Obturation of simulated lateral canals using heat and vibration techniques and the effect of irrigation methods

BY

MOE THAUK

Universiti Sains Malaysia

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DEDICATION

To Mom, Suu and my family

No support could ever compare to what I have received.

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SIGNED STATEMENT

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I gave consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Signature……………

Name: Dr. Moe Thauk

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ABSTRAK

Kajian ini bertujuan untuk menilai keberkesanan dua teknik obturasi vertikal panas dan tindakan tambahan dua kaedah irigasi dengan mengukur peratusan jarak penusukan getah perca kedalam kanal sisi buatan. Ia juga bertujuan untuk membuat perbandingan keberkesanan dua kaedah irigasi melalui penilaian lapisan lumur dengan menggunakan pemeriksaan SEM.

Sejumlah 140 gigi premolar mandibel kedua digunakan dalam kajian ini. Tiga kanal sisi buatan dibuat pada permukaan akar distal korona, bahagian tengah dan pada sepertiga apeks. Gigi-gigi kemudiannya dibahagikan kepada 4 kumpulan (G1, G2, G3 dan G4) (n=35). Kikir putar K3 digunakan untuk membuat persediaan kanal akar dengan menggunakan teknik ‘crown-down’. Irigasi untuk kumpulan G1 dan G2 dilakukan secara berselang seli menggunakan 5.25% NaOCl dan 17% EDTA secara berturut-turut menggunakan picagari irigasi. Prosedur yang sama juga dijalankan pada G3 dan G4, namun begitu untuk cucian terakhir, NaOCl diagitasikan menggunakan kikir putar berasaskan polimer. Kumpulan G1 dan G3 di obturatkan dengan sumber haba system B sahaja sementara itu G2 dan G4 di obturatkan dengan alat Downpack (haba dengan getaran). Gigi-gigi tersebut kemudiannya di radiograph secara bukolingual dan jarak kanal sisi dan jarak penusukan GP dalam kanal sisi diukur menggunakan perisian VixWin™ Pro 2000. Jarak penusukan GP kemudian ditukarkan kepada peratusan. Data dianalisis menggunakan ujian multifaktorial –ANOVA.

Bagi kajian SEM pula, tiga puluh dua mandibel premolar kedua digunakan. Gigi-gigi kemudian di bahagikan kepada dua iatu Kumpulan A dan Kumpulan B (n=16). Kanal akar disediakan menggunkana teknik ‘crown-down’ dengan kikir putar K3. Kaedah irigasi Kumpulan A sama dengan kaedah yang digunakan untuk G1 dan G2. Sementara itu, kaedah Kumpulan B pula sama dengan yang digunakan pada G3 dan G4. Selepas irigasi gigi-gigi tersebut dibelah membujur menggunakan disk intan. Bahagian korona, bahagian tengah dan sepertiga apeks permukaan akar kanal berdasarkan laluan ke kanal sisi kemudian diperiksa dengan SEM. Skor lapisan lumur pada fotomikrograf dinilai pada 1000X. Data kemudiannya dianalisis dengan ujian Mann-Whitney.

Min (SD) PGP pada sepertiga apeks kanal lateral adalah 44.90 (15.81)% dalam GI, 78.06 (4.50)% dalam G2, 44.10 (18.90)% dalam G3 dan bagi G4 adalah 80.41 (5.26)%. Dengan penggunaan alat Downpak pada sepertiga apeks, PGP adalah lebih tinggi dan signifikan (G1 vs G2, G3 vs G4) (p=0.01). Bagi aksi tambahan kaedah irigasi pula, min PGP tidak menunjukkan sebarang perbezaan signifikan dalam semua tahap kanal lateral antara semua kumpulan. Kajian SEM pula menunjukkan skor median (IQR) lapisan lumur pada aras sepertiga apeks adalah lebih rendah dan signifikan dalam Kumpulan B yang menggunakan kedua-dua pengairan dengan picagari dan kikir putar perasakan polimer [2.50(1.13)] berbanding Kumpulan A yang menggunakan pengairan dengan picagari sahaja [3.25(1.50)] (p<0.05).

Teknik getaran dengan haba didapati lebih berkesan berbanding teknik haba sahaja. Kaidah pengairan didapti tidak memudahkan obturasi kanal sisi. Pembuangan lapisan lumur adalah lebih berkesan apabila pengairan menggunakn picagari digandingkan bersama kikir berasaskan polimer.

Obturation of simulated lateral canals using heat and vibration techniques and the effect of irrigation methods

ABSTRACT

The aims of this study were (a) to evaluate the effectiveness of two warm vertical obturation techniques and the auxiliary action of two irrigation methods by measuring the percentage gutta-percha penetration (PGP) into the simulated lateral canals: (b) to compare the cleaning efficiency of two irrigation methods through the assessment of smear layer using SEM examination.

A total of 140 mandibular second premolars were used in this study. Three simulated lateral canals were crated at distal root surface; coronal, middle and apical third. The teeth were then divided into four groups (G1, G2, G3 and G4) (n= 35). Root canal preparation was done using K3 rotary file in crown-down technique. In G1 and G2 irrigation was performed by alternate use of 5.25% NaOCl and 17% EDTA respectively using irrigation syringe. The same procedure was performed for G3 and G4, but for final flush, NaOCl was agitated by polymer-based rotary file with rotation. G1 and G3 were obturated by using system B heat source (heat only). G2 and G4 were obturated using DownPak device (heat with vibration). Subsequently the teeth were radiographed bucco-lingually and the length of penetrated GP into the lateral canals was measured using VixWin™ Pro 2000 software. The length of GP penetration was transformed into percentage. The data were analyzed using multifactorial-ANOVA test. While SEM study, thirty-two mandibular second premolars were used. Teeth were divided into two groups as Group A and Group B (n=16). Root canals were prepared using crown-down

technique using K3 rotary file. The method used for Group A the same as G1 and G2 whereas for Group B the method was same as G2 and G4. After irrigation the teeth were split longitudinally using diamond disc. The coronal, middle and apical third levels of the root canal surfaces were then examined under SEM and taken photomicrographs. The smear layer scores were evaluated from the photomicrographs at 1000X. The data were analyzed using Mann-Whitney test.
canal surfaces were then examined under SEM and photomicrographs taken. The smear layer scores were evaluated from photomicrographs at 1000X. The data were analyzed by Mann-Whitney test.

Mean (SD) PGP at the apical third of the lateral canals was 44.90 (15.81)% in G1, 78.06 (4.50)% in G2, 44.10 (18.90)% in G3, and G4 80.41 (5.26)%. PGP at the apical third was significantly higher when DownPak device was used (G1 vs G2, G3 vs G4) (p=0.01). As for the auxiliary action of irrigation methods, no significant difference of mean PGP was found in all level of the lateral canals between the groups. SEM study revealed that the median (IQR) of smear layer score at the apical third level was significantly lower when both syringe irrigation and polymer-based rotary file was used [2.50 (1.13)] compared to syringe irrigation above [3.25 (1.50)] (p<0.05).

Within the limitation of this study, heat with vibration technique is found to be more efficient for the obturation of lateral canals compared to heat only technique. Irrigation methods do not facilitate lateral canal obturation. Polymer-based file coupled with syringe irrigation is more efficient than syringe irrigation in removal of smear layer.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The naturally retained tooth is recognized as the most excellent implant and the precisely performed root canal therapy (RCT) can save the retained tooth for long-lasting in the dental arch (Lost and Kieferheilkunde, 2006). The purpose of RCT is to prevent bacterial growth, penetration of tissue fluid and bacterial degrading products between the root canal and periapical tissues (Jarret *et al.*, 2004).

Root canal system has numerous branches and these branches communicate to the periodontium in furcally, laterally and often terminate apically into multiple exits. Any opening from the root canal system to the periodontal ligament space should be considered as a portal of exit and these exits can lead into persistent inter-radicular or secondary infections. Secondary infection is one of the major causes of RCT failure (Ruddle, 1992). The coronal leakage, apical leakage and portal of exits from accessory and lateral canal can lead to secondary infection (Hommez *et al.*, 2002). The study of De-Deus (1975) found lateral canals in 27% of 1140 teeth, whereas 17% of the teeth had these canals located in the apical third, 9% in the middle third and 2% in the coronal third. These small canals (100-150µm in diameter) additional to the main canals do not allow direct access during biomechanical preparation because of their position and also diameter (Venturi and Breshi, 2005). Lack of obturation of these accessory and lateral canals allows the communication between the main canal and the periodontium that can lead to spread of infection through the portal of exit. During obturation process all these canals should hermetically be sealed through their portal of exits.

Proper root canal filling should compact and completely be sealed three-dimensionally inside the entire root canal system (Dumsha and Gutmann, 2000). Gutta-percha (GP) is still used as a standard material for obturation and it can be used in various methods to obturate the root canal system (Nguyen, 1994). Warm GP can produce three-dimensional obturation of the canal space and heated moldable GP can easily be compacted and replaced into the original pulp anatomy of the entire pulp-less root canal (Schilder 2006). During obturation, heat can be carried to GP in various ways including flame or electrically heated carriers. Complete obturation of the root canal system with a dimensionally stable material is a fundamental procedure in conventional RCT.

Obturation using GP can generally be cold GP, heat-softened GP and solvent-softened GP (Dummer, 2004). On the other hand, the technique used to obturate root canal with GP mainly divided into lateral condensation and warm vertical compaction techniques. During warm GP obturation process, the heated soften GP is moved down into the root canal with vector of forces both apically and laterally.

In 1965, Dr. Schilder first introduced the warm vertical compaction technique (Schilder *et al.*, 1985). The objective is to fill all the portal of exits with maximum amount of GP. This technique used a set of pluggers for warm vertical compaction of GP and the plugger was used to transfer heat from a bunsen burner to the GP. Modifications to Schilder's technique have been advocated to improve its efficacy and efficiency. Buchanan introduced System B in 1996; the single continuous wave for warming GP in the canal. System B monitors temperature at the tip of heat carrier plugger to deliver a precise amount of heat and it was designed to fill the apical root canal system with a single continuous wave of thermo-plasticized GP (Buchanan, 1996). The other similar device prior to System B is Touch' N Heat 5004 (SybronEndo/Analytic, USA), an electronic device which was specially developed for the warm GP technique and this device was introduced in 1981 by Johan Masreillez of Analytic Technology. The Touch N' Heat electric heat carrier was intended to be faster, better and safer than flame-heated heat carriers. While flame-heated heat carriers required five to ten seconds to be adequately heated in a Bunsen burner flame, the Touch N' Heat required one-half second to reach desire temperature (Blum *et al.*, 1997).

Moreno (1977), first introduced the technique of plastizing GP in the canal using ultrasonic instrument. This method involved the softening of GP using frictional heat generated by introducing an ultrasonically activated file into the canal. Bailey *et al.* (2004) found that the Enac (Osada, Japan) ultrasonic device increased the density of the obturation heat derived from vibration. Although the spreader tip was considered an efficient way of delivering heat to GP for denser obturation, their study assumed the heat produce by ultrasonic activation can damage surrounding periodontal tissue.

DownPak (Hu-Friedy, Chicago, IL) handheld cordless unit was introduced in 2007. It utilizes both heat and vibration to compact and disperse GP into the root canal system. The main issue in a root canal treatment is to have a good compaction of filling material (Beer, 2006). Some studies stated that the difficulty of filling lateral canals especially at the apical root third of the canal portion when using vertical compaction method (Goldberg *et al.*, 2002; Joao *et al.*, 2007). During GP compacting process, the use of both heat and vibration can enhance more homogenous distribution of GP into all the space of root canal system for three-dimensional obturation. Heat associated with vibration not only produces better adaptation with the root canal walls, but also might improve the compaction of GP. Study by Wu *et al.* (2004) found that the highest score of filling material in the root canal using heat with vibration technique in straight canal. Their study has lead to interest in the evaluating of root canal in other form of root canal system. In vitro study using replica methods by Kulid *et al.* (2007) showed, warm vertical condensation of heat softened GP with heat and vibration technique gave better result than heat only technique to replicate the created inter-canal defects especially in coronal and middle segment of the canal. However, there was no significant difference result in the apical segments. As a conclusion, the study of Kulid also suggested that further investigation is needed to determine the obturation result in small diameter canals such as lateral canals.

Digital imaging technique was used to analyze the tracings of the obturated canal and it has been shown to be fast, precise and unbiased compared with other analogue techniques (Conover *et al.*, 1996). The digital X-ray systems offer the possibility of quantifying the distance between two points in a scaled-enlarged image (Cederberg *et al.*, 1998; Loushine *et al.*, 2001). This is the one of the major advantages of digital systems in endodontics. Furthermore, areas of interest were easily and accurately measured by using computer with specific software.

Although ideal obturation of the root canal system is widely accepted as a key factor for successful endodontic therapy, removal of smear layer can be considered as an essential step in successful RCT (Guerisoli *et al.*, 2002). Smear layer is an amorphous layer of muddy material which composed of organic and inorganic substances, and sometimes it includes bacteria. Smear layer is formed as a consequence of the instrumentation during root canal preparation (Sakae *et al.,* 1988; Gambarini, 2004). No smear layer is found on areas which are not instrumented (West *et al.,* 1994). Smear layer can give porous and weakly adherent interface between the obturation material and dentine, and removal of it improves the sealing ability of root canal (Sjogren *et al.,* 1990). Sometimes smear layer can be pushed into the dentinal tubules 0.5 to 1mm during instrumentation and it will form a smear plug in the tubules that reduces dentine permeability up to 78% (Zivkovic *et al.,* 2005). This layer is acid soluble and can be dissolved by fluids with pH between 6.0 and 6.8 (Hulsmann *et al.,* 2003). A correct choice of two or more irrigants is fundamental to enhance the cleaning effect of root canal system. The most effective method to remove smear layer is using EDTA (Ethylene diamine tetra acetic acid) in combination with NaOCl (Ruddle, 2006).

During irrigation process, the irrigation solutions must be in direct contact with all intricacies of the root canal surfaces for effective action (Clark-Holke *et al.,* 2003). Due to the small diameter of root canal, it is often difficult for the irrigation solutions to reach the apex of the tooth. The microorganisms which remain in the apical portion of the root canal have been considered as the main cause of RCT failure (Nair *et al.,* 1990).The cleaning ability of root canal can be assisted by micro-streaming action of solution by effect of sonic or ultrasonic instrumentation against solution (Walmsley *et al.,* 1992). However, using of ultrasonic file for irrigation has some disadvantages. It is time consuming, high cost, damage the finished preparation, possibility to breakage of instrument in the canal, perforation of root and unwanted volume of solution that can cause over instrumentation into the periodontium and spill over to oral mucosa (Bahcall, 2000). Moreover, ultrasonic irrigation has much higher velocity and volume of irrigant flow created in the canal. Two hundred milliliters of irrigant was applied during three minutes of ultrasonic irrigation, as against 50ml of irrigant during seven minutes of syringe irrigation (Lui *et al.*, 2007).

The new endodontic polymer-based non-ultrasonic rotary file (Plastic Endo LLC, Lincolnshire, IL) has been introduced in 2008 and its rotation will remove the dentinal debris by agitating of irrigation solution instead of using ultrasonic filing. Rotation of the file with 600-900rpm will produce streaming action of irrigation solution. The action of NaOCl is potentiated by agitation during irrigation (Al-Kilani *et al.*, 2003). However, no studies have been found on cleansing efficiency of this rotary file on root canal surface. Smear layer removing still remains a controversial issue and many other bio-mechanical factors may affect the outcome of root canal treatment. The effect of irrigating solutions and irrigation methods appear more critical than instrumentation techniques (Bertrand *et al.*, 1999).

Introduction of scanning electron microscope (SEM) has proved to be a valuable method for assessment of the ability of the endodontic procedures to remove smear layer from root canal systems (McComb and Smith, 1975). Consequently, this assessment is valuable for comparison of irrigation methods for canal surface cleansing action. Therefore, studies have been carried out to access the degree of cleanliness of smear layer removal from the root canal system by using SEM (Bertrand *et al.*, 1999; Gambarini, 2004).

1.2. Statement of the problem

Inadequate sealing of the accessory and lateral canals is one of the most important causes of root canal treatment failure (Canalda-Sahli *et al.*, 1992). For vertical compaction, different endodontic heating systems have been introduced to ensure correct heating of the GP cones after their placement within the instrumented root canals. Warm vertical condensation is in order to obtain the correct pressure of the warm and soft GP to allow the homogenous distribution of the filling into main and accessory canals. The effect of vibration to GP compaction is still questionable. Many previous studies have been done on obturation efficiency of heat only and heat with vibration on main canal only but not much information on obturation of lateral canals (Pagavino *et al.*, 2006; Kulid *et al.*, 2007).

Moreover, no studies have been found on the efficacy of warm vertical obturation methods in lateral canals between heats only and heat with vibration techniques and these systems need to be evaluated further.

Additionally, the selection of effective irrigation method is paramount for a satisfactory final outcome of root canal treatment. Agitation of irrigation solution can remove more debris from root canal (Al-Kilani *et al.*, 2003). Since the polymer-based rotary file is a new device for micro-streaming (Plastic Endo, 2008), there is no direct study found on the result of this file on canal cleansing action.

1.3. Justification of the study

This study will show the efficacy of heat only and heat with vibration technique on warm vertical condensation obturation methods into artificial lateral canals. As far as we are concerned, there is no published study focused on comparison of heat only and heat with vibration on the lateral canal within the range of our finding.

This study will also show the efficacy of two different irrigation methods; one is using irrigation syringe and the other using polymer-based rotary file for fluid agitation. At present there are no studies that evaluate on the micro-streaming of using polymer-based rotary files for the cleaning effectiveness of prepared root canal surfaces as an irrigation method.

The finding of this study will clarify the efficiency of heat only and heat with vibration techniques coupled with the impact of two irrigation methods.

CHAPTER TWO

LITERATURE REVIEW

2.1 RCT or Endodontic

In the early part of the 20th century, when problem arises from the tooth or the dental pulp was injured, the only accepted treatment was extraction. However, beginning in the late 1950's teeth with infection or injured dental pulp was being successfully treated using a procedure called endodontics or root canal therapy (RCT). Early 1960's were important years of transition and changes in endodontics treatment, this improvement had made up our endodontic treatment in this present day (Glenner, 2000).

In RCT, the diseased or pulp of the tooth is removed and the canal systems are filled and sealed with inert materials. The main aim of endodontic therapy is to preserve and maintain the diseased tooth and restore the tooth which failed in the previous endodontic therapy. These purposes are to allow the tooth to remain functional in the dental arch as its naturally retained (Garg and Garg, 2008).

There are numerous reasons why endodontics does not work which probably due to poor instrumentation, inadequate obturation, missed or unfilled accessory canals (Chohayeb, 1992; Bergenholtz, 2006). Regardless of the way endodontic treatment procedures are completed, the objectives have remained the same. The purposes of cleaned, filled and sealed the prepared root canal space are to eliminate all possible leakage from the oral cavity (mainly coronal leakage) and periradicular tissues into the root canal system, and to seal any irritants that cannot be fully removed during the cleaning and shaping procedures (Peterson, 2002). These objectives indicate the microbial irritants and pulp tissue degeneration products as a prime cause of root canal contamination and failure to remove these factors can lead continual irritation and subsequently failure of RCT (Gutmann and Witherspoon, 2002).

Theoretically, perfect RCT can save the teeth with 95% success rate but failures of treatments still exist in daily practices (Tronstad, 2003). Moreover, failure is an important factor to explain clearly either short period or long period after treatment. Most of the results might be evaluated 6 months to 1 year only after treatment. Cailleteau and Mullaney (1997) stated that the actual long-term success rate of endodontic therapy probably less than 90 %, however the records of the patients' history of RCT should be clearified whether it was done within 1 to 2 years or 20 years ago. The survey study of Eckerbom *et al.* (2007) verified that almost 30% of the root canal treated teeth were lost whilst the corresponding figure for the teeth without root fillings was lost only 10%. That means a root canal treated tooth had a three times greater risk of being lost during this 20-year period and 76.1% of the teeth with apical periodontitis were associated with previous RCT. Endodontic re-treatment, apical surgery and extractions of the teeth are consequences of the endodontic treatment failure (Abrams and Samual, 1995; Bradford and Johnson, 1999). Nevertheless, studies have shown that successful outcome in endodontic treatment essentially depends on: cleaning and shaping, disinfection and three-dimensional obturation of the root canal system (Buchanan, 1996; Ruddle, 2002; Schilder, 2006).

2.2 Root canal anatomy

2.2.1 Root canal system

The root canal system has an extremely complex anatomy, characterized by the presence of curvatures, fins, webs, accessory and lateral canals, and deltas (Tronstad, 2003). Root canals extend the length of the root, beginning as a funneled orifice and exiting as an apical foramen (Walton and Vertucci, 2002). Most of the root canal system have additional canals from the main canal and may have some varieties of canal configuration. Numerous studies have shown that lateral canals are present in a significant percentage of the teeth (De-Deus, 1975; Ng *et al.*, 2001; Venturi *et al.*, 2003). The pulpal and periodontal tissues not only maintain connection through the apical foramina but also through accessory and lateral canals.

2.2.2 Root canal system and its portal of exits

Accessory canals are usually branches of the main canal and these canals mainly exist somewhere in the apical region and form as portal of exits (POE). Each POE along the root surface is biologically significant; this includes bifurcations, trifurcations, as well as canals exiting at the base of infra-bony pockets and apical termini. The lesions of endodontic (LEOs) are formed due to pulpal breakdown and these LEOs are always situated adjacent to the POE (Ruddle, 2002). Therefore, the cleaning and subsequent obturation of these portals of exit is essential for biologic endodontic success (Glassman, 2002). Satisfactory diagnosis and treatment of these LEOs reveal the inter-relationships between pulpal disease flow and the egress of irritants along the complex root canal system (Sundqvist *et al*., 1998).

2.2.3 Lateral or accessory canals

The pulpal and periodontal tissue not only maintain connection through the apical foramina but also through the accessory canals which may be located at any level along the canal and these canals do form an exit (Peters and Wesselink, 2002). The accessory canals open approximately at right angle to the main pulp cavity, are termed “lateral canals” and may be present anywhere on a root surface (Nair *et al.*, 1990).

Harrinton and Steiner (2002) stated that estimation of the presence of lateral or accessory canals is about 30% to 40% of teeth and the majority is located in the apical third of the root. These anomalous openings are presumed to be caused by localized failure in the formation of Hertwig's root sheath, with a consequent lack of odontoblast differentiation and dentine formation. At this point pulp remains in contact with follicular or periodontal tissues since the gap in Hertwig's sheath is probably produced by the persistence of abnormally placed blood vessels reaching the pulp (Scott and Symons, 1977).

Most of the accessory canals can be visible at 120X magnification whereas the dentinal tubules can be visible at higher magnification of 1200X (Kumar, 2009). The mild trauma to the teeth during development of the root apex may cause disturbance or breakage in the continuity of the Hertwig’s root sheath that can lead to the formation of many accessory canals at the level of apical third (Berkovitz *et al.*, 1992). Villigas *et al.* (2002) found that 99% of the accessory canals were within the apical 3mm level with the diameter of less than 0.1mm. Venturi *et al.* (2003) also found 308 lateral canals in 30 roots, most of them located at the apical third level of the roots. The diameters of the lateral canals less than 0.15mm (150 µm) were reported in the furcal area (Vertucci and Beatty, 1986). On the mandibular incisors it has been observed that 30.7% lateral branches had thickness less than a number 10 reamer, 22.7% similar to number 15 reamer, and very few were larger than number 20 reamer (Mayashita *et al.*, 1997). In the pulpless teeth bacteria and necrotic tissue debris contained in accessory and lateral canals are difficult to be removed by instrumentation and irrigation. Thus in this case, three-dimensional obturation of the root canal system becomes extremely important (Walmsley *et al.*, 1992). Some studies revealed that incomplete filling of lateral canals can cause failure of endodontic treatment, as these empty passages represent pathways for bacteria and diffusion of toxins between endodontic and periodontal tissues. On the other hand, complete healing of LEOs after endodontic retreatment with perfect obturation is one of the proofs for endodontic success due to complete sealing of the lateral canals (Cohn, 2005; Friedman, 2005).

2.3 Biomechanical canal preparation

2.3.1 Objectives

The primary aim of biomechanical canal preparation is the elimination of contamination (damaged pulp tissue, necrotic debris, infected dentine, bacteria and their degradation products) in the root canal system and directly toward shaping the canal to achieve the biological objectives and to facilitate placement of a high quality root filling (Young *et al.*, 2007). Furthermore, the mechanical objectives for successful cleaning and shaping are: the root canal preparation should develop a continuously tapering cone (to mimic the natural canal shape), making the preparation in multiple planes which introduces the concept of flow (to preserve the natural curve of the canal), making the canal narrower apically and widest coronally (to create a continuous tapers up to apical third which creates the resistance form to hold gutta-percha in the canal) and avoid transportation of the foramen and keep the apical opening as small as possible (Schilder, 2006).

Before the completion of obturation procedure, the operator must first shape and clean the canal with the objectives of three-dimensional obturation in mind (Ruddle, 2002). The shaping procedure removes the restrictive dentine from the canal system and creates a smooth, tapered opening to the terminus. The removal of restrictive dentine during shaping facilitates to get better pathway for obturation and it allows effective volume of irrigants and instruments to work deeper and more quickly into the entire root canal system. Consequently, canal shaping is critical for both effective cleaning and three-dimensional obturations of RCT (Rhodes, 2006). Consistently production of optimal shape will continuously develop well-obturated canals and become the foundation in a clinician's endodontic success (Dummer, 2004).

2.3.2 Preparation techniques

Basically, there are two approaches used for biomechanical preparation as mentioned below (Dumsha and Gutmann, 2000).

2.3.2.1 Step back technique

Usually, preparation starts at working length of the apex with fine instruments and continue up to the orifice with progressively larger instruments. Hand instruments such as reamers, file (K file, Hedstrom file and ultrasonic file) are used to enlarge the canals.

2.3.2.1.1 Balanced force technique

An excellent technique for hand preparation of curved canals, should results in minimal canal transportation. Essentially a specific sequence of clockwise, counterclockwise rotations (reaming actions) using hand files. Balanced force is not used as a stand-alone preparation method and another technique, such as step back technique is followed after balance force.

2.3.2.2 Crown down technique

In this technique, preparation starts from the coronal portion with larger instrument and continuity to the apex with smaller instruments. Nickel-Titanium rotary or hand files are used to enlarge the canals in this technique.

2.4 Rotary files for Crown down preparation

2.4.1 Nickel-tiatnium rotary files for root canal preparation

Rotary nickel–titanium (Ni-Ti) instruments are known for their efficient preparation of the root canals (Glosson *et al.,* 1995). This is mainly due to the super-elasticity of the Ni-Ti alloy. The properties of Ni-Ti alloy gives an increased flexibility that allows the instruments to efficiently follow the original path of the root canal especially with new design features such as varying tapers, non-cutting safety tips and varying length of cutting blades in new generation of instruments (Thompson, 2000). During the root canals shaping, the complications such as ledging, apical zipping, blockage and perforations, all inherent in stainless steel hand instrumentation techniques, were responsible for adversely affecting the long-term outcome of many endodontic treatments (Frederic and Kenneth, 2002).

The introduction of Ni-Ti instruments for root canal instrumentation prevented these iatrogenic problems (Himel and Levitan, 2003). Ni-Ti rotary files have been shown to reduce the physical stress of endodontic therapy (pressure-less technique) and to optimize the shaping of the root canal system. The overall quality of the completed endodontic case is significantly improved as complications such as transportation, ledging and zipping can virtually be eliminated. However, file breakage and inefficient cutting become some of the drawbacks of previously available systems (Bahchall, 2000). When choosing among the available Ni-Ti rotary systems, the clinician will need to decide which feature designs and protocols are suitable and best fit their shaping and cleaning pattern (Himel and Levitan, 2003). Protaper, GT files, twisted files and K3 files are some examples of the Ni-Ti rotary instruments.

2.4.2 K3™ rotary system

The K3™ rotary file system was introduced in January 2002 at North America, designed by Dr. John McSpadden. The files are available with a fixed taper of 0.02, 0.04 or 0.06. The 0.02 tapered K3 files are available in 15-45 tip sizes and 21, 25 and 30mm lengths, the 0.04 and 0.06 tapered K3 files are available in 15-60 tip sizes and 21, 25 and 30mm lengths with a slightly positive rake angle (Elham *et al.*, 2006). The K3 Ni-Ti rotary system represents a significant advance in safety and effectiveness over other currently available systems. K3 Ni-Ti rotary file possesses a non-cutting tip, which is safer with regard to minimizing procedural errors, such as ledging, transportation and apical perforation. It also has triple and asymmetrical radical lands of unequal width and unequal flute width and depth that aid in avoiding the file from screwing into the canal (Frederic and Kenneth, 2002). Additionally, non-cutting tipped rotary files also possess radial lands which will stay centered within the canal and thus minimize or prevent canal transportation (Melo *et al.*, 2002).

Although all rotary files have the ability to enter and enlarge calcified root canal, there are a few potential problems associated with it's used, such as inadvertent instrumentation through the apical foramen that will deform and tear foramen morphology and compromising the quality of the obturation (Ayar and Love, 2004).

2.5. Smear layer

2.5.1 What is smear layer?

Smear layer is consequently generated by any instrument utilized to cut or sand the dentin (Hulsmann *et al.*, 2003). According to the American Association of Endodontics (1994), smear layer is a surface film of debris retained on dentine after instrumentation and consists of dentine particles, remnants of vital or necrotic pulp tissue, bacterial components and retained irrigants. This thin layer occludes dentinal tubules and covers inter tubular dentine of prepared root canal surfaces. It has negative influence on the sealing ability of obturated canals because of its weakly adherent interface between the obturation material and the dentine wall (Gulabivala *et al.*, 2005). The removal of debris and smear layer from the root canal system prior to obturation is one of the primary aims of endodontic treatment (Abbott *et al.*, 1991).

2.5.2 Removal of smear layer

Sodium hypochlorite (NaOCl) solution is used as the main irrigation agent for removing the organic component (pulp tissues) because of their bactericidal effect and capacity to dissolve organic matter and necrotic tissue. However, its action does not affect to inorganic material such as dentinal debris (Zehnder *et al.*, 2002).

Some studies relate the presence or absence of smear layer and success of endodontic therapy (Dautel-Morazin *et al.*, 1994; Sen *et al.*, 1995). Ciucchi *et al.* (1989) and Moraes and Silva (2005) stated that the larger difficulty of cleansing of root canal walls were at the apical third. According to the Peters and Barbakow (2000) neither technique was superior in removing debris, but larger canal preparations obtained in their study with low-speed instruments enabled a more effective removal of the smear layer in the EDTA-NaOCl group.

Gambarini (2004) demonstrated that NaOCl in combination with SmearClear (SybronEndo, Orange, CA) obtained best overall result on the radicular surface among others irrigation regime. Moraes *et al.* (2004) found that there are no difference results between combination uses of irrigation solution (1% NaOCl with trisodium EDTA; 2% chlorhexidine gel with saline solution; cream Endo Dakin's solution with Tergentol-Furacin; File-Eze with 1% NaOCl). However a study also stated that the unwanted effect of using rotary instrumentation for canal shaping produces heavy amount of slurry that formed as smear layer (Perez-Heredia *et al.*, 2008). The components of inorganic and organic material such as dentine filings and pulp tissue remnants, coagulated proteins, saliva, blood cells, bacteria and fungi in infected canals can lead to failure of tight sealed root canal system (Zivkovic *et al.*, 2005). Moreover, this layer could block dentinal tubules orifice and may therefore protect bacteria in root dentine from antimicrobial agents (Naaman *et al.*, 2007). Smear layer degradation by proteolytic bacteria enzymes leads to the formation of hollow spaces between the root canal filling material and the root canal wall, which might allow microleakage (Meryon and Brook, 1990). The presence or absence of smear layer is still controversial and different endodontic procedures may produce different morphology of smear layer. The possible role of smear layer is preventing lateral canals sealing, apical sealing, and bacterial contamination of dentinal tubules. The design of instrument and method of application, type of irrigation method and type of irrigant may affect the removal of smear layer (Prati *et al.*, 2004). On the other hand, the smear layer could also prevent or delay diffusion of irrigants and medicaments into dentinal tubules and reduce the sealing ability of obturation materials (Torabinejad *et al.*, 2002).

2.6 Root canal Irrigation

2.6.1 Back ground of irrigation

During cleaning and shaping of the root canal system, it is impossible to shape and clean the root canal completely as the nature of root canal anatomy is very complex (Ingle *et al.*, 1994; Jardine and Gulabivala, 2000). A study stated that no mechanical instrumentation can completely reach into the entire root canal surface because of its complex anatomy and the only clinical performances that can reduce bacterial colonization are irrigants and filling materials (Siqueira and Lopes, 2001). Likewise, the Ni-Ti rotary instruments currently available only act on the lumen of the canals and leaving canal fins, isthmus, and set of the webs untouched after completion of preparation (Elham *et al.*, 2006). Root canal irrigation is necessary to clean these instrument untouched areas, an important factor for effective chemo-mechanical preparation. It enhances bacterial elimination, not only facilitates the removal of necrotic tissue and dentine chips from the root canal but also can prevent packing of the infected hard and soft tissue apically in the root canal and into the periapical area (Regan and Gutmann, 2004).

2.6.2 The objectives of irrigation

The objectives of irrigation are to eliminate microorganisms, flush out debris, lubricate root canal instruments and dissolve organic debris (Lost *et al.*, 2006). According to Harrison (1984), an ideal root canal irrigant should be biologically compatible, chemically able to remove both organic and inorganic substances, be antibacterial, have good surface wetting, have no adverse effects on remaining tooth structure, and be easy to use and effective within clinical parameters. Commonly used irrigants in endodontic treatment includes sodium hypochlorite, iodine solutions, chlorhexidine gluconate, Ethylene-Diamine-Tetra-Acetic acid (EDTA), mixture of tetracycline and disinfectant (MTAD), electrochemically activated water, photo-activated disinfection (PAD), Ozone and Endox (Hegde and Singh, 2006). However, there are no ideal irrigants that can fulfill all necessities after modification, such as lowering the pH in the study of Hulsmann *et al.* (2003), increasing the temperature in the study of Haapasalo *et al.* (2005) and adding of surfactants to increase the wetting ability of the solutions in the study of De-Deus *et al.* (2008). Irrigation process during cleaning of the root canal provides an opening for three-dimensional obturation for long-term success of treatment (Ruddle, 2008). The effective chemo-mechanical debridement can reduce the bacterial load in the root canal system and promote periapical healing about 80% of cases (Sjogren *et al.*, 1990). Interestingly, study by Nair *et al.* (1990) reported that tight-sealed obturation be able to heal the periapical lesions even if the apical bacterial biofilm exists in 88%.

2.6.3 Sodium Hypochloride (NaOCl) as an irrigation solution

The intracanal reagents selected and their sequences of use are significant factors that influence cleaning of the canal surface. NaOCl is the most widely used irrigant that can potentially destroy spores, viruses and bacteria, and importantly, has been shown to digest vital and necrotic pulp tissue from all aspects of the root canal system (Sakae *et al.,* 1988). In water, NaOCl ionizes to produce Na^+ and hypochlorite ion, OCl^-, which establishes equilibrium with hypochlorous acid (HClO). Between pH 4 and 7, chlorine exists predominantly as HClO, the active substance, whereas above pH 9, OCl^- predominates (Sundqvist and Figdor, 2003). Hypochlorous acid has long been considered as the active substance responsible for bacterial inactivation by chlorine-releasing agents, the OCl^- ion having a minute effect compared with undissolved HOCl (Bergenholtz, 2006). This correlates with the observation that the activity of NaOCl is greatest when the percentage of undissolved HOCl is highest (Sundqvist, 2003). Hypochloric acid has been found to disrupt oxidative phosphorylation and other membrane-associated activities (Bergenholtz, 2006). It has also been indicated that DNA synthesis of bacteria is sensitive to HOCl (Haapasalo *et al.,* 2005). Despite the experimental variables inherent in the studies mentioned, it may be concluded that NaOCl is efficient at debris removal in thecoronal and middle thirds of root canals but fails to disperse the smear layer and plugs from dentinal tubules (Moodnik *et al.,* 1976). Zehnder *et al*. (2005) also stated combination of NaOCl with surface tension reduced chelation agent could not clean the apical region of the root canal. In addition, the challenge of debridement of the apical anatomy has not been fully resolved (Ruddle, 2008).

2.6.4 The Chelating agents

EDTA, citric acid, tannic acid and polyacrylic acid are the examples of chelating agent. The chelating agents have direct and indirect antimicrobial actions and may also be used as a lubricant to soften dentine, and keep dentine chips in suspension as well as remove metallic irons (such as calcium) by binding them chemically (Walton and Rivera, 2002). The chelating agents can also dissolve dentine chips within the root canal system although the demineralizing effect of the chelating agent is self-limiting (Hulsmann *et al.*, 2003).

2.6.4.1 EDTA as a chelating agent for smear layer removing

Nontoxic chelating solutions are advocated for smear layer removal and Ethylene-Diamine-Tetra-Acetic acid (EDTA) is the most frequently used chelating agent in endodontics (Hulsmann *et al.*, 2005). It was introduced to endodontics and serve as a reagent for negotiating of narrow or sclerosis canals, where demineralization of root dentine on application of 15-17% EDTA is relatively effective (Lui *et al.*, 2007). EDTA is use for removal of smear layer and combination with antibacterial action of sodium hypochlorite. The chelating action of EDTA is biocompatible to the periapical tissues and its optimal cleansing ability can be used to negotiate smaller-diameter canals to remove the smear layer (Koskinen, 1980). EDTA changes pH during demineralization and the effect is self-limiting; as the pH decreases, both the rate of dentine demineralization and the amount of dentine dissolved decrease (Hulsmann *et al.*, 2003). EDTA mixed with quarternary ammonium compound Cetavlon (Sigma Chemical. Co., St Louis, MO, USA) exhibits lower surface tension, better efficiency and quicker action in root canal therapy than the original formulation (Torabinejad *et al.*, 2003). This combination is also known as EDTAC and acts on the dentine walls to produce a clean surface, as well as open dentinal tubules

(Goldberg and Spielberg, 1982). A modified new irrigating solution has recently been developed such as SmearClear (SybronEndo, Orange, CA). SmearClear is a solution consisting of 17% EDTA combined with cetrimide and additional proprietary surfactants (Gambarini, 2004).

2.6.4.2 The effects of EDTA on smear layer

Study by Takeda *et al.* (1999) confirmed that a final flush with EDTA, has the potential of removing the smear layer but did not produce the expected smear-free surfaces in the apical one-third of the canal. Based on evaluation of some studies on instrumented and uninstrumented root canal surfaces it may be reasonable to assume that the combination NaOCl and EDTA would help to remove the biofilm layer (Baumgartner and Mader, 1987; Baumgartner and Cuenin, 1992). Even the precise mechanism is unknown, it may be assumed that combination of EDTA helping to remove debris obstructing access to the uninstrumented surfaces and chelating heavy metal ions that help to bind bacterial cells together in the biofilm (Spratt *et al.*, 2001; Perez-Heredia *et al.*, 2008).

2.7 Scanning Electron Microscope (SEM) for smear layer evaluation

2.7.1 Background of SEM

The first SEM image was obtained in 1935 by Max Knoll who achieved an image of silicon steel showing electron channeling contrast. Further establishing work on the physical principles of the SEM and beam specimen interactions was performed by Manfred von Ardenne in 1937, but he had never completed for a practical instrument (Suzuki, 2002). The SEM was further developed by Professor Sir Charles Oatley and his postgraduate student Gary Stewart and was first marketed in 1965 by the Cambridge Instrument Company as the Stereoscan (Barnes *et al.*, 2002).

2.7.2 Evaluations of smear layer cleanliness under SEM

Several studies evaluated debris and smear layer scores on canal walls prepared with hand instruments (McComb and Smith, 1975; Samuel *et al.*, 1975; Shahi *et al.*, 2009) and engine-driven techniques (Peters and Barbakow, 2000; Sonntag *et al.*, 2007). Some study evaluated the smear layer cleanliness of different irrigation solutions (Spratt *et al.*, 2001) and irrigation methods (Takeda *et al.*, 1999), and some obturation methods (Timpawat *et al.*, 2001). A reliable and effective technique for evaluation of the smear layer in the root canals surface is essential. A scanning electron microscopy studies is needed when comparing various instruments and techniques used for consequences of endodontic procedure (George *et al.*, 2008). Comparing the methods for the effectiveness of smear layer removal usually involves scoring at high magnification (1000X) photomicrographs from SEM examination, particularly of the apical third of the root canal (Gambarini and Laszkiewicz, 2002; Foschi *et al.*, 2004). The images are coded and then scored by using qualitative or semi-quantitative scales were the most commonly used techniques (Hulsmann and Schafers, 1997; Hulsmann *et al.,* 2005). Other methods have involved tracing SEM photomicrographs onto graduated tracing paper for subsequent measurement and using resin replicas of the surface under examination (Schilke *et al.*, 2000). The dentinal tubules of the root canals proximity to pulp are 2.0-3.2 µm in diameter with the amount of $45x1000/mm^2$ in numbers (Trowbridge *et al.*, 2002). The opening of dentinal tubules can be examined by using SEM under high power of magnification and subsequently taking photomicrographs that can be saved.