

In the study by Elmsallati, Wadachi, Ebrahim, Suda 2006, it was found that Profile® (Dentsply Maillefer, Switzerland) significantly retained more debris even after ultrasonic cleaning, within the U-shaped grooves of the instrument, which might decrease its efficiency to remove debris. In the same study ProTaper®(Dentsply Maillefer, Switzerland), tended, to behave the same as its predecessor Profile, and was shown to entrap more debris within its flutes.
Therefore in the interest of debridement efficiency, it is necessary to wipe the instrument clean with a cotton roll dipped in sodium hypochlorite, during the debridement process to improve its efficacy (Schafer, Vlassis 2004). In addition, the slight negative rake angle and radial lands of both Profile® and ProTaper® tend to cut less aggressively than those with active cutting blades such as Endowave® (Morita Co., Osaka, Japan), which tends to remove more dentine chips than deemed necessary (Elmsallati, Wadachi, Ebrahim, Suda 2006).

2.3 Canal shaping and preparation

Successful canal shaping is said to demand that the root canals provide good access for disinfectants and a good form for the final seal of the root canal system (Cohen and Burns 1998). Optimal shaping and cleaning of the root canal using hand instruments is fairly difficult and as a result requires much more experience of the operator. Nickel-titanium instruments are well known for their strength and flexibility (Walia, Bantley, Gernstein 1988), and can be used both manually and with rotary instruments.

Walia and co-workers (1988) were the first to assess the bending and torsional properties of K-type files fabricated from nickel-titanium blanks. Due to their low values of modulus of elasticity, the nickel-titanium files were found to have two to three times the elastic flexibility of stainless-steel files.

The superior resistance of Ni-Ti files to torsional fracture and their inherent ductility (Walia *et al* 1988) meant that these instruments were useful in the preparation of the curved root canal, because they could easily follow the canal shape without any distortion, and possible adverse effects on the root canal such as formation of zips and ledges.

They have an ability to maintain canal shape and this has been confirmed by many studies (Thompson and Dummer 1997, Bryant *et al* 1998). They have also been shown to have an advantage of being significantly faster compared to hand instrumentation (Esposito, Cunningham 1995) with the potential to reduce operator and patient fatigue (Beeson *et al* 2000).

However, in the studies by Thompson and Dummer 1997, Bryant *et al* 1998 they have reported on the potential of instruments to shape canals and have demonstrated that Nickel-titanium instruments maintain canal shape but have the potential of creating aberrations such as zips, perforations and danger zones especially near the furcation areas of multi-rooted teeth with curved canals.

A greater taper of rotary instruments was introduced to improve the cutting efficiency of nickel titanium instruments and to allow better access to the apical third of the root canal in order to reduce the incidence of instrument failure and to enhance canal shape so as to allow more apical placement of the irrigant and to facilitate root canal filling, especially when thermofil obturation is employed (Schafer and Florek 2003). In their study, 11-nickel titanium instruments separated when 96 canals were instrumented, independent of the shape and curvature of the canals emphasising the risk of instrument fracture associated with canal debridement.

Results of their study showed that, the rotary instrument K3 achieved better canal geometry, showed less canal transportation and straightening and created fewer aberrations, even in canals with a curvature of 35 degrees or more compared to manual instrumentation. This was an indication that rotary instruments have a tendency of maintaining the original shape of curved canals. In addition, the K3 instruments were significantly faster than hand instruments in preparing the canals. This is in corroboration with the findings of various other studies such as those conducted by Thompson and Dummer (1997), Schafer and Lohmann (2002). It is accepted that proper biomechanical cleaning and shaping of root canals is the basic foundation for successful root canal therapy (Suffridge, Hartwell, Walker 2003).

Beeson *et al* 2000, cited by Suffridge, Hartwell, Walker 2003 showed that rotary instrumentation, when carried out 1mm short of the radiographic apex, significantly reduced the amount of debris extruded apically. However what was encountered in the studies with the use of NiTi rotary instruments was an increased risk of instrument separation as a result of files binding within the canal (Suffridge *et al* 2003). They concluded that this was a procedural error, rather than a limitation of the instrument but would influence the success or failure of a particular case of root canal therapy and therefore the future use of these instruments.

In the study by Guelzow, Stamm, Martus, Kielbassa 2005, rotary instruments were compared to hand instrumentation, with regard to the canal shape and instrument fracture. It was found that none of the canals became blocked with dentine debris; however, the loss of working length was found in several canals instrumented with manual instrumentation techniques. The cross-sectional diameter of the canals was classified as round, oval, and irregular. ProTaper® achieved the lowest number of irregularly shaped cross-sections in the apical, middle and coronal thirds of the canal, when compared to K-files. In addition all instrument fractures occurred in the region of the tip of the instruments when working in the apical aspect of the root canals, in all instrument types.

These were classified as procedural errors, where, it was found that in the manual technique group, only one instrument out of 60 (K-File size 20, curvature 20degree) fractured during instrumentation, while in the NiTi group two files (S1) with .04 taper fractured out of 60 canals investigated.

Dobo-Nagy, Serban, Szabo *et al* 2002, conducted a comparative study on shaping ability of hand versus rotary instruments and they concluded that post-instrument shape of curved canals was superior when prepared with flexible stainless steel rotary instruments compared to conventional hand files.

In their study, they found that in straight and c-form canals there were no significant differences between the two instrument types used (Nickel titanium K and S hand files). Significantly less transportation was observed from the NiTi K-files in the J-form canals compared to the NiTi S-files in the same anatomical group. NiTi S files produced less transportation in the C-form canals compared to the J-form canals.

They also found that the S-files removed more dentine compared to the K-type files because of the rake angle of the S-file being positive compared to the K-file, which has a negative rake angle. In a comparative study conducted by Schafer and Lohmann 2002, it was found that hand instrumentation using K-Flexofile produced better results in so far as better canal cleaning than rotary FlexMaster. However, the FlexMaster instrument maintained the original curvature significantly better than the K-Flexofile.

Hulsmann, Rummelin, Schafer (1997) also indicated that the cleaning ability of manual root canal instrumentation was superior to automated instruments. However, other investigators (Thompson and Dummer 1997, Schafer and Zapke 2000) found that automated rotary nickel titanium instruments with various taper led to good instrumentation results, even in severely curved canals. Their results have shown that there were no completely clean root canals, however, on average, more effective cleaning was observed in the coronal and the middle thirds of all the root canals compared to the apical third when using rotary instruments.

In the study by Guelzow *et al* (2005), it was found that all rotary Ni-Ti systems as well as the manual technique achieved good results with regards to the evaluation of canal aberrations, even in the more severely curved canals. The mean difference between the pre- and post-operative angle was between 0, 5 degrees and 1,2degrees for all groups with minor canal transportation towards the outer aspect of the curvature in the apical region.

Even the preparation with stainless-steel hand instruments resulted in only minor aberrations; transportation was comparable with that found in the studies performed by Schafer Lohmann 2002, Kereke, Tronstad 1977. Based on these results, flaring the canal using a serial step-back approach to facilitate cleaning was advocated (Kereke, Tronstad 1977) in order to overcome the iatrogenic problems associated with conventional filing that resulted in problems such as transportation and perforations.

Morgan and Montgomery (1984), suggested the use of rotational techniques with modified instruments, such as, blunt tips, flexible shanks, less aggressive flutes, and manipulation methods including crown-down, pressure-less and balanced force techniques for optimal debridement of root canals.

It is said that these techniques (crown-down, pressure- less and balanced force), were generally shown to produce rounder preparations in cross-section, resulting in cleaner canals with the maintenance of the original shape of the canal (Calhoun, Montgomery 1988, Al-Omari *et al* 1992)

In order to enhance and to prepare canals for obturation, many techniques have been described using a variety of instrument designs in an attempt to achieve a consistently flared canal shape.

Canal curvature plays an important role in the removal of debris and final canal shape. Canals with 40-degree curves generally end up wider in cross-section in comparison to canals with 20-degree curves as a result of more debris being removed from the outer aspect of the curve in the canals with the greater curvature with the use of the Profile® rotary instruments (Thompson and Dummer 1997).

Anatomic variations of root canal systems is said to be an important factor to consider when instrumenting narrow, curved and flattened root canals, as these shapes present difficulties accessing all areas of the root canal, resulting in an increased amount of residual debris in the canal after debridement (Barbizam, Fariniuk, Marchesan *et al* 2002)

The results of the above study showed that there was a 19.44 % +- 2.01% of the canal area with debris in the root canal instrumented with rotary instrument (Profile® 04) and a 7.18% +- 1.78% of the canal area with debris in the root canals instrumented manually (K-File). This reinforces the notion that neither of the instrumentation techniques used completely cleaned the root canal; however rotary instruments seemed to have been more efficient in this study.

Widening of the canals, at the canal orifice, resulted in the phenomenon known as canal transportation. It was presumed that there is a tendency for Ni-Ti instruments to straighten during instrumentation in severely curved specimens (Glosson 1995, Thompson and Dummer 2000 (a), Bryant *et al* 1998), resulting in the "moving" of the canal orifice

The study by Schirrmeister, Strohl, Altenburger *et al* 2006 showed that nickel-titanium rotary files with active cutting blades increased the cleanliness by removing the smear layer more effectively than instruments with radial lands, which seemed to burnish the smear layer. Examples of the instruments with active cutting blades are RaCe (Reamer with alternating Cutting edges) and ProFile®.

Schirrmeister *et al* 2006 produced evidence to indicate that the use of instruments with more efficient cutting ability did not seem to decrease the instruments' ability to remain centred within the canal; therefore there was no exaggerated apical transportation according to them. However, such instrument designs have an undesired tendency to thread dangerously into canals (Schirrmeister *et al* 2006) Therefore, in order to reduce contact zones between the file and dentine and to eliminate threading, according to the manufacturer the ProTaper shaping files have multiple, increasingly larger tapers over the length of their cutting blades.

The above researchers concluded that the design with alternating cutting edges of RaCe® rotary files revealed less unprepared areas and minor loss of working length compared to ProTaper (rotary) and hand files. They also found that hand instruments together with ProTaper (rotary) showed a higher risk of canal aberrations compared to RaCe rotary files.

A study by Tan and Messer 2002 on the quality of apical canal preparation showed that instrumentation with a nickel titanium rotary file such as LightSpeed® instrumentation allowed greater apical enlargement with significantly cleaner canals, less apical transportation, and a better overall canal shape compared to hand instrumentation.

However, none of the instrumentation techniques (hand and rotary) were totally effective in cleaning the apical canal spaces. They concluded that greater apical enlargement using LightSpeed rotary instruments was beneficial in an attempt to further debride the apical third region in especially mesiobuccal canals of Mandibular molars. They (Tan, Messer 2002) also found that instrument designs, alloy properties, and canal curvature are important factors in determining the feasibility of greater apical enlargement.

2.4 Sodium hypochlorite

Sodium hypochlorite has been used for irrigation of the root canal for many years as it is both an oxidising, and tissue dissolving agent (Berutti, Angelini, Rigolone *et al* 2006). Various strengths have been formulated. Milton is the most popular form of sodium hypochlorite in use, for the disinfection of the root canal, irrigation of the canals and also for disinfecting endodontic instruments.

Sodium hypochlorite has the ability to dissolve organic matter and is bactericidal and virucidal. However, it is highly corrosive to metals and can cause corrosion of endodontic files. It is known to remove nickel from NiTi alloys (Berutti, Angelini, Rigolone *et al* 2006). The usual corrosive pattern involves surface pitting that can lead to areas of stress concentration and crack formation and potentially weakening the structure of the instrument (O'Hoy, Messer, Palamara 2003) Milton has a disadvantage of a high salt concentration, which acts to stabilize the free chlorine present in the solution thereby enhancing its effectiveness. However, the high salt content is likely to increase its corrosive effect on metals. This corrosion of the files could influence the mechanical properties of NiTi files and may lead to the undesirable and unexpected file fracture during root canal instrumentation (Pashley *et al* 1985, as cited by O'Hoy, Messer, Palamara 2003)

O'Hoy, Messer, Palamara 2003 conducted a study on the possible corrosive effects of sodium hypochlorite solution on endodontic instruments. They suggested that effective cleaning methods should be performed prior to sterilization of endodontic files. The cleaning may involve pre-soaking of the instruments in Milton as a disinfectant and subsequently placing them in an ultrasonic bath, with the same solution for only five minutes to minimise the contact time of the instrument with the solution.

According to Berutti *et al* 2006, they found that despite minor signs of corrosion being detected, it did not appear to cause a clinically significant alteration of the mechanical properties and performance of the instrument. However, they noticed that the instruments in their study groups, at the moment of immersion into the sodium hypochlorite solution produced marked effervescence in the solution, with the formation of visible dark particles in suspension. This was attributed to the presence of different metals in the ProTaper instruments tested that in the presence of an electrolytic solution such as sodium hypochlorite, could set off galvanic reactions and initiate the corrosion process.

They then formed a hypothesis that the corrosive phenomenon is triggered by the contact between metals with different electrochemical activities in the presence of sodium hypochlorite, and this may alter the structural integrity of the surface of a NiTi instrument, predisposing the NiTi endodontic instrument to fracture. The pitting caused by corrosion appears to be random, which might explain the occurrence of unexpected and unpredictable premature fracture of some NiTi endodontic instruments.

2.5 Instrument Design

Design changes have been made to endodontic instruments in order to help prevent procedural errors, increase efficiency, and improve the quality of canal shaping. (Cohen and Hargreaves 2006)

Cohen and Hargreaves (2006) suggested the following design components in an attempt to prevent excessive stress application on the instrument

1. The differences between the files minimum and maximum diameters can be minimised in order that the amount of torque that is required for rotating the larger diameter does not exceed the plastic limit of the smaller diameter.
2. The space between the tip of the instrument and its maximum diameter can be reduced so that the required torque does not exceed the ultimate strength of any part of the file
3. A provision can be made using zero taper or nearly parallel and fluted working portion of the file for curved canals in order that the apical portion of the canal can be enlarged without undue file stress and compression of the debris.
4. The continuity of the blade engagement can be interrupted.
5. There can be a reduction in the number of flute spirals or they can be completely eliminated to prevent excessive torque, which results from the accumulation of debris.
6. A means can be provided to complete the file function before the flutes fill with debris
7. Nickel titanium's land width can be minimized to reduce abrasion on the canal surface.
8. Files can be manufactured such that they have an asymmetric cross-section to help maintain the central axis of the canal.
9. The number of flutes with similar helix angles can be reduced or even be eliminated completely. When helix angles are dissimilar, screwing-in forces are reduced; when flutes have no helix angles, screwing-in forces are eliminated.
10. Positive cutting angles can be incorporated to enhance the efficiency of canal enlargement.

11. Blades can be made appendages or projections from the file shaft rather than ground into the shaft.
12. Channels can be cut along the long axis of the file to facilitate its retrievability in cases of instrument separation.

2.6 Properties of individual nickel titanium rotary files.

2.6.1 Profile and Profile GT® files

These files are available in sizes with diameters of .02, .04, .06 or .08 taper. Their trihelical symmetrical U-shaped flutes separated by lands distinguish them from other known nickel titanium files in the market. The blade has a slightly negative rake angle. The Profile and Profile GT NiTi instruments essentially have the same cross-sectional configuration.

The Profile has a 16mm working length; in contrast the length of each taper of the Profile GT varies as a result of having the same tip sizes and maximum diameters. The Profile GT has slightly more spirals at the tip portion of the instrument and slightly fewer at the handle portion. The Profile GT series does not include diameter of .02 taper. As with most systems using a large taper, the instrument becomes stiff before the apical preparation has been sufficiently enlarged. This puts a limitation on the use of this instrument in narrow, curved root canals.

Profile GT instruments are divided into three primary size families (numbers 20, 30, 40) based on the tip size. Each series has four tapers with diameters of 04, 06, 08, 10. The largest taper is also available in number 35, 50, and 70.

2.7 Profile and ProTaper in clinical use

Shen, Cheung, Bian *et al* 2006, observed the defects occurring on Profile and Protaper files during their study. Each profile and ProTaper instrument was limited to a maximum number of uses according to the tooth treated: four molars, 20 premolars, or 50 incisors and canines in order to prevent instrument separation and canal aberrations.

More ProTaper files separated than profile. Two thirds of the separated profile instruments were of 0.04 taper. All instrument separation occurred in molars or premolars. In their study, they found that the amount of flexural fatigue accounted for two thirds and that of torsional failure only a third of all the separation.

Results for the ProTaper group, found that the most separation was in the S1 files. These occurred mostly in the molars, followed by premolars and anterior teeth. Instrument separation may occur for two different reasons: torsion (shear) or flexural fatigue.

Torsional fracture occurs when the tip or any other part of the instrument binds to the canal wall while the hand-piece keeps turning. Flexural fatigue occurs when the instrument does not bind but rotates freely in a curved canal; fracture then occurs at the point of maximum flexure

It has been suggested that regular tapered instrument (Profile) was more likely to suffer from torsional failure than variable tapered instruments (ProTaper). A high magnitude of stresses seems to develop at the base of flutes of a profile instrument, whereas the stresses appear to be more evenly distributed and of lower magnitude in ProTaper files.

With the lesser and more evenly distributed stresses, ProTaper files might be less likely to become permanently deformed, but ultimately would fail because of material fatigue. Given the same torque, smaller diameter instruments would therefore be more susceptible to torsional failure than larger instruments.

2.8 Other Rotary Instruments available commercially.

2.8.1 LightSpeed®

The LightSpeed instrument (Light speed technology, San Antonio, Texas) has essentially the same cross-sectional design as the Profile and Profile GT NiTi instruments. However, it has a unique short flame-shaped working portion and a reduced-diameter shaft similar to that of a Gates-Glidden drill.

The long unspiraled shaft provides good flexibility around curved canals. The minimal working surface requires higher rotation speeds (1000-2000 revolutions per minute) compared with other files. The tip has a long non-cutting pilot portion. The LightSpeed instrument comes in sizes of 20 to 140. It also includes "half" sizes, (example 22,5, 27,5) up to size 60.

In the smallest sizes, the head is less well defined. The design has been shown to vary with the instrument size. The manufacturer (Light Speed technology, San Antonio, Texas) recently proposed that these instruments be used in a Hybrid technique. Other instruments would be used to shape the coronal segment of the root canal, and a limited number of LightSpeed instruments would then be used to enlarge the apical segment.

This suggestion is based on reports that larger than normal apical preparations sizes can be obtained with these instruments without compromising the remaining dentin thickness in the more coronal segments of the canal. This capability takes on greater importance because increasing the size of the apical preparation without necessarily over-preparing the coronal third, has been shown to be directly related to the clinician's ability to disinfect the critical segment (the apical third) of the infected canal.

In one study (Grossman, Oliet, del Rio 1988), a combination of tapered rotary and LightSpeed instruments was used in forty patients; the study showed that instrumentation to apical preparation sizes larger than those typically used (60 for molars and 80 for cuspids and premolars) more effectively removed culturable bacteria from the canals.

2.8.2 Quantec®

The Quantec instrument (Sybron ENDO) was designed to have double helical, asymmetrical flutes separated by lands, the width of which is reduced by a relief. The quantec instruments also have positive cutting blades on the working portion. The lands of the instrument are set to enhance the instruments' strength.

This file is available with two tip designs, a cutting tip and a safety-cutting tip. The instruments have the diameters of 02, 03, 04, 05, 06, 08, 10, and 12 taper and are available in sizes ranging from a number 15 to a number 60 instrument.

2.8.3 K 3®

Similar in concept to the Quantec, the K3 instrument (Sybron ENDO) was designed to have three asymmetrical flutes separated by lands, and a safety tip was incorporated into the design. This instrument has the most positive cutting angle of the instruments currently available and is considered among the most resistant to fracture because of its cross-sectional geometry. It is available in the following diameters .02, .04, .06 taper. A series of body shapers in diameters of .08, .10, .12, are also available and have become a common component of most instrument sets.

2.8.4 Hero 642

The Hero 642(Micromega, Geneva) was designed to have trihelical, sharp flutes resembling a Hedstrom file. They have recessive lands that do not extend axially to the circumference, but are designed to reduce stress, along the length of the blades. Consequently, the recommended rotation speed is 500-600revolutions per minute; excessive speeds might result in fracture of the instrument. The Hero 642 has a large central core similar to that found in the K3 series. This instrument is available in sizes ranging from 20-to-45. All sizes are available in, .02 taper, at sizes of 20, 25 and 30. They are also available in .04 and .06 taper.

2.8.5 RaCe®

The race instrument (Brasseler, Savannah) has been designed to incorporate alternating non-spiralled and spiralled segments along its working length to minimize torsion of engagement and torsion resulting from screwing-in forces (thus its name, reamer with alternating edges).

These instruments were found to do an excellent job of removing debris while maintaining the original canal curvature in extracted teeth. Resembling a K-reamer, the sequence file (Brasseler, FKG Dentaire) has a slight corkscrew configuration with variable pitch and helix angles.

Due to this design there is a reduction in the amount of force with which some parts of the blades become engaged in the canal wall. These instruments are available in .04 and .06 taper. The tip design is set to be non-cutting with the first blade positioned 1mm from the tip.

2.8.6 Mtwo Instruments

The new Mtwo instruments (VDW, Munich, Germany) have S-shaped cross-sectional design and a non-cutting safety tip. These instruments are characterized by a positive rake angle with two cutting edges, which are claimed to cut dentine effectively. Moreover, Mtwo instruments have an increasing pitch length (blade camber) from the tip to the shaft.

This design is alleged to have two functions:

1. To eliminate threading and binding in continuous rotation
2. To reduce the transportation of debris towards the apex

The basic series of Mtwo instruments comprises eight (8) instruments with tapers ranging between 4% and 7% and sizes from 10-to-40. According to the manufacturer the instruments should be used in a single length technique. That means, all file sequence should be used to the full length of the root canal.

2.8.7 Oscillating/Reciprocating files

The geromatic hand- piece, a rotary instrument in use since 1969, delivers 3000-quarter turn reciprocating movements per minute. Rasps and barbed broaches are most often used in geromatic hand-pieces, but K-type and H-type instruments can also be used.

2.9 Cyclic fatigue of nickel-titanium rotary instruments

Endodontic instruments upon rotation are subjected to both tensile and compressive stress in the curved canal. This stress is localized at the point of curvature. In the study conducted by Li, Lee, Shin *et al* 2002, the results demonstrated that the time to failure significantly decreased as the angle of curvature or rotational speeds increased.

However, as pecking distances increased, the time to failure increased. This is because a longer pecking distance gives the instrument a longer time interval before it once again passes through the highest stress area (Li, Lee, Shin *et al* 2002). The microscopic evaluation they conducted indicated that ductile fracture was the major cyclic failure mode.

They recommended to prevent breakage of nickel-titanium rotary instrument, appropriate rotational speeds and a continuous pecking motion be used in the preparation of the root canal.

Several studies have looked at the deterioration of nickel-titanium files such as those conducted by Sattapan *et al* (2000) and Eggert, Peters, Barbakow (1999). They did not agree on how many times or how long a file can be used in the canal system. However, they do agree that a visibly distorted or fractured instrument should be discarded.

The study performed by Svec and Powers (2002) found that all of the nickel-titanium instruments showed signs of deterioration after one use. Two of the instruments had visible distortions. The distortion is accompanied by a cracking of the metal. It does seem that even the smallest of the instruments can be used multiple times without fear of fracture, unless there is visible distortion of the instrument, then it must be discarded.

The super elasticity (SE) nature of nickel-titanium has been attributed to a reversible austenite to martensite transformation (Kuhn and Jordan 2002). It is believed austenite is transformed to martensite during loading and reverts back to austenite when unloaded. The transformation is reversible when used in the clinical setting, because the NiTi alloys have a transitional temperature that is lower than mouth temperature

2.10 General fatigue of rotary instruments

Nickel-titanium rotary instruments are subject to torsional stress and cyclic fatigue resulting in distortion and fracture during root canal shaping. Sattapan *et al* (2000) measured the torque generated by rotary instruments at constant speed and determined that the torque generated at the moment of rotary instrument fracture was greater than at any other time during canal instrumentation.

Li, Lee, Shin *et al* (2002) found that rotary instruments subjected to cyclic fatigue testing were more susceptible to fracture when they were severely flexed. A SEM examination of the fractured surfaces of nickel-titanium rotary instruments revealed the presence of peripheral cracks, craters and dimples indicative of a ductile type of fracture that occurs when a metal is unable to withstand deformation without rapture

Independent investigations (Svec, Powers (2002),Kuhn, Jordan (2002) concerning the effect of rotary speed on nickel-titanium rotary instrument fracture indicated that instruments rotated at higher rotational speeds of 300-350 revolutions per minute are more susceptible to fracture than at lower rotational speeds of 200 revolutions per minute.

2.11 Surface debris after root canal preparation

It has been found that it is not possible to have completely clean canal walls after preparation as seen by the study conducted by Serafino, Gallina, Cumbo *et al* (2004). In their study, teeth were placed in four groups of single canal teeth. In all the groups, it was found that at the middle and coronal levels, the SEM evaluation showed discontinuous areas of dentine demineralization alternating with areas covered by smear layer. It was frequently found that there were open dentinal tubules only partially occluded by smear layer plugs.

In the same study higher scores of debris were found in all the groups at the apical level. The smear layer and its quantity is also very challenging in cases of retreatments of failed root canal treatment and in cases where root canals are prepared to receive posts, because the action of the drills used to remove the root filling material to create the post space, produces a new smear layer rich in sealer and gutta-percha remnants plasticized by the frictional heat of the drill (Serafino *et al* 2004)

Torabinejad *et al* 2002 found that all instruments created dentine debris and smear layer as a consequence of their action on the root canal walls. This debris may be compacted along the entire surface of the canal walls increasing the risk for bacterial contamination and thereby reducing the adaptation of both the sealer and the Gutta-Percha obturation material. Furthermore, this debris may be compacted apically and create an apical plug that prevents the complete filling of this important region (Iqbal *et al* 2003)

In the study by Foschi, Nucci, Montebugnoli *et al* 2004), inorganic debris was easily discernible from pulpal debris and detected only in the apical third of some samples. Despite differences being observed, the study demonstrated that both NiTi instruments (Mtwo and ProTaper) produced a similar dentine surface on the root canal walls for all parameters considered.

It confirmed that the apical third has a small number of dentinal tubules with a reduced diameter that were only partially covered by a thin smear layer. They concluded that the use of Mtwo and ProTaper instruments produced a clean and debris-free dentine surface in the coronal and middle thirds. However, these two instruments were unable to produce a dentine surface free from smear layer and debris in the apical third (Foschi *et al* 2004).

According to Schafer, Dzepina, Danesh (2003),the resistance to bending of root canal instruments tends to influence the results of instrumentation in curved canals, because this results in excessive removal of dentine in areas that make first contact with the instrument, and this also limits accessibility to the apex. However, instruments with increased flexibility cause fewer undesirable changes in the shape of curved canals than those with greater resistance to bending. This increase in flexibility is achieved either by different design features or by the use of nickel titanium alloys according to the authors.

They found that resistance to bending of root canal instruments depended on their metallurgic properties such as different alloys and their geometric shape. These instruments have a tendency of causing procedural errors such as canal transportation.

CHAPTER 3

AIMS AND OBJECTIVES

3.1 AIMS AND OBJECTIVES

The aims of this study were

1. To use the scanning electron microscope to compare the cleanliness of the root canal walls following the use of rotary and manual debridement methods
2. To assess the transportation of the apical part of the root canal orifice when using rotary and manual debridement methods

3.2 PURPOSE OF THE STUDY

The purpose of this study was:

1) To evaluate the root canal dentine surfaces using a scanning electron microscope after standard endodontic debridement performed with ProTaper® nickel titanium rotary instruments and stainless steel K-file hand instruments.

2) To evaluate the degree of apical transportation that occurs after standard endodontic debridement performed with ProTaper® nickel Titanium rotary instruments and stainless steel K-files (hand instruments).

3.3 STATEMENT OF THE PROBLEM

It is accepted that using both rotary and manual files produces a smear layer and debris of varying degrees. The amounts thereof should be reduced to avoid debris from being pushed into the periapical tissues as the debris harbour micro-organisms. The significance of the smear layer is that it has been shown to interfere with final obturation of the root canals.

3.4 NULL HYPOTHESIS

- There is no significant difference in the quality of the surfaces of the canals prepared using rotary or manual debridement techniques
- There is no significant difference in the amount of apical transportation that results when canals are prepared with either rotary or manual debridement techniques.

CHAPTER 4

MATERIALS AND METHODS

4.1 SPECIMEN COLLECTIONS

4.1.1 Study Sample and Sample size

Extracted teeth were collected from dentists in the Mitchell's Plain metropolis. These were stored initially in a solution of Thymol crystal pre-operatively and later stored in normal saline during the study period in order to avoid desiccation.

Ninety extracted maxillary incisors were randomly divided into three groups, where the first forty were debrided using K-Files®, the next forty debrided using ProTaper® nickel-titanium files, and the final ten teeth were used as negative controls.

Fig 4.1 Extracted maxillary incisors

4.2 STUDY DESIGN

4.2.1 Design

This was an *in vitro* descriptive study analyzing the efficacy of rotary and manual debridement of root canals during simulated root canal therapy.

4.3 STUDY SAMPLE

4.3.1 Inclusion Criteria:

Anterior maxillary teeth of approximately 27millimetre in lengths were collected from dental practitioners in the Mitchell's Plain area and were used in the study. The teeth had minimal dental caries and if caries was present it did not encroach on the pulp, as observed both clinically and radiographically. All teeth had intact crowns.

4.3.2 Exclusion Criteria:

- All teeth that showed the presence of calcification and sclerosis in the pre-operative radiographs.
- Badly broken down carious teeth.
- Heavily restored teeth.
- Teeth with signs of resorption (internal or external resorption)
- Teeth showing the possible presence of hairline fractures.

4.4 PILOT STUDY

A pilot study was carried out using ten teeth from each group (rotary and manual) and five control teeth that were debrided and studied using the Scanning Electron Microscope to assess the feasibility of the study. This pilot study was repeated in order to limit researcher bias and to check the consistency of the results obtained. The samples were measured at a 1mm field at the most apical aspect of all segments under examination.

4.5 ETHICAL CONSIDERATION

4.5.1Teeth Collection

The teeth collected for this study were extracted for reasons other than the purpose of this study, and were stored in accordance to the specifications of this research project.

4.5.2 Teeth Disposal

On completion of the study the teeth were discarded in accordance with the current medical waste disposal practice carried out at the Dental faculty of the University of the Western Cape and these were subsequently incinerated.

4.6 ENDODONTIC THERAPY

4.6.1 Endodontic therapy on specimens

The pulps of the ten control teeth were exposed (access cavity) on the palatal aspect incisal to the cingulum. Medium barbed broaches were used to extirpate the necrotic pulp tissues from the root canals and the teeth were then stored in normal saline during the treatment phase. A standardized pre-operative radiograph was obtained using a 25cm long cone at a distance of 5cm for each tooth to measure the working length (Facilitated by the use of a Rinn holder).

The eighty experimental teeth were also exposed (access cavities) and barbed broaches were used to negotiate the root canals to remove the necrotic pulp tissue. A solution of 0,5% sodium hypochlorite was used copiously to irrigate the canals during debridement, followed by 5 millilitres of sterile saline solution after completion of debridement. The canals were thoroughly dried with sterile paper points

Fig 4.2 Stainless Steel K-files used in the one study group

Fig 4.3 Nickel –Titanium rotary files used in the second study group

Figs 4.2 and 4.3 show the files that were used, in the study, in their proper sequencing. Hand files used were in the standard ISO sizes and for the rotary instruments the manufacturer's recommendation was followed. For all hand instrumentation procedures the standardized circumferential filing method was used whereby, all K-files were used to their full length prior to the next K-file. The debridement was done up to a size 50 file, without any observed loss of working length.

All ProTaper NiTi files were used in the crown-down method, where the coronal aspect of the tooth was widened first with a 2mm round bur, to improve visibility and access to the root canal. This debridement technique was generally shown to produce rounder preparations in cross-section, which were cleaner and are said to maintain the original curvature of the canal (Calhoun, Montgomery 1988 as cited by Jardine and Gulabivala 2000a). The manufacturer also recommends this debridement technique (Dentsply Maillefer)

One set of nickel-titanium rotary files, and one set of stainless steel hand files, was used to clean and shape eight teeth before being discarded to avoid instrument separation (based on the work of Shen *et al* 2006) and this was also recommended by Li *et al* 2002.

The instruments that bent or showed signs of unwinding during debridement were discarded. On completion of the debridement, the teeth were examined under an endodontic microscope, in order to assess the presence or absence of apical transportation.

All the experimental teeth were sectioned vertically in a mesio-distal direction, using a diamond bur to a depth of 3mm, and finally splitting the sections apart using a flat plastic hand instrument to avoid contamination of the canals during the separation process (Jeon, Larz, Spangberg *et al* 2003, Ahlquist *et al* 2001). The root canal walls remained intact and available for quantitative measurements at the apical, middle and coronal thirds for smear layer and debris evaluation.

The apical 1mm of all three segments of the canal walls was examined using the scanning electron microscope for debris and smear layer. The apical third of the canal was also assessed for the amount and direction of apical transportation, if any existed, using an endodontic microscope. The quantitative measurement of smear layer was achieved by checking tubular coverage, homogeneous smear layer or heterogeneously thick smear layer covering the dentinal tubules.

The canal surfaces were classified at different levels with reference to the amount of debris and smear layer. Scores ranging from one for clean walls, and five for walls completely covered with smear layer were recorded. As regards debris a score of slight debris, moderate (less than 50% of the surface covered) or substantial debris (more than 50% of surface being covered) were recorded.

4.7 *DEFINITIONS*

1. Debris was defined as dentine chips, pulpal remnants, other particles loosely stuck to the canal walls according to Hulsmann and Stryga (1993)

2. Smear layer was defined as a film of debris attached to dentine and other surfaces following instrumentation with rotary files or manual endodontic files. It therefore consisted of dentine particles, remnants from vital or necrotic pulp tissue, bacterial products and retained rinsing fluid according to McComb, Smith (1975)

4.8 SCORING OF SMEAR LAYER AND DEBRIS

4.8.1 SMEAR LAYER (According to Hulsmann and Stryga, 1993, McComb and Smith 1975)

Score I: No smear layer, open dentinal tubules.

Score II: Slight smear layer, more dentinal tubules open than closed

Score III: Homogeneous smear layer covering major part of the surface, Fewer dentinal tubules open than closed.

Score IV: Homogeneous smear layer covering the surface, no open dentinal tubules

Score V: Thick non-homogenous smear layer covering the surface.

4.8.2 DEBRIS: (According to Hulsmann and Stryga*, 1993,* Ahlquist *et al* 2001)

Score I: Clean root canal wall, very slight debris

Score II: Slight debris

Score III: Moderate amount of debris, less than 50% of the sample Surface

Score IV: Substantial debris, more than 50% of the sample covered.

Score V: Complete coverage of the root canal wall by debris

4.9 SPECIMEN PREPARATION

4.9.1 Preparation of specimen for scanning electron microscope(SEM) examination

The prepared specimens were placed in the desiccator for a period of two days or forty-eight hours, to allow all moisture from the specimen to escape under pressure. Conductive carbon adhesives were placed on aluminium stubs to retain the specimen. These stubs were used to transport the specimen into the SEM for evaluation.

The specimens on the aluminium stubs were first transferred to a sputter coater in order that the specimens could be gold plated/coated. The gold coating is an ionization process where the argon gas is directed onto the gold plate on the machine, under pressure, resulting in gold ion release and thereby coating the specimen for observation, as seen in figs 4.4 and 4.5

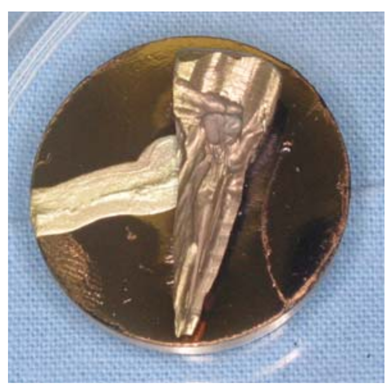


Figure 4.4 multiple specimens in groups after gold coating

Figure 4.5 Close-up view of a Single gold coated specimen

Prepared specimens for the Scanning Electron Microscopic study

The gold-coated specimens were maintained in their experimental groups (figure 4.4). It took four minutes to completely coat a specimen.

4.8.2 Specimen preparation for scanning electron microscope evaluation and image production.

- The image was displayed on a cathode ray tube, where the specimen was bombarded with electrons generated by the electron gun, releasing a primary electron (that did not generate the image). These primary electrons then knocked the electrons from the specimen. Secondary electrons were then released and the detector collected these creating the viewed image.

- A vacuum has to be created before the shutter door of the SEM can be opened (a vacuum is important for the prevention of moisture contamination of the specimen).

- The image is then captured via an electronic digital camera and can be displayed on the monitor. These images can be recorded either on film or on computer disc.

4.10 SCHEMATIC REPRESENTATION OF THE STUDY

Group 1 Control group	Group 2 Test group 1	Group 3 Test group 2
10 Maxillary incisors Extirpated Undebrided Sectioned Studied Under SEM	40 Maxillary Central Incisors Extirpated Debrided with ProTaper® under copious irrigation Sectioned Studied Under SEM	40 Maxillary Central Incisors Extirpated Debrided with K-Files® under copious irrigation Sectioned Studied Under SEM

CHAPTER 5

RESULTS

5.1 Apical transportation

Eighty root apices were evaluated using the endodontic microscope, forty of which were instrumented by stainless steel K-files (hand instrumented), and forty were instrumented using nickel titanium rotary files (ProTaper® Dentsply Maillefer).

Fig 5.1 A cross-section of a specimen illustrating apical transportation

Fig 5.2 A cross-section of two specimens illustrating Apical transportation

TABLE 5.I Apical Transportation Tabulated Scores

TRANSPORTATION	HAND	ROTARY	TOTAL
YES	4	0	4
NO	36	40	76
Number of teeth examined	40	40	80

There were four teeth out of forty, in the hand-instrumented group that showed the presence of apical transportation while the remaining thirty-six teeth remained centred.

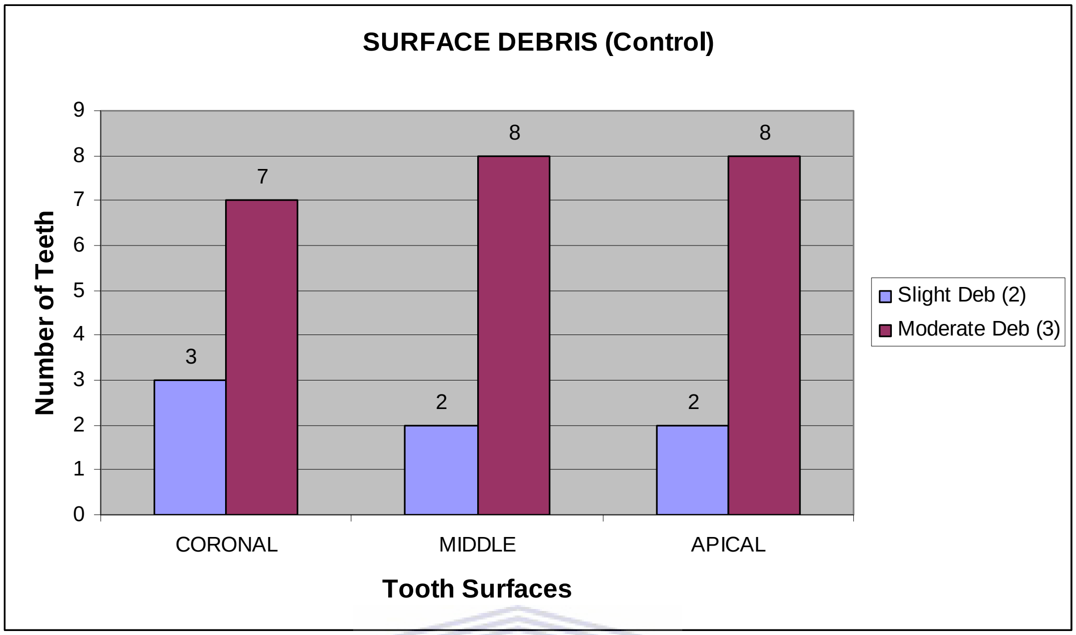
However, all forty teeth in the rotary-instrumented group remained centred.

TABLE 5.II Control Group Surface Debris

SCORES	CORONAL	MIDDLE	APICAL
1	-	-	-
2	3	2	2
3	7	8	8
4	-	-	-
5	-	-	-

In the control debris group, all surfaces showed a presence of debris. Three of the coronal surfaces, two of the middle third and two of the apical surfaces had a score of two while seven of the coronal, eight of the middle and eight of the apical third surfaces had a score of three, indicating moderate debris covering less than 50% of the specimen.

However, there was no smear layer formation, because only a barbed broach was used.



Graph 5.1 Control Surface Debris graphically illustrated

The above is the illustration of the amount of surface debris that remained on the control teeth following only extirpation, where only the barbed broach was used.

The x-axis indicates all the tooth surfaces that were examined from all ten-control samples.

The Y-axis indicates the scores obtained and they ranged from 2-4 according to the criteria of Hulsmann and Stryga 1993.

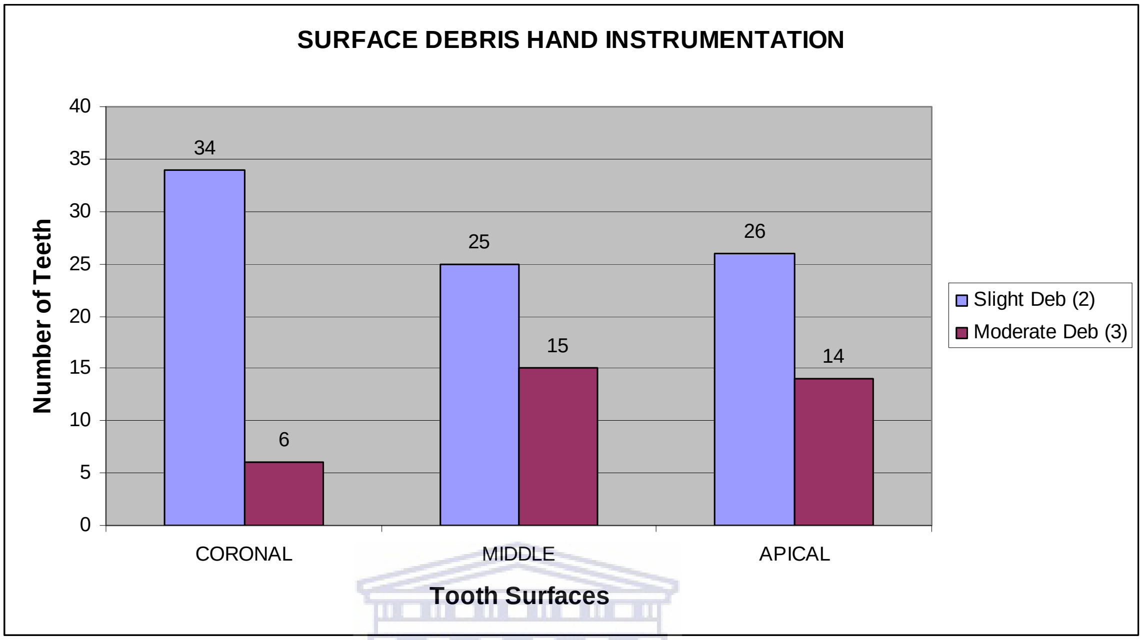
The amount of debris remaining in the middle third and the apex indicates that the barb broach was not effective in removing the debris. However no specimen was rated as 5

TABLE 5.III Surface Debris Scores –Hand instrumented group.

SCORES	CORONAL	MIDDLE	APICAL	TOTAL
1	-	-	-	-
2	34	25	26	85
3	6	15	14	35
4	-	-	-	-
5	-	-	-	-
	40	**40**	**40**	**120**

In the hand -instrumented group, the bulk of the specimen surfaces, 85 out of a total of 120 surfaces had a score of 2, implying that only a minimal amount of surface debris remained, following debridement with hand instruments.

There were no surfaces that registered a score of 4 or 5.



Graph 5.2 Surface Debris –Hand instrumented group

Graphically Illustrated

The X-axis represents the number of tooth surfaces that were examined in the hand debridement group.

The Y-axis represents the scores obtained and they ranged between 2 and 3. The bulk of the scores were 2 (85 surfaces) and the remaining score of 3 was obtained in 35 surfaces.

There was no score of 4 or 5 recorded in this group.

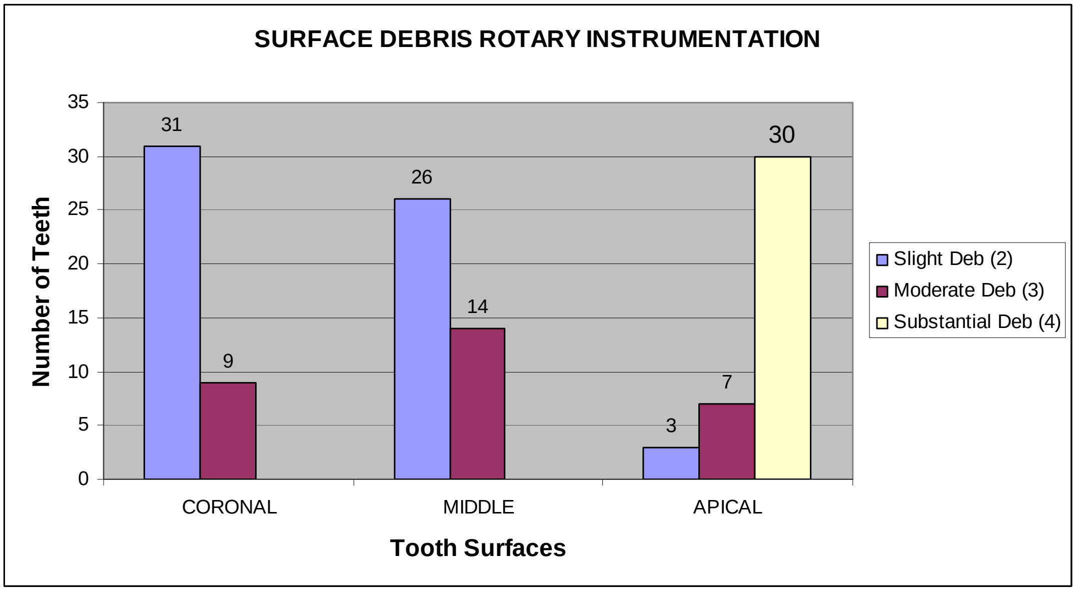
TABLE 5.IV Surface Debris Rotary instrumented group

SCORES	CORONAL	MIDDLE	APICAL	TOTAL
1	-	-	-	-
2	31	26	3	60
3	9	14	7	30
4	-	-	30	30
5	-	-	-	-
	40	**40**	**40**	**120**

In the rotary instrumented group, 60 out of a total of 120 surfaces had a score of 2, 30 of the surfaces had a score of 3 and the remaining 30 surfaces registered a score of 4, implying that debris tended to be compacted more apically in the rotary instrumented group.

The bulk of the coronal third registered a score of 2 (31 surfaces) as compared with the 9 surfaces registering a score of 3. In the middle third, a high number of surfaces (26) registered a score of 2 compared to only 14 surfaces with a score of 3.

In the apical third, a larger number of surfaces (30) registered a value of 4 implying that more than 50% of the specimen was covered by debris while 7 surfaces registered a score of 3 and the remaining 3 surfaces a value of 2.



Graph 5.3 Surface Debris rotary instrumented group Graphically Illustrated

The X-axis represents the number of tooth surfaces that were examined in the rotary debridement group.

The Y-axis represents the scores obtained and these ranged from 2 to 4. 60 surfaces had a score of 2, 30 surfaces a score of 3 and the remaining 30 surfaces had a score of 4.

There were no surfaces that registered a score of 5.

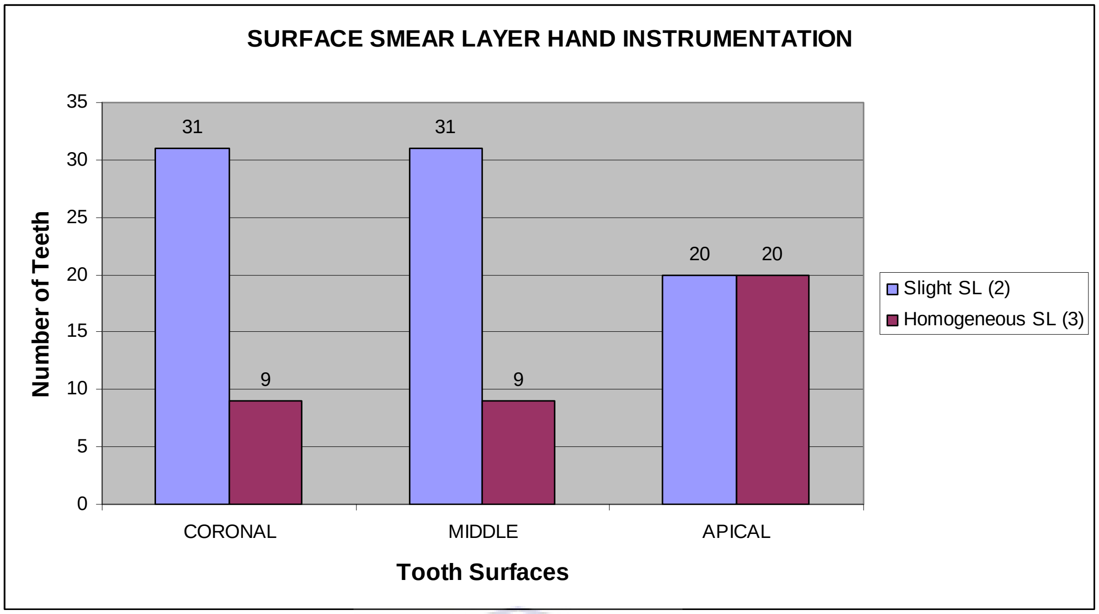
TABLE 5.V Smear Layer Scores – Hand instrumented group

SCORES	CORONAL	MIDDLE	APICAL	TOTAL
1	-	-	-	-
2	31	31	20	82
3	9	9	20	38
4	-	-	-	-
5	-	-	-	-
	40	40	40	120

In the hand-instrumented group, the bulk of the specimen surfaces, 82 out of the total of 120 surfaces had a score of 2 for the presence of the smear layer.

The remaining 38 surfaces had a score of 3 for the presence of the smear layer.

There were no surfaces in any third of this group with a score of 4 or 5 as regards the presence of smear layer.



Graph 5.4 Smear Layer Scores Hand instrumented group Graphically Illustrated

The X-axis represents the tooth surfaces that were examined in the hand debridement group for smear layer assessment.

The Y-axis represents the scores obtained and they ranged from 2 to 3, with 82 surfaces out of 120 having a score of 2 and the remaining 38 surfaces with a score of 3. There were no surfaces with a score of 4 or 5

TABLE 5.VI Smear Layer Scores Rotary instrumented group

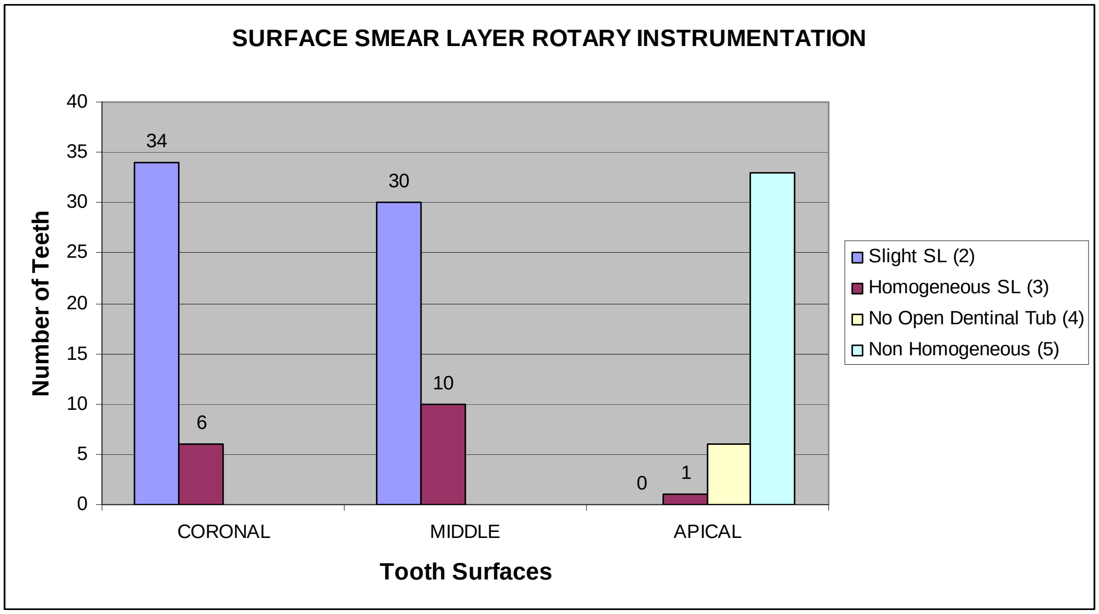
LEVELS	CORONAL	MIDDLE	APICAL	TOTAL
1	-	-	-	-
2	34	30		64
3	6	10	1	17
4	-	-	6	6
5	-	-	33	33
	40	40	40	120

In the above table, 64 surfaces out of a total of 120 had a score of 2, 17 surfaces had a score of 3, 6 surfaces a score of 4 and 33 surfaces a score of 5 as regards the presence of a smear layer in the rotary instrumented group.

Scores of the coronal third were further divided into 34 surfaces with a score of 2 and 6 surfaces a score of 3.

In the middle third, 30 surfaces had a score of 2 and 10 surfaces a score of 3.

In the apical third, no surface had a score of 2, only 1 surface had a score of 3, 6 surfaces had a score of 4 and 33 surfaces had a score of 5.



Graph 5.5 Smear Layer Scores Rotary instrumented group Graphically Illustrated

The X-axis represents the tooth surfaces that were examined using the rotary debridement group for smear layer assessment.

The Y-axis represents the scores obtained and they ranged from 2 to 5. 64 surfaces in total had a score of 2, 17 surfaces a score of 3, 6 surfaces a score of 4 and the remaining 33 surfaces had a score of 5.

5.2 Instrument separation

Two rotary instruments in the S1 (shaping files) with .04 taper fractured at the tips (figure 5.4) and only one of the smaller sized (size 20) K-files fractured during instrumentation due to fatigue (Figure 5.3).

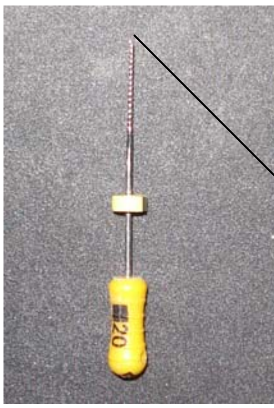


Fig 5.3 Fractured tip of K-File

Fig 5.4 Fractured tips of S1 ProTaper

Fractured tips of both K-file and S1 ProTaper

Figure 5.3 is the picture of the only K-file size 20 that separated during the manual debridement procedure, and figure 5.4 is the picture of the two S1 ProTaper files that separated during the rotary debridement procedure.

Scanning Electron Microscopic Views

(1) Control group

Assessment for debris

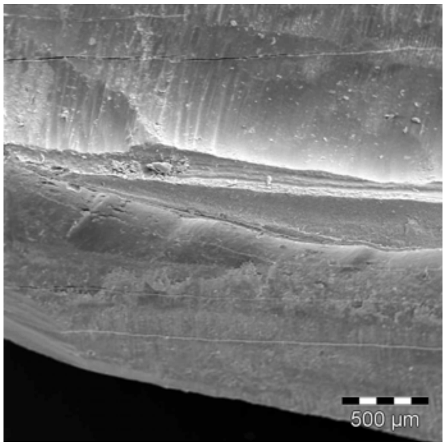


Fig 5.5

Apical third

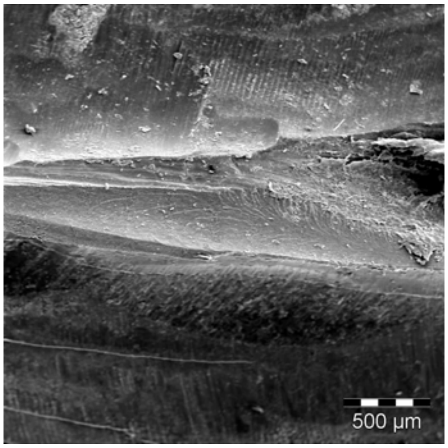


Fig 5.6

Middle third

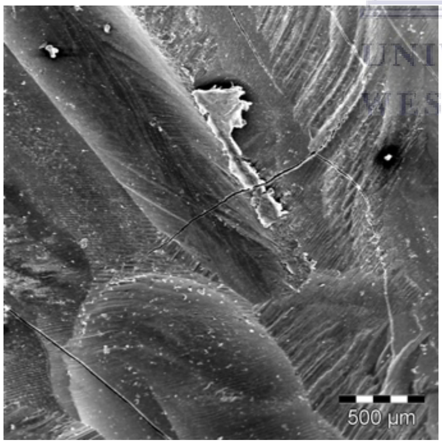


Fig 5.7

Coronal third

In fig 5.5, a score of 2 was assigned as there is very limited amount of debris found on the apical third

Fig 5.6 was assigned a score of 3, as the amount of debris does not cover all the surfaces of the middle third of the root canal. On higher magnification, more than 50% of the dentinal tubules could be demonstrated.

Fig 5.7 was assigned a score of 3, as the nerve tissue was seen due to larger areas which were uninstrumented. On higher magnification it was shown than there were large interlacing areas with more that 50% of the dentinal tubules clearly demonstrated, even in the presence of residual nerve tissue.

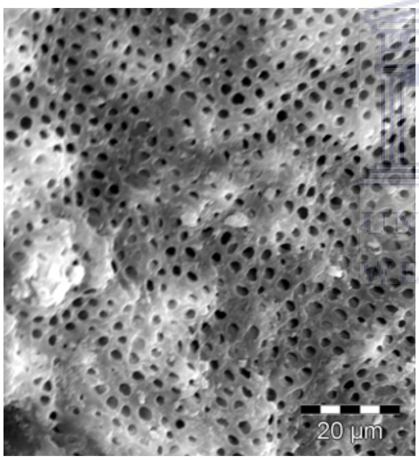


Fig 5.8 X1000

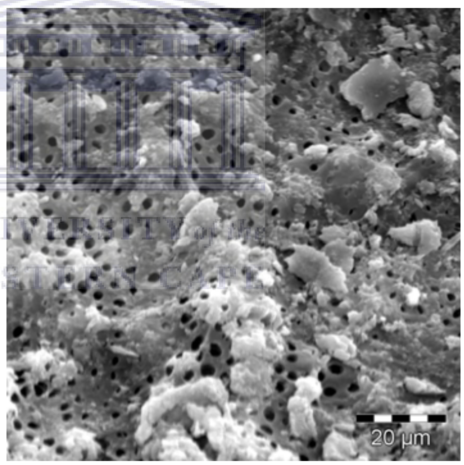


Fig 5.9 X1000

Figures 5.8 and 5.9 have been included to show that the residual debris did not occlude the dentinal tubules

(2) Hand Instrumented group

Assessment for surface debris

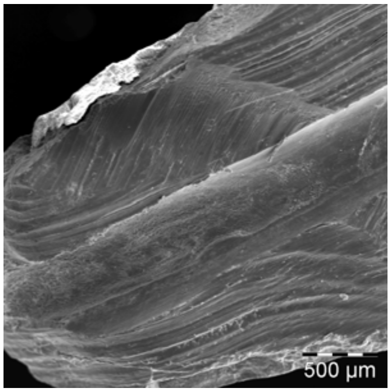


Fig 5.10

Apical third

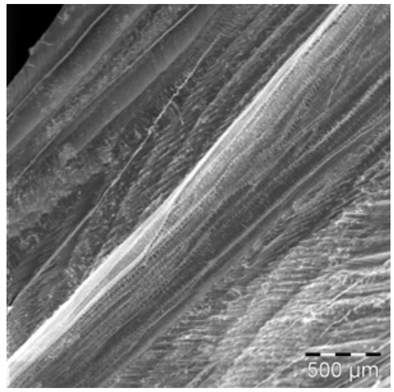


Fig 5.11

Middle third

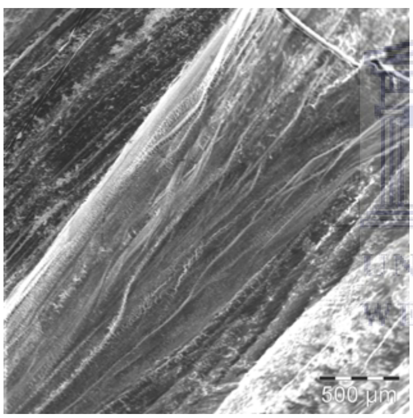


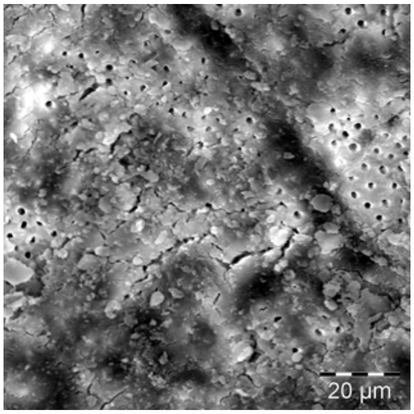
Fig 5.12

Coronal third

Fig 5.10 was given a score of 3, for the apical aspect of the root canal, because moderate amounts of debris are seen, with less than 50% of the sample surface covered. Fig 5.11 was assigned a score of 2, where there is only slight debris on the surface. Fig 5.12 was assigned a score of 2, where only slight debris remained on the surface of the sample.

It can be clearly seen that the amount of residual debris that remained following hand instrumentation is quiet small and we can be sure that most of the necrotic debris has been removed.

Assessment for smear layer



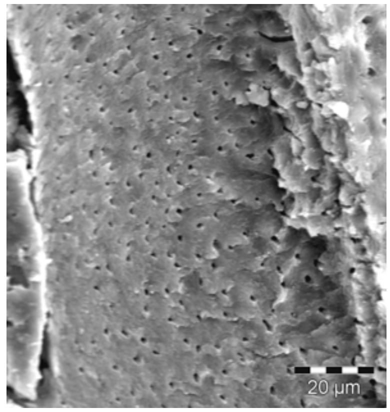


Fig 5.13

Apical third

Fig 5.14

Middle third

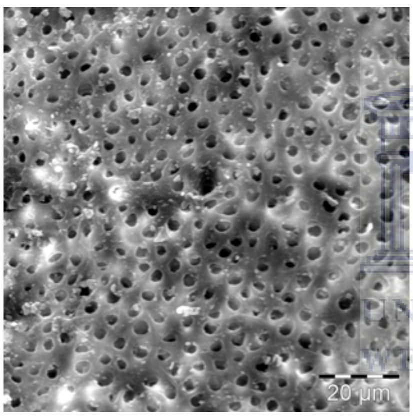


Fig 5.15 Coronal third

Fig 5.13 was given the score of 3, where there was a homogeneneous smear layer covering the surface, with few dentinal tubules open. In figure 5.14, a smear layer score of 3 was assigned for this slide. Fig 5.15 was assigned a smear layer score of 2, where the amount of smear layer was very slight, with most dentinal tubules remaining open.

On average the amount of smear layer found on the root canals debrided using hand files is found to be minimal, resulting in lower scores. It is clearly visible that most of the dentinal tubules remain patent and can be clearly discerned.

(3) Rotary Instrumented group

A) Assessment of debris

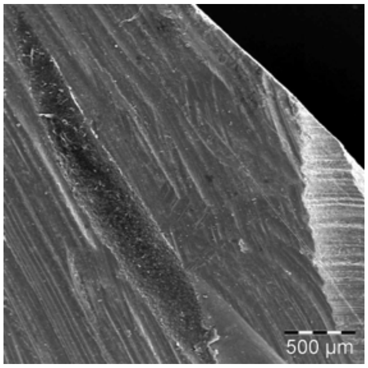


Fig 5.16

Apical third

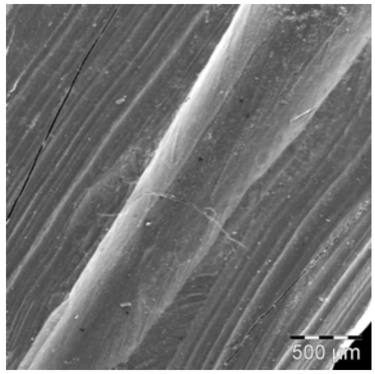


Fig 5.17

Middle third

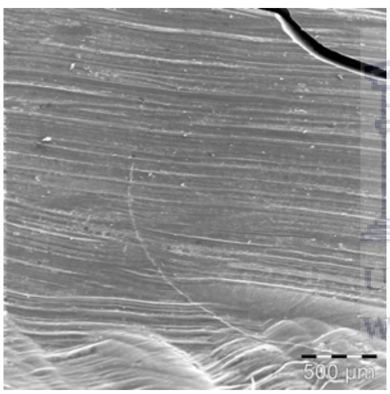


Fig 5.18

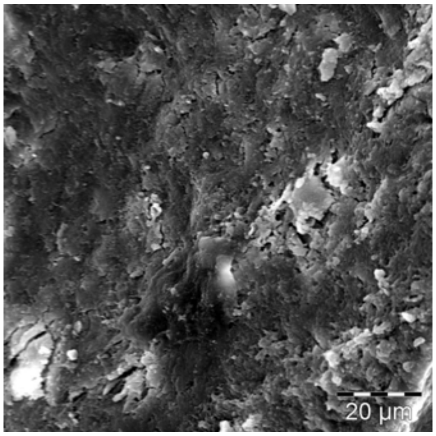
Coronal third

Fig 5.16 was assigned a value of 4, where a substantial amount of surface debris can be seen covering more than 50% of the sample surface.

Fig 5.17 was assigned a value of 3, where moderate amounts of debris were left behind, covering less than 50% of the sample surface. Fig 5.18 was assigned a score of 2, where only slight debris was seen covering the surface of the sample.

From the above slides it can be seen that the coronal third of the tooth tends to be cleaner than all the other surfaces, and the apical third has the highest amount of debris remaining in the rotary instrumented group.

B) Assessment of smear layer



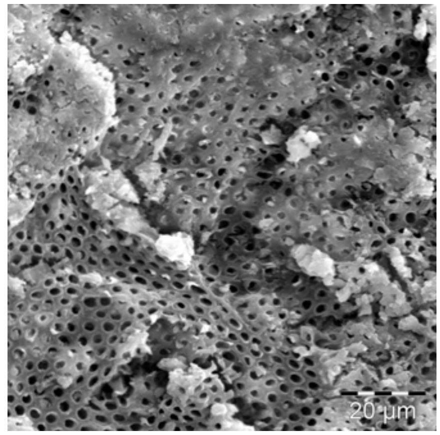


Fig 5.19 Apical third   Fig 5.20 Middle third

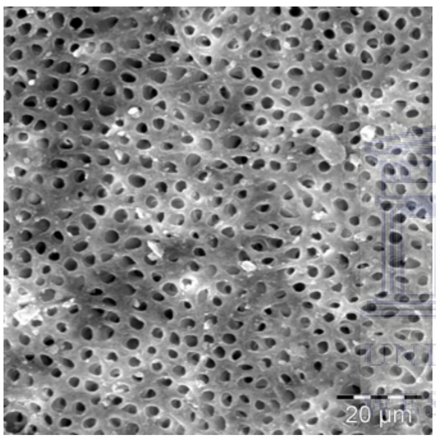


Fig 5.21 Coronal third

Fig 5.19 was assigned a score of 5, where a thick non-homogeneous smear layer was seen covering the surface of the root canal wall.

Fig 5.20 was assigned a score of 2, where a slight smear layer was seen covering the surface but most dentinal tubules remained open.

Fig 5.21 was assigned a score of 2, where there was no smear layer covering the canal wall and all the dentinal tubules remained open.

CHAPTER 6

DISCUSSION

The scanning electron microscopic study analysis seem to be an adequate method used to investigate the influence of endodontic instruments on the morphology of dentine surfaces, therefore the methodology employed in the present study is in line with previous investigators (Ahlquist *et al* 2001).

Maintenance of the original canal as far as possible is a pre-requisite during root canal preparation; so that, iatrogenic complications arising from cleaning and shaping can be avoided. Results obtained in the present study, indicate that there were only 4 teeth (10%) that showed signs of apical transportation. All these teeth were from the hand-instrumented samples.

These procedural errors of apical transportation and loss of working length were only associated with the use of stainless steel hand files and could be attributed to insufficient flexibility in the instruments. Tan and Messer 2002, reported similar results, whereby two sites in twenty locations (10%) examined exhibited canal transportation.

They found that more canal transportation occurred in the apical 1mm level than at the 3mm level away from the apical foramen of hand instrumented specimens, especially when the step back technique was employed.

Iqbal *et al* 2003 demonstrated that different instrumentation sequences used with nickel titanium rotary instruments produced similar results with minimal apical transportation and loss of working length. Similarly, the amount of apical transportation noticed in the present study corresponds with the study conducted by Bryant *et al* 1998.

However, in the present study, an endodontic microscope was used to evaluate the presence of apical transportation instead of radiographs used in all the other studies. As expected, all sample teeth in the rotary-instrumented group were found to have remained centred during the preparations, while the 10% in the hand instrumented group that showed apical transportation would have made making complete obturation impossible in the clinical context.

These results correspond to those reported by other researchers such as Iqbal *et al* 2003, Jardine and Gulabivala 2000(a), Tan and Messer 2002, Sonntag, Delschen, Stachniss 2003.

In the study by Jardine and Gulabivala 2000(a), they suggested that the reason nickel titanium instruments cause less transportation than stainless steel K-files, when the same filing technique was used, may not only be due to the increased flexibility of the nickel titanium instruments, but rather to their decreased cutting ability.

They also noted that the curvature of the canal did not affect the outcome of the efficacy of both hand and rotary instruments and that the curvature of the root canals was maintained in all groups under investigation, that is, there was no visible canal transportation in all the groups that they examined. However, rotary nickel titanium files separated in the presence of acute curves in root canal topography or shape. Overall, the minor straightening or apical transportation that was observed in the present study is comparable with other investigations.

Two files in the S1 or shaping range of the ProTaper® nickel titanium rotary files separated and only one size 20 stainless steel K-file separated. This was in line with results found by several investigators. Li *et al* 2002, found that rotary instruments were susceptible to fracture especially the shapers, because they are more rigid and are therefore not able to engage curved canals without strain and distortion.

Shen *et al* 2006 also found that defects and distortions occurred with rotary files. They found that these defects occurred on ProTaper® files and the minimum number of times that these instruments can be safely used is related to the anatomy and the morphology of the treated tooth. In a study conducted by Schafer *et al* 2006, they found that during the preparation of 120 teeth, a total of 10 instruments (12%) separated probably as a result of instrument fatigue. It is therefore imperative that the operator should inspect each and every instrument prior to clinical use

In the study conducted by Schafer and Vlassis 2004, two ProTaper and three RaCe instruments out of ten sets fractured, similar to the findings in the present study.

In the study by Foschi *et al* 2004, the amount and the morphology of the smear layer, presence of pulpal and dentinal debris and the morphology of the inner dentinal walls were parameters they used for the evaluation of shaping and cleaning efficacy of rotary nickel titanium instruments.

According to Torabinejad *et al* 2002, all endodontic instrumentations create dentine debris and smear layer as a consequence of their action on root canal walls. They indicated that the so formed debris might be compacted along the entire root canal surface, thus increasing the risk for bacterial contamination with subsequent reduction in the adaptation of the sealer and Gutta-Percha.

Iqbal *et al* 2003, said that this debris might be compacted apically creating an apical plug that prevents complete filling of this important region. It was also noted that it was very important that endodontic instruments remove dentine and debris from all canal walls, rendering the walls free from any bacteria.

However, from the results obtained in the present study, it was shown that the apical aspect of all root canals especially those debrided using rotary instruments had large amounts of both debris and smear layer.

The results in table 5.II imply that by using only the barbed broach for the extirpation, a large amount of debris still remained in the middle and the apical thirds of the canal. In 80% of the specimen examined in this group and therefore this in no way can be the only method of debridement.

From table 5.III it is evident that between 35% and 49% of the canals in this group still had debris classified as moderate (score 3) in the middle and apical thirds of the canals and this would have impacted on the clinical success if only this method of debridement was used.

From table 5.IV, it is apparent that substantial debris (score 4) was present in the apical third of 75% of the canals debrided with the rotary technique implying that this method on its own is not very efficient in debriding the canal especially in the apical third of the root canal.

Figure 5.V illustrates that at least half the canals (50%) in the hand-instrumented group had a homogeneous smear layer (score 3) still present in the apical third of the canal and this will negatively impact on bonding and sealing of the root canal especially in the apical third.

From table 5.VI it is apparent that in this rotary-instrumented group the majority of the canals (82.5%) had a thick homogeneous smear layer covering the dentine surfaces (score 5) in the apical third of the canals and would make it difficult clinically to obtain a hermetic seal especially in this part of the root canal.

It can be clearly seen that the use of rotary instruments resulted in the formation of a large quantity of both smear layer and debris, as indicated by the high scores recorded

Scanning electron microscopic analysis demonstrated a substantial portion of the dentine surface in the coronal third to be free from smear layer. This corresponds to the findings of Ahlquist *et al* 2001. However the

SEM findings in the apical third of the canals instrumented with rotary instruments corresponds with previous scanning electron microscopic (SEM) studies by Ahlquist *et al* 2001, Schafer and Lohmann 2002, Versumer *et al* 2002, who also reported the presence of great amounts of smear layer after the use of nickel titanium rotary and stainless steel manual instruments in the apical third of the root canals.

It is likely that the nickel titanium rotary instruments produced fine dentine particles and shavings that were spread out and compacted along the dentine wall. Schafer *et al* 2006(b) concluded that the use of nickel titanium rotary files produced a clean and debris free dentine surface in the middle and coronal thirds; however, they were unable to produce a dentine surface free from smear layer and debris in the apical third of the root canal instrumented.

The reason for this difference in the debris-removal capability of these rotary instruments especially in the apical third but also in the rest of the root canal is probably due to the fact that the final apical preparation diameter of the ProTaper group of instruments was the size 30. It has been shown by Hulsmann *et al* 2003, that larger apical preparation sizes are necessary in many cases in order to contact as much of the circumference of the root canal as possible in the apical third of the canals to ensure optimal debridement in this critical area of the root canal

According to Ahlquist *et al* 2001, significantly less debris was found in the apical region when using the manual filing technique. This was found to correspond with the results of the present study. They (Ahlquist *et al*

2001) concluded that the manual technique employed in their study produced cleaner root canal walls than the rotary ProTaper® technique probably due to the tactile feel and the experience of the operator.

However, neither of the instrumentation techniques achieved total debridement of the root canal, with both debris and smear layer remaining on the dentinal walls of the canals especially in the apical third of the root canals. This was also found to be true in the present study.

In the present investigation, the two rotary instruments fractured occurred with instrument size 30 or S1 tip, and only one size 20 K-file as a result of fatigue. These results are in accordance with a previous study (Guelzow *et al* 2005), where the incidence of fractures was avoided with increasing file sizes, and with most fractures occurring with sizes 30 and 35.

AS regards the cleanliness of the canals these findings are in contrast with the regularly held belief, that because the apex is narrower, and the files should be engaging all the surfaces of the canal during debridement, this region should be the cleanest. However, the results obtained in this study corroborate with all the other studies conducted and show that the apical third is the least instrumented of all the areas of the root canal especially when using rotary instrumentation.

The weakness of the present study was that the SEM measurements for debris and smear layer were arbitrary as no standardization is available at this stage. The drying process resulted in crack formation; the badly cracked specimens could thus not be used. Only two teeth showed severe numbers of cracks and these were then discarded and replaced by two new slides. The sources of these cracks could not be clearly determined because the collection of the samples (teeth) was not standardized. The researcher did not specify to the dentists that the patient's ages should have been noted. It would have made the results more predictable if, for instance, the dentists were asked to collect teeth in the age group of patients between 20 and 30 years of age, which would have meant that the teeth would have been fairly young.

It could therefore not be ascertained with certainty what the main cause of the cracks was, whether the cracks were present preoperatively, during the experimentation or as a result of the drying process for SEM analysis. Also the reason for tooth loss was not determined; therefore the possibility of traumatic fracture could not be excluded.

The preoperative storage of these teeth was not specified in relation to the time required to place the extracted teeth in normal saline, where slight drying might have occurred if the practitioners delayed placing these teeth in the storage jars provided. The observed cracks resulted in the distortion in the smear layer, probably due to the shrinkage that took place during the drying process.

Ahlquist *et al* 2001, also used the desiccator for the drying of their specimens but they used platinum for specimen coating, however, Foschi *et al* 2004 used critical point drying for their specimens prior to gold sputter coating and these are alternatives that could be considered in future studies using SEM analysis

Using higher magnification such as those used in figures 5.15 and 5.16(X1000) tended to zone in on a small area, thus limiting the size of the surface area being analysed but provided detailed information as regards the canal wall status and the patency of the dentinal tubules. However this magnified view could not be used for debris and amount of smear layer analysis as it was too limited a portion of the canal wall.

In the present investigation, most of the instrument fracture occurred at the tips but these could be retrieved.

The amount of smear layer that remains after instrumenting with rotary instruments is larger when compared to that remaining in the hand instrumented samples.

In the present study, EDTA was not used because the aim of the study was to assess the clinical efficacy of two instrumentation methods. However, it is known that the use of EDTA removes most of the formed smear layer thus exposing the dentinal tubules as demonstrated by a study carried out by Ahlquist *et al* 2001. The application of EDTA is known to improve the adhesion of root canal sealers for final obturation.

CHAPTER 7

LIMITATIONS

The following limitations were identified in the present study.

- Cracking of teeth during the specimen preparation, and the aetiology of such cracks could not be established, as they could have occurred pre-operatively, during the debridement, as a result of the storage conditions, or during the drying process for SEM analysis.
- There is a narrow margin between the first two scores in the assessment of surface debris. There were no surfaces, which were completely debris free, however the amount varied slightly, therefore, to differentiate between a score of 1 and 2 was impossible and these should in future be combined into one score.
- All samples were first measured or studied using both low magnification (40) and higher magnification (1000). At lower magnification, all sites chosen were 1mm on the apical aspect of all the specimens. However, the higher magnification, tended to zoom in on a small or narrow field of study, thus limiting the correct assessment of root canal cleanliness as regards quantitative analysis but was very valuable for qualitative assessment of the canal walls and the patency of the dentinal tubules.
- The ProTaper files sequence is limited as compared to the K-files, where debridement was continued up to file size 50 and only a size 30 was used to reach the apex when using ProTaper.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Within the parameters of this study, it can be concluded that both hand instrumented and rotary-instrumented canals had evidence of debris and smear layer after debridement especially in the apical third of the canals. However hand instrumentation using K-files resulted in better cleanliness of the root canal compared to rotary instrumentation using ProTaper instruments. Both types of instrumentation techniques resulted in limited amounts of instrument separation and need to be carried out with care. ProTaper maintained the shape of the root canal more effectively compared to hand instruments that resulted in 10% of the canals showing evidence of apical transportation.

8.2 RECOMMENDATIONS

Based on the results of this study

- Care must be taken when using rotary or hand instruments for canal debridement to avoid the possibility of instrument separation
- Rotary instruments should not be used more than six times and must be diligently examined prior to utilization for signs of distortion, which can result in instrument separation.
- The results of this study show that neither hand instrumentation nor rotary instrumentation methods resulted in all areas of the

root canal which were completely clean and therefore the need for chemical debridement in addition to mechanical debridement to better prepare the canal for the obturation process.

- In the event of SEM analysis, critical point drying of specimen which is a completely controlled drying mechanism, instead of placing the samples in the desiccator to dry over a 48 hour period before sputter coating for SEM observations is recommended because some samples showed varying degrees of crack formation which cannot be accounted for and the specimens were therefore excluded from the present study.

APPENDIX I

DEBRIS

TOOTH	CORONAL	MIDDLE	APICAL
1 Control 1	3	2	4
2 Control 2	3	3	4
3 Control 3	3	3	3
4 Control 4	2	3	4
5 Control 5	2	3	4
6 Control 6	2	3	2
7 Control 7	3	3	2
8. Control 8	3	3	4
9 Control 9	3	3	4
10 Control 10	3	2	4
11 Hand 1	2	2	2
12 Hand 2	2	2	2
13 Hand 3	3	2	3
14 Hand 4	3	2	3
15 Hand 5	2	2	3
16 Hand 6	3	2	2
17 Hand 7	2	2	3
18 Hand 8	2	2	3
19 Hand 9	2	2	3
20 Hand 10	2	2	3
21 Hand 11	2	2	3
22 Hand 12	2	2	3

23 Hand 13	3	2	3
24 Hand 14	3	2	3
25 Hand 15	3	2	3
26 Hand 16	2	2	2
27 Hand 17	2	2	3
28 Hand 18	2	2	3
29 Hand 19	2	2	2
30 Hand 20	2	2	2
31 Hand 21	2	2	2
32 Hand 22	2	2	2
33 Hand 23	2	2	2
34 Hand 24	2	2	2
35 Hand 25	2	2	2
36 Hand 26	2	2	2
37 Hand 27	2	2	2
38 Hand 28	2	2	2
39 Hand 29	2	2	2
40 Hand 30	2	2	2
41 Hand 31	2	2	2
42 Hand 32	2	2	2
43 Hand 33	2	2	2
44 Hand 34	2	2	2
45 Hand 35	2	2	2
46 Hand 36	2	2	2
47 Hand 37	2	2	2
48 Hand 38	2	2	2
49 Hand 39	2	2	2

50 Hand 40	2	2	2
51 Rotary 1	2	2	4
52 Rotary 2	2	2	4
53 Rotary 3	3	2	4
54 Rotary 4	3	2	4
55 Rotary 5	2	2	4
56 Rotary 6	2	3	4
57 Rotary 7	2	2	4
58 Rotary 8	2	2	4
59 Rotary 9	2	2	4
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64 Rotary 14	3	3	4
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69 Rotary 19	2	3	4
70 Rotary 20	2	3	4
71 Rotary 21	3	3	4
72 Rotary22	3	3	4
73 Rotary23	3	3	4
74 Rotary 24	3	3	4
75 Rotary 25	2	3	3
76 Rotary 26	2	3	3

77 Rotary 27	2	2	4
78 Rotary 28	2	2	3
79 Rotary 29	2	3	4
80 Rotary 30	2	2	4
81 Rotary 31	2	2	2
82 Rotary 32	2	2	2
83 Rotary 33	2	2	4
84 Rotary 34	2	2	3
85 Rotary 35	2	2	4
86 Rotary 36	2	2	4
87 Rotary 37	2	2	3
88 Rotary 38	2	2	4
89 Rotary 39	2	2	4
90 Rotary 40	2	2	4

APPENDIX II

SMEAR LAYER

TOOTH	CORONAL	MIDDLE	APICAL
1 Manual 1	2	2	3
2 Manual 2	2	2	3
3 Manual 3	2	2	2
4 Manual 4	2	2	2
5 Manual 5	2	2	2
6 Manual 6	2	2	3
7 Manual 7	2	2	3
8 Manual 8	2	2	3
9 Manual 9	2	2	2
10 Manual 10	3	3	3
11 Manual 11	3	3	3
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14 Manual 14	2	2	3
15 Manual 15	2	2	3
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17 Manual 17	3	3	3
18 Manual 18	3	3	3
19 Manual 19	3	3	3
20 Manual20	3	3	3
21 Manual 21	3	3	3

22 Manual22	2	2	3
23 Manual23	2	2	3
24 Manual24	2	2	3
25 Manual25	2	2	2
26 Manual26	2	2	2
27 Manual27	2	2	2
28 Manual28	2	2	2
29 Manual29	2	2	2
30 Manual30	2	2	2
31 Manual 31	2	2	2
32 Manual32	2	2	2
33 Manual33	2	2	2
34 Manual34	2	2	2
35 Manual35	2	2	2
36 Manual36	2	2	2
37 Manual37	2	2	2
38 Manual38	2	2	2
39 Manual39	2	2	2
40 Manual40	2	2	2
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42 Rotary 2	2	3	5
43 Rotary 3	3	3	5
44 Rotary 4	3	2	5
45 Rotary 5	3	3	5
46 Rotary 6	2	3	5
47 Rotary 7	3	3	5
48 Rotary 8	3	3	5

49 Rotary 9	2	3	5
50 Rotary 10	2	3	5
51 Rotary 11	2	3	4
52 Rotary 12	2	2	5
53 Rotary 13	2	2	3
54 Rotary 14	2	2	4
55 Rotary 15	2	2	5
56 Rotary 16	2	2	5
57 Rotary 17	2	2	5
58 Rotary 18	2	2	5
59 Rotary 19	2	2	5
60 Rotary20	2	2	5
61 Rotary 21	2	2	5
62 Rotary 22	2	2	5
63 Rotary 23	2	2	5
64 Rotary 24	2	2	5
65 Rotary 25	2	2	4
66 Rotary 26	2	2	4
67 Rotary 27	2	2	5
68 Rotary 28	2	2	5
69 Rotary 29	2	2	5
70 Rotary 30	2	2	5
71 Rotary 31	2	2	5
72 Rotary 32	2	2	5
73 Rotary 33	2	2	5
74 Rotary 34	2	2	5
75 Rotary 35	2	2	5

76 Rotary 36	2	2	4
77 Rotary 37	2	2	4
78 Rotary 38	2	2	5
79 Rotary 39	2	2	5
80 Rotary 40	2	2	5

APPENDIX III

APICAL TRANSPORTATION

TOOTH	APICAL THIRD
1 Control 1	None
2 Control 2	None
3 Control 3	None
4 Control 4	None
5 Control 5	None
6 Control 6	None
7 Control 7	None
8 Control 8	None
9 Control 9	None
10 Control 10	None
11 Hand 1	None
12 Hand 2	None
13 Hand 3	None
14 Hand 4	None
15 Hand 5	None
16 Hand 6	None
17 Hand 7	None
18 Hand 8	None
19 Hand 9	None
20 Hand 10	None
21 Hand 11	None

22 Hand 12	None
23 Hand 13	None
24 Hand 14	None
25 Hand 15	None
26 Hand 16	None
27 Hand 17	None
28 Hand 18	None
29 Hand 19	None
30 Hand 20	Present
31 Hand 21	None
32 Hand 22	Present
33 Hand 23	None
34 Hand 24	Present
35 Hand 25	None
36 Hand 26	None
37 Hand 27	None
38 Hand 28	None
39 Hand 29	Present
40 Hand 30	None
41 Hand 31	None
42 Hand 32	None
43 Hand 33	None
44 Hand 34	None
45 Hand 35	None
46 Hand 36	None
47 Hand 37	None
48 Hand 38	None

49 Hand 39	None
50 Hand 40	None
51 Rotary 1	None
52 Rotary 2	None
53 Rotary 3	None
54 Rotary 4	None
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56 Rotary 6	None
57 Rotary 7	None
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60 Rotary 10	None
61 Rotary 11	None
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74 Rotary 24	None
75 Rotary 25	None

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77 Rotary 27	None
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81 Rotary 31	None
82 Rotary 32	None
83 Rotary 33	None
84 Rotary 34	None
85 Rotary 35	None
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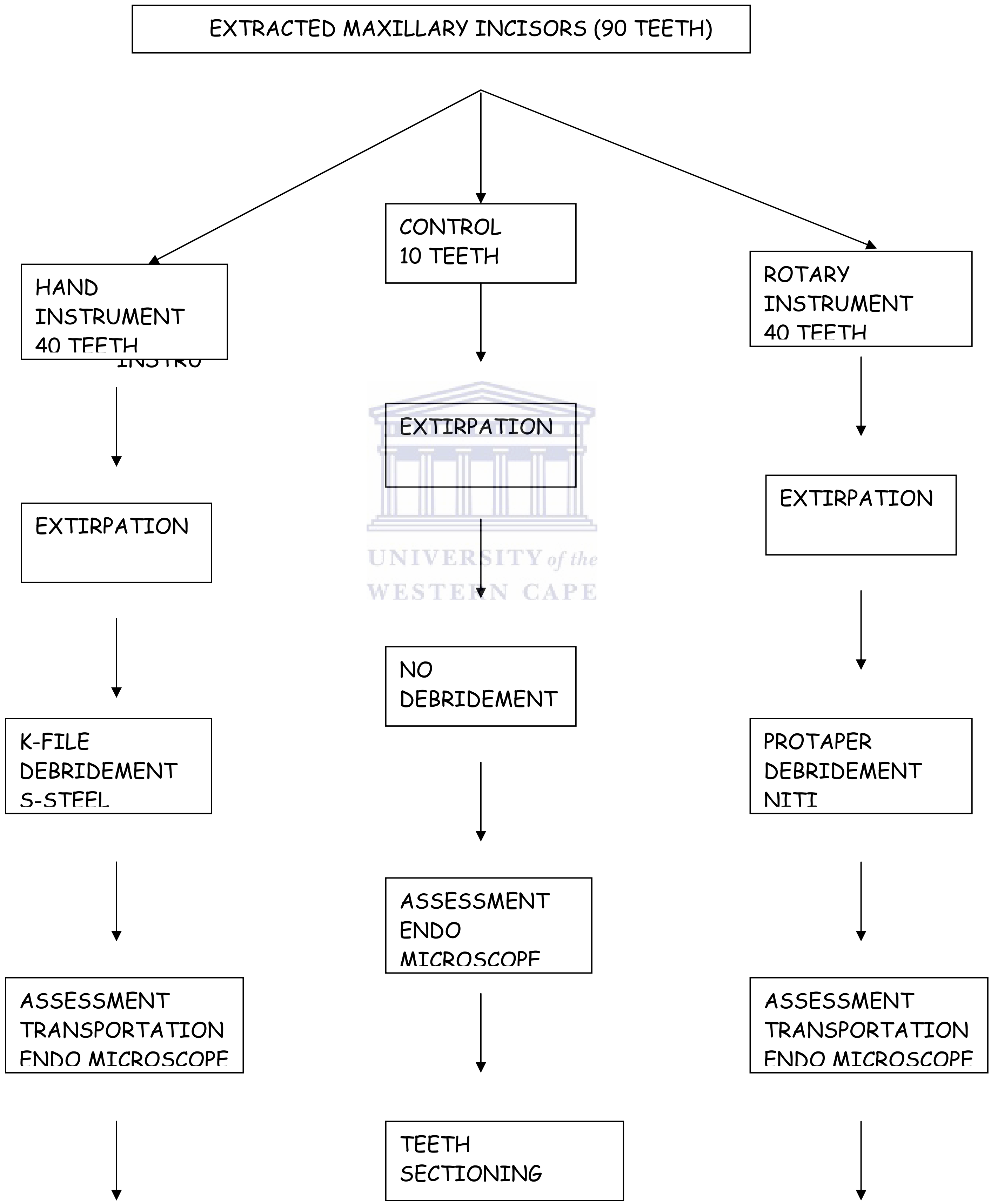
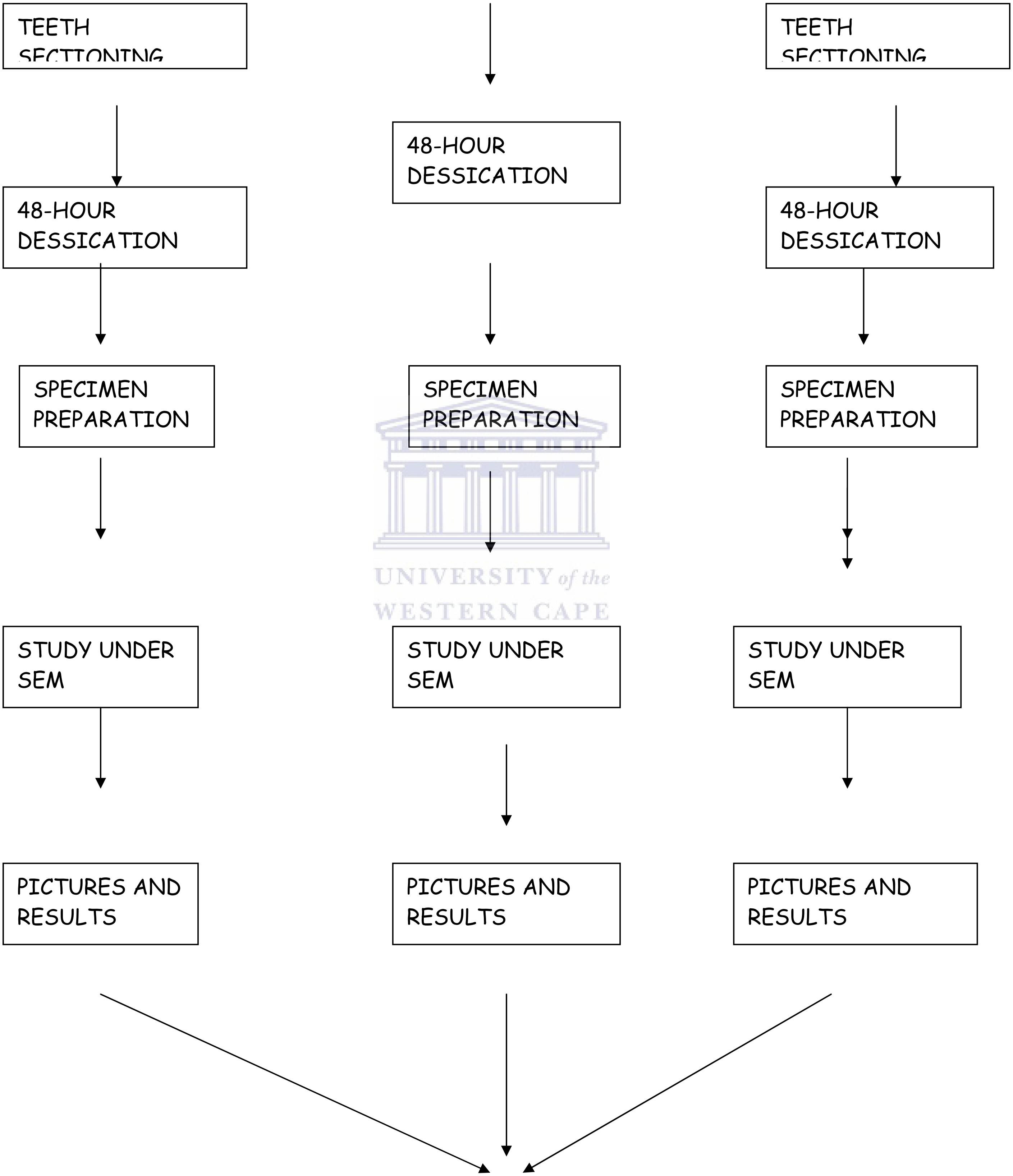
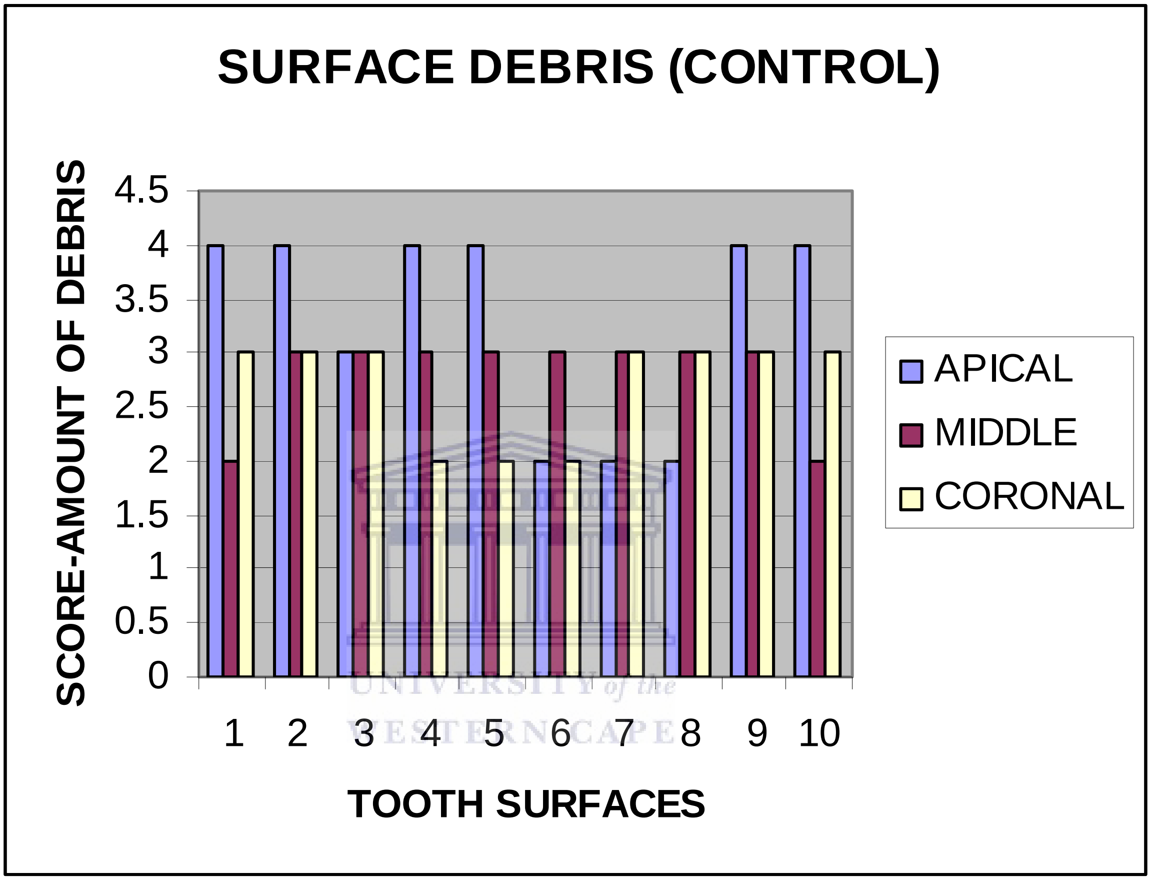
APPENDIX IV

FLOW CHART OF RESEARCH METHODOLOGY

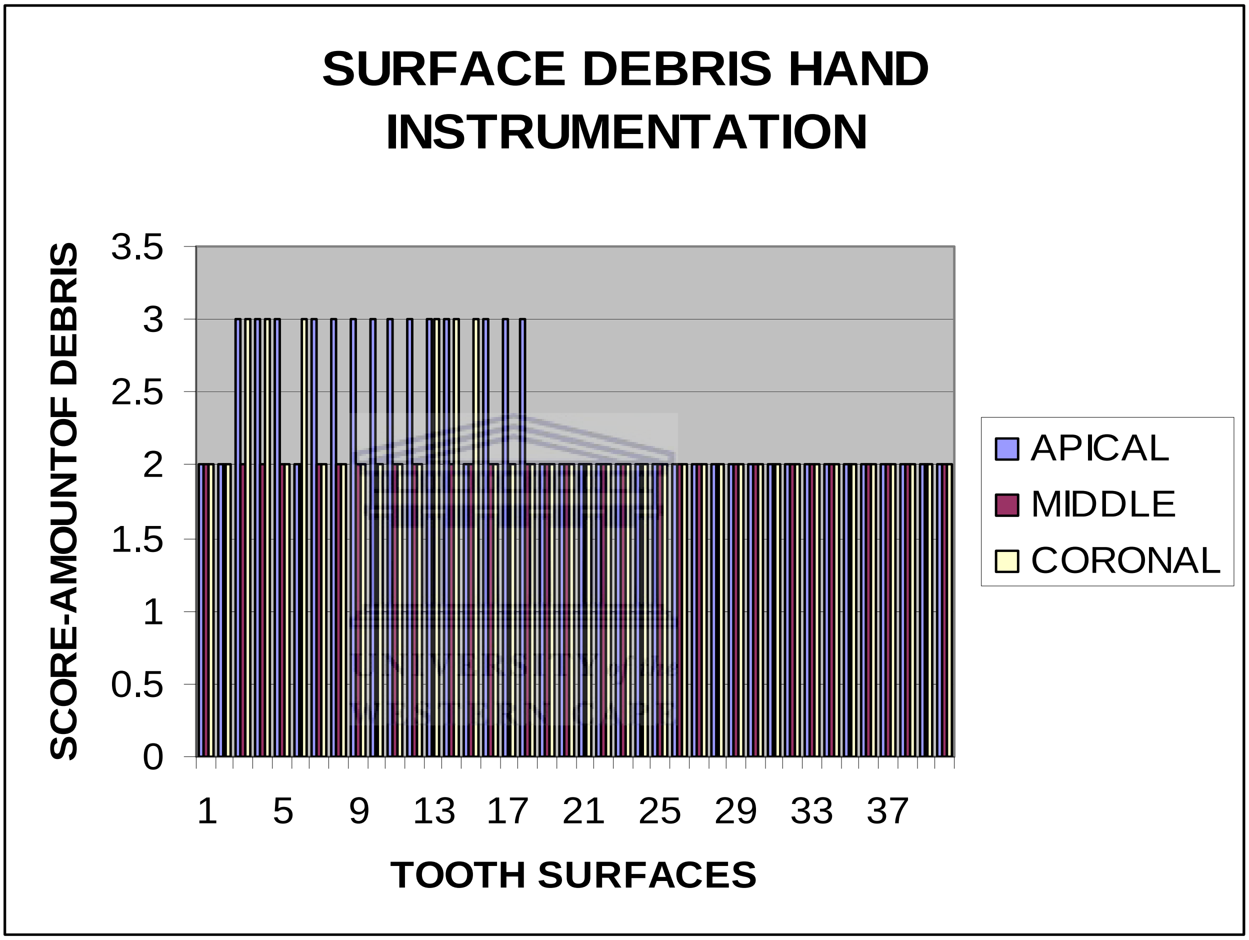



TEETH SECTIONING
48-HOUR DESSICATION
SPECIMEN PREPARATION
STUDY UNDER SEM
PICTURES AND RESULTS
TEETH SECTIONING
48-HOUR DESSICATION
SPECIMEN PREPARATION
STUDY UNDER SEM
PICTURES AND RESULTS
48-HOUR DESSICATION
SPECIMEN PREPARATION
STUDY UNDER SEM
PICTURES AND RESULTS

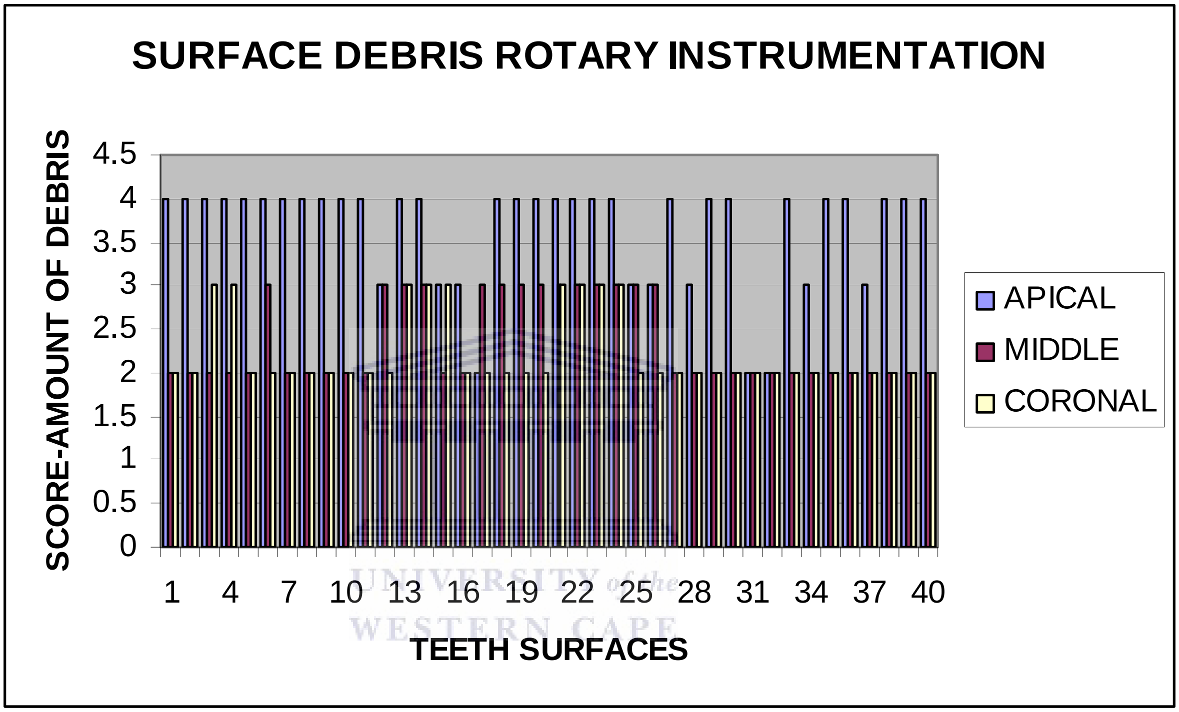
APPENDIX V


SURFACE DEBRIS (CONTROL)
SCORE-AMOUNT OF DEBRIS
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
TOOTH SURFACES
APICAL
MIDDLE
CORONAL

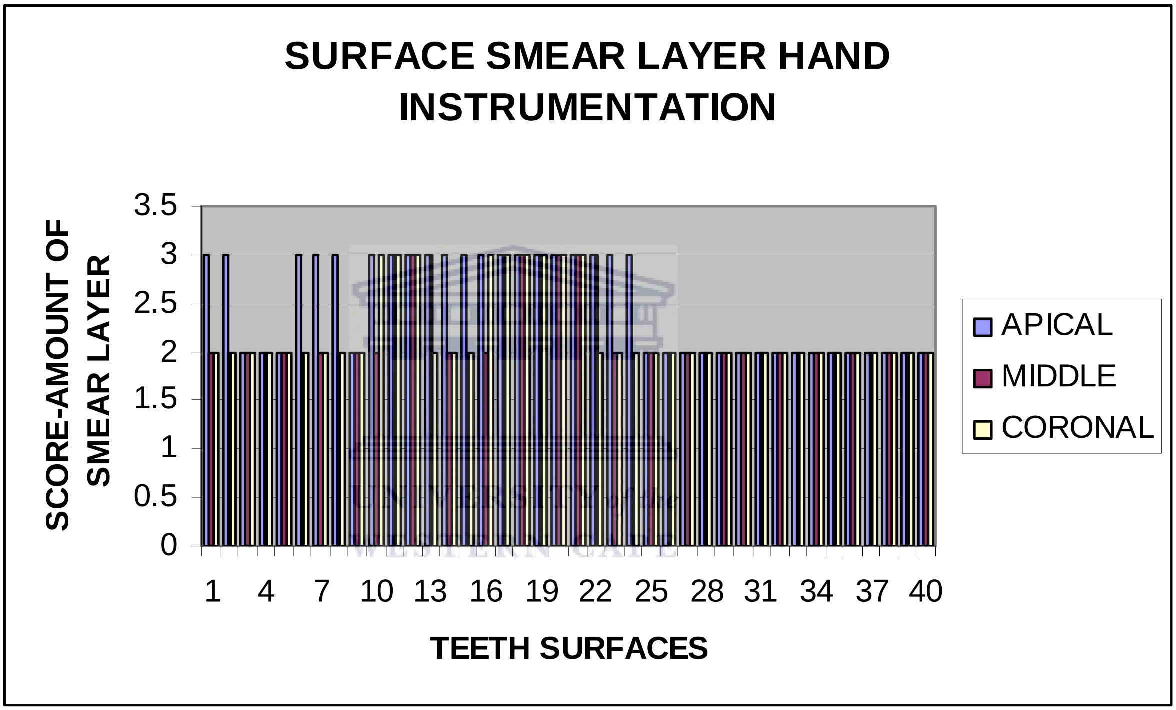
APPENDIX VI


SURFACE DEBRIS HAND INSTRUMENTATION
SCORE-AMOUNTOF DEBRIS
3.5
3
2.5
2
1.5
1
0.5
0
1
5
9
13
17
21
25
29
33
37
TOOTH SURFACES
APICAL
MIDDLE
CORONAL

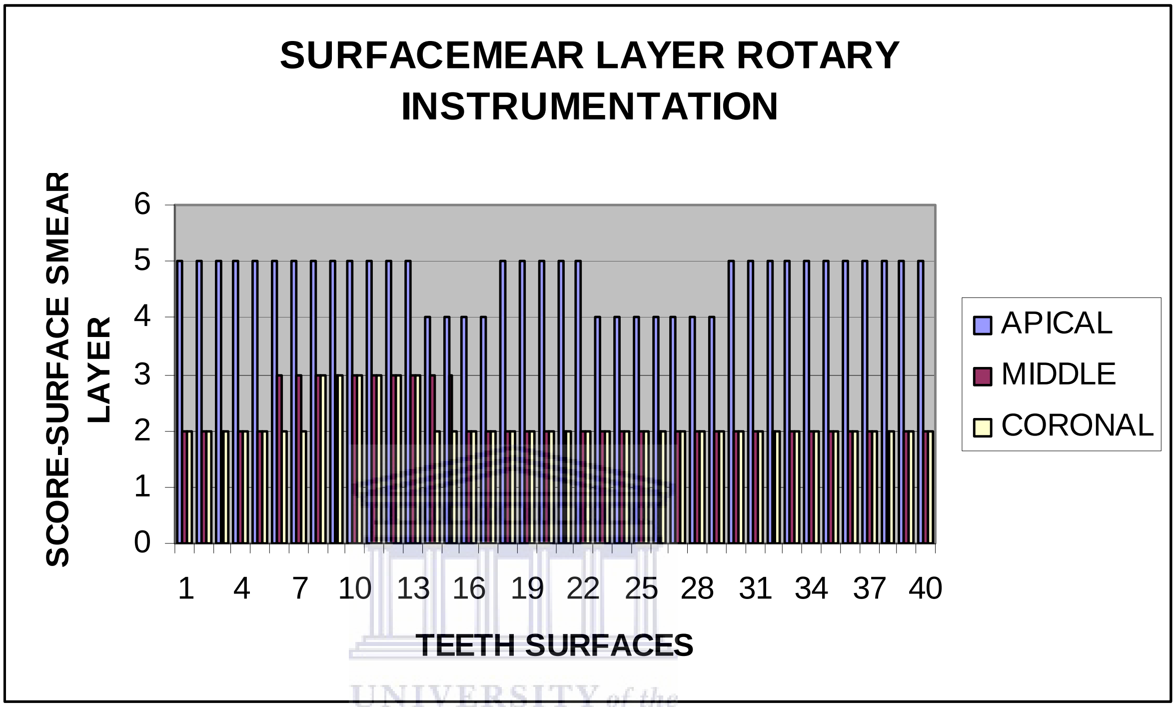
APPENDIX VII



APPENDIX VIII



APPENDIX IX


SURFACEMEAR LAYER ROTARY
INSTRUMENTATION
SCORE-SURFACE SMEAR
LAYER
0
1
2
3
4
5
6
1
4
7
10
13
16
19
22
25
28
31
34
37
40
TEETH SURFACES
APICAL
MIDDLE
CORONAL

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