EVALUATION OF APICAL SEALING ABILITY OF A NEWLY DEVELOPED NANO-HYDROXYAPATITE SEALER USING COLD LATERAL AND CONTINUOUS WAVE CONDENSATION TECHNIQUES: AN *IN VITRO* STUDY

by

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Dedication

To my beloved husband, **Rani**, who is the eye by which I can see the future and the beats that keep my heart alive. Your support, patience and understanding beside me throughout my study tremendously helped me to complete this research project.

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Abbreviations

NL	Nano-HA sealer with cold lateral condensation technique
AL	AH 26 sealer with cold lateral condensation technique
NB	Nano-HA sealer with System B continuous wave condensation technique
AB	AH 26 sealer with System B continuous wave condensation technique
N	Nano-hydroxyapatite sealer
A	AH 26 sealer
L	Cold lateral condensation technique
B	System B continuous wave condensation technique
ICC	Intra class Correlation Statistic
SD	Standard deviation
CI	Confidence interval

PENILAIAN KEUPAYAAN PENGAPAN APIKAL BAHAN PENGAP NANO-HIDROKSIAPATIT YANG BARU MENGGUNAKAN TEKNIK KONDENSASI LATERAL SEJUK DAN KONDENSASI GELOMBANG BERTERUSAN: SATU KAJIAN *IN VITRO*

ABSTRAK

Kajian ini bertujuan untuk membuat perbandingan dan menilai keupayaan pengapan apikal bahan pengap endodontik nano-HA dengan bahan pengap AH 26 menggunakan teknik kondensasi lateral sejuk dan kondensasi gelombang berterusan. Sebanyak dua ratus tiga puluh dua batang gigi manusia berakar tunggal digunakan. Korona dipotong pada bahagian "semento-enamel" menggunakan alat pemotong-Exakt. Kanal akar disediakan dengan teknik pengurangan korona menggunakan sistem berputar titanium-nikel ProTaper dan dibahagikan secara rawak kepada 4 kumpulan kajian dengan 53 batang gigi bagi setiap kumpulan. Dua puluh batang gigi yang selebihnya dijadikan sebagai kumpulan kawalan positif dan negatif dengan 10 batang gigi dalam setiap kumpulan. Dalam kumpulan NL, gigi diobturasi menggunakan bahan pengap nano-HA dengan teknik kondensasi lateral sejuk. Dalam kumpulan AL, gigi diobturasi menggunakan bahan pengap AH 26 dengan teknik kondensasi lateral sejuk. Dalam kumpulan NB, gigi diobturasi menggunakan bahan pengap nano-HA dengan teknik kondensasi gelombang berterusan. Dalam kumpulan AB, gigi diobturasi menggunakan bahan pengap AH 26 dengan teknik kondensasi gelombang berterusan. Semua gigi disimpan dalam inkubator pada suhu 37˚C selama 7 hari supaya bahan pengap set secukupnya. Permukaan akar ditutup dengan dua lapisan pengilap kuku kecuali bahagian apikal 2 mm dan ia kemudiannya diletak dalam larutan akuas pewarna methylene biru

2%. Selepas 72 jam gigi dibilas di bawah air paip mengalir, dikeringkan dan pengilap kuku d itanggalkan. Setiap spesimen kemudiannya dibenamkan kedalam resin “isobornyl methacrylate’’dan dipolimer cahaya menggunakan unit pempolimeran cahaya untuk memudahkan pelekatan di dalam pemotong tisu keras. Enam keratan melintang dengan ketebalan 1 mm dibuat bermula pada paras apikal penyediaan dan menaik secara apiko-koronal kepada keseluruhan 6 mm bagi setiap gigi. Permukaan koronal keratan seterusnya dinilai untuk melihat penyerapan pewarna dengan menggunakan stereomikroskop yang disokong oleh perisian analisis imej. Penyerapan keseluruhan pewarna bagi setiap gigi dikira sebagi nisbah antara keseluruhan kawasan penyerapan methylene biru dan keseluruhan kawasan permukaan dentin kesemua enam peringkat. Data dimasukkan ke dalam perisian SPSS dan dianalisis menggunakan ANOVA dwi-cara dimana nilai $P < 0.05$ di anggap sebagai signifikan secara statistik. Min kebocoran apikal pewarna untuk bahan pengap nano-HA 9.33% dan bahan pengap AH 26 8.94%. sementara itu min kebocoran apikal pewarna untuk teknik kondensasi sejuk lateral 12.15% dan teknik kondensasi gelombang berterusan 6.11%. Tiada perbezaan yang signifikan dikesan dalam kebocoran apikal pewarna ($P= 0.087$) antara bahan pengap nano-HA dan bahan pengap AH 26. Sementara itu, kumpulan yang diobturasi dengan teknik kondensasi sejuk lateral lebih bocor secara signifikan ($P < 0.001$) berbanding kumpulan yang diobturasi secara teknik kondensasi gelombang berterusan.

EVALUATION OF APICAL SEALING ABILITY OF A NEWLY DEVELOPED NANO-HYDROXYAPATITE SEALER USING COLD LATERAL AND CONTINUOUS WAVE CONDENSATION TECHNIQUES: AN *IN VITRO* STUDY

ABSTRACT

The aim of this study was to evaluate the apical sealing ability of an experimental nano-HA containing endodontic sealer and compare it with AH 26 sealer using cold lateral and continuous wave condensation techniques. Two hundred and thirty two extracted single rooted human teeth were used. Crowns were amputated at the cemento-enamel junction using Exakt-cutting system. The root canals were prepared using a crown-down technique with ProTaper nickel titanium rotary system and randomly divided into 4 experimental groups of 53 teeth each. The remaining 20 teeth were served as positive and negative control groups of 10 teeth each. In group NL, teeth were obturated using nano-HA sealer and cold lateral condensation technique. In group AL, teeth were obturated using AH 26 sealer and cold lateral condensation technique. In group NB, teeth were obturated using nano-HA sealer and continuous wave condensation technique. In group AB, teeth were obturated using AH 26 sealer and continuous wave condensation technique. All teeth were stored in an incubator, at 37°C for seven days to allow adequate setting of sealers. Root surfaces were covered with two layers of nail polish except for the apical 2 mm and then placed in an aqueous solution of 2% methylene blue dye. After 72 hours, the teeth were rinsed under running tap water, dried and the nail polish removed. Each specimen was then embedded in isobornyl methacrylate resin and light cured using Light Polymerization Unit to facilitate their

mounting in a hard tissue cutter. Six transverse sections of 1 mm thickness were taken starting at the apical limit of the preparation and ascending apico-coronally to a total of 6 mm of each tooth. The coronal surface of each consecutive section was assessed for dye penetration using stereomicroscope supported by image analyzer software. Overall dye penetration for each tooth was then calculated as the ratio between the total methylene blue infiltrated surface areas and the total dentinal surface areas of the six levels. Data was entered into SPSS software and analyzed using two-way ANOVA where $P < 0.05$ was considered statistically significant. The mean of apical dye penetration was 9.33% for the nano-HA sealer and 8.94% for the AH 26 sealer. While the mean of apical dye penetration was 12.15% for the cold lateral condensation technique and 6.11% for the continuous wave condensation technique. No significant difference was found in the apical leakage of dye ($P= 0.087$) between nano-HA and AH 26 sealers. While groups obturated by cold lateral condensation technique leaked significantly more ($P < 0.001$) than groups obturated by continuous wave condensation technique.

CHAPTER ONE

INTRODUCTION

1.1 Study Background

When the dental pulp undergoes pathologic changes because of trauma or the progression of dental caries, bacteria and other irritants from the oral cavity invade the root canal system. The major objectives of root canal therapy are removal of pathologic pulp, cleaning, and shaping of the root canal system; disinfection of contaminated root canals and three-dimensional obturation to prevent reinfection (Walton and Torabinejad, 2002; Orucoglu *et al.*, 2005; Torabinejad *et al.*, 2005; Cohen and Hargreaves, 2006). Therefore, the tooth may remain as a functional unit within the dental arch (Pitt Ford, 1997).

Basically, two materials are used in combination for the root canals filling; a semisolid material (gutta-percha) and a sealing cement. The gutta-percha serves as the core-filling material, whereas the root canal sealer is required to fill the discrepancies between the core-filling material and the root canal walls (Lucena-Martin *et al.*, 2002), to fill the accessory canals, to serve as a lubricant and to obtain a fluid tight apical seal (Pommel and Camps, 2001b).

Sealing of the apical foramen is an important aim of endodontic treatment in order to prevent the penetration of tissue fluids into the root canal and the diffusion of irritants and/or bacteria out of the canal if bacteria are present (Oliver and Abbott, 2001). The so-called ‘Washington study’, suggested that apical percolation of periradicular exudate into the incompletely filled canal accounted for approximately 60% of endodontic failures (Ingle *et al.*, 2002b). As a result of these findings, many changes in the techniques of biomechanical preparation and root canal obturation have been made on the basis of apical leakage studies (Oliver and Abbott, 1998).

On the other hand, the apical root filling should provide a seal; especially after post-space preparation since only 3-4 mm of root filling remains (Wu *et al.,* 2002b). Moreover, it has been shown that numerous lateral canals are present in the apical third of the canal (De-Deus *et al.*, 2006). Therefore, the development and maintenance of apical seal is desirable and considered to be a major prerequisite to improve the outcome of root canal treatment (Paque and Sirtes, 2007). However, obtaining an impervious seal is difficult; therefore different endodontic-filling materials and technologies have been introduced to improve the apical seal (Cobankara *et al.*, 2002; Johnson and Gutmann, 2006).

The use of sealers along with well-adapted gutta-percha gives the optimum chance of success (Walton and Johnson, 2002; Kardon *et al.*, 2003). However, the confirmed solubility of sealers implies the necessity to limit its presence to a thin film and increasing the mass of the gutta-percha (Kontakiotis *et al.*, 1997; De Deus *et al.*, 2003).

Many types and brands of endodontic sealers are commercially available, but none of them fully satisfy all the requirements that outlined by Grossman, (1988). They can be grouped according to their basic components such as zinc oxide-eugenol, calcium hydroxide, resins, glass-ionomers, and silicon-based sealer (Himel *et al.*, 2006). In the last few years, new hydroxyapatite-containing sealers were developed, such as Bioseal (Ogna, Laboratori Farmaceutici, Italy) (Gambarini and Tagger, 1996), Sankin apatite Type 1 and Sankin apatite Type 2 (Sankin Trading Co., Tokyo, Japan) (Telli *et al.*, 1999). The fact that hydroxyapatite (HA) is a naturally occurring product and that bone grows into and eventually replaces extruded material, makes it very acceptable biologically (Ingle *et al.*, 2002a).

Recently, the School of Dental Sciences, USM, has prepared a new experimental nano HA-filled epoxy resin based endodontic sealer using a simple and inexpensive technique. The HA nano crystals were synthesized using wet preparation technique (Masudi *et al.*, 2007). The material was prepared at nano level and nano HA particles size are believed to have several advantages over normal HA particles size in its use in hard tissue formation. In addition, nano sized HA is useful as an effective surface modification agent for binding numerous biological molecules (Ong *et al.*, 2004). The nano structured HA-based materials are therefore a promising material that may have a future prospect and considerable clinical dental applications. The materials are biocompatible, reactive and have capability to adhere to the dentinal tubules. In addition, the smaller the particle size, the lower will be the gravity cohesion and higher intermolecular physical bonding (*van-der Walls* Forces) which leads to the higher surface activity (Roberson *et al.*, 2002).

The composition of the experimental sealer is similar to that of various sealers of the epoxy resin based sealer type but with different additive. This additive (nano-HA) is assumed to influence the apical healing. However, the possibility that the physical nature of the set material that incorporates an inorganic filler (nano-HA) within a matrix that has no specific affinity for it, may allow capillary leakage between the particles (Gambarini and Tagger, 1996; Masudi *et al.*, 2007).

The cold lateral condensation is a "golden standard" and probably the most commonly taught and practiced filling technique worldwide (Inan *et al.*, 2007). It provides for length control during compaction (Johnson and Gutmann, 2006). However, a common criticism of this technique is that it is a time-consuming method (Whitworth, 2005) and may predispose to vertical root fractures (Lipski, 2005). In addition, the shape of many root canal systems can complicate its application to gain a homogeneous mass of gutta-percha (Gulsahi *et al.*, 2007). Therefore, different filling techniques based on heated or preheated gutta-percha have been introduced to enhance three-dimensional filling of the root canal (Wu *et al.*, 2002b; Gatewood *et al.*, 2004).

Studies have shown that softened gutta-percha can easily be moved into the canal irregularities, thus replicating the intricacies of the root canal system (Schilder, 1967; Buchanan, 1996; Gencoglu *et al.*, 2007). System B continuous wave of condensation is a new warm gutta-percha root filling technique that has rapidly gained popularity; it was designed to modify Schilder’s technique by obturating the root canal system with a single continuous wave of thermoplasticized gutta-percha (Buchanan, 1996). Again, little is known regarding the apical sealing ability of the new experimental nano-HA sealer when used with different obturation techniques. Moreover, during the process of heating gutta-percha, the filler is heated as well which might influence its sealing ability (Wu *et al.*, 2004).

1.2 Statement of the Problem

Inadequate apical seal, which causes microleakage, is considered to be one of the most common causes of failure of endodontic treatment. Although a wide range of root canal sealers is available for root canal obturation, none of these materials are able to provide a fluid-tight seal (Walton and Torabinejad, 2002; Zmener *et al.*, 2008).

Cold lateral condensation is one of the most commonly used techniques for root canal filling (Whitworth, 2005). However, voids, incomplete fusion of gutta-percha cones, excessive amounts of sealer and its ability to replicate the inner surface of the root canal have been questioned. In an attempt to overcome these inherent disadvantages, a number of warm gutta-percha techniques were introduced, including continuous wave of condensation with System B heat source.

This new experimental nano HA-containing sealer is still need to be evaluated on its ability to prevent apical leakage with different obturation techniques.

The most widely used method for measuring dye leakage is linear dye measurements; splitting the root longitudinally or decalcifying the tooth (Gatewood *et al.*, 2004). However, these two methods suffered from limitations such as only the visible dye is measured, the total leakage cannot be assessed from a single section with less possibility to know if the section goes through the deepest dye penetration in longitudinal sectioning technique and dye dissolution in clearing technique; whereas cross-sectional technique yields a more accurate quantification of leakage (Ahlberg *et al.*, 1995; Veis *et al.*, 1996; Camps and Pashley, 2003).

1.3 Justification of the Study

This study will determine the ability of the new experimental nano-hydroxyapatite (Nano-HA) containing sealer in preventing apical leakage using cross-sectional technique and area-metric measurements. On the other hand, comparing sealers performance in conjunction with either cold lateral or continuous wave condensation techniques will aid and assist in selecting the suitable sealer that performs satisfactorily.

This study will also determine whether there is a difference in sealing ability between the two obturation techniques.

The results of this study will also add value to the properties of the currently locally-produced nano-HA sealer which leads to its usage in clinical practice and it may become a good alternative to the currently available commercial materials. Moreover, this will help to reduce the overall cost of treatment for patients- as the material is locally produced- and in commercialization.

CHAPTER TWO

LITERATURE REVIEW

2.1 Root Canal Treatment

Root canal treatment can be summarized as a series of procedures of cleaning, shaping and filling of the root canal system (Karadag *et al.*, 2004).

Microorganisms are the cause of pulpitis and apical periodontitis (Siqueira *et al.*, 2000) as well as failure in endodontic treatment (Siqueira, 2001). One of the main goals of endodontic treatment is the reduction or elimination of microorganisms from the root canal system. However, complete elimination of microorganisms cannot be achieved consistently with current treatment methods (Sjögren *et al.*, 1997; Nair *et al.*, 2005). On the other hand, tissue fluid may provide sufficient nutrients to allow bacteria to survive and proliferate if they have not been eliminated during the endodontic treatment or if they have re-entered the canal subsequently through caries, cracks and/or leaking of the restorations margins. Once bacteria are established within the canal, then their by-products can induce apical periodontitis by diffusing through the apical foramen, or the bacteria themselves may migrate out of the canal to induce an acute exacerbation of apical periodontitis if the foramen is not completely sealed (Nair, 1997; Nair *et al.*, 1999).

Not all teeth with positive bacterial cultures fail, nor do all teeth with negative cultures succeed (Sjögren *et al.*, 1997). Thus, ‘entombing’ residual microorganisms and irritants by sealing them within the root canal system may have a major influence on clinical outcome (Weis *et al.*, 2004; Aqrabawi, 2006).

The hermetic sealing of the root canal space is one of the major objectives in root canal therapy. This emphasizes the need for using materials that are able to create a hermetic seal. Microleakage studies on the sealing properties of endodontic materials have thus played an important role in their development (Tunga and Bodrumlu, 2006).

2.2 Root Canal Obturation Materials

2.2.1 Core obturation material

There are three categories of materials to obturate the root canal: solids, semisolids, and pastes (Liewehr and Johnson, 2002; Johnson and Gutmann, 2006). They comprise the bulk of material that will fill the canal space (Walton and Johnson, 2002). The ideal properties of an obturation material as outlined by Grossman, (1988) are listed in Table 2.1.

Table 2.1 Ideal properties of an obturation material

1. It should be easily manipulated and provide ample working time.
2. It should be dimensionally stable and not shrink.
3. It should seal the canal laterally and apically, conforming to its complex internal anatomy.
4. It should not irritate the periapical tissue.
5. It should be impervious to moisture and nonporous.
6. It should be unaffected by tissue fluids and not corrode or oxidize.
7. It should not support bacterial growth.
8. It should be radiopaque and easily discernible on radiographs.
9. It should not discolour tooth structure.
10. It should be sterile.
11. It should be easily removed from the canal if necessary.

2.2.1 (a) Silver Points

A silver point was designed to correspond to the last file size used in preparation and to fill the canal precisely in all dimensions. However, it is impossible to prepare canals to a uniform size and shape and also difficult to remove the silver points for the post space preparation (Walton and Johnson, 2002).

In addition, the disadvantage of the silver point is its inability to fill the irregularly shaped root canal system which encouraging leakage. When leakage occurred and the points contacted the tissue fluids, they corrode and further increased the leakage. The corrosion products themselves were found to be highly cytotoxic, which impeded periapical healing. Thus, silver cones are no longer utilized for root canal obturation (Liewehr and Johnson, 2002).

2.2.1 (b) Gutta-percha

For many years, gutta-percha, a semisolid material has proven to be the material of choice for successful obturation when used in combination with a root canal sealer (Grossman, 1988). It is a natural product that consists of the purified coagulated exudates of mazar wood trees (Isonandra percha) from the Malay Archipelago or from South America. Chemically, gutta-percha is the trans-isomer of poly-isoprene, a naturally occurring relative of rubber (Schmalz, 2003).

Gutta-percha can exist in three phases: α, β and amorphous (molten). Conventional gutta-percha point can exist in β form which transforms to the α phase and amorphous phase on heating. When heating the gutta-percha during obturation; there will be shrinkage on cooling as the phase changes occur. Heated gutta-percha requires pressure to compact it as it cools to prevent contraction gaps from developing (Pitt Ford *et al.*, 2002).

Walton and Johnson, (2002) reported that gutta-percha is the standard to which other materials are compared:

- First, because of its plasticity, it adapts with compaction to irregularities in prepared canals;

- Second, it is relatively easy to manage and manipulate despite some complex obturation techniques;
- Third; it is easy to remove from the canal, either partially to allow post placement or totally to allow retreatment;
- And last, gutta-percha has relatively little toxicity, being nearly inert over time when in contact with connective tissue.

2.2.1 (c) Resilon

Resilon (Pentron Clinical Technologies, USA) is a thermoplastic, synthetic, polymer-based root canal filling material which contains bioactive glass, bismuth and barium salts as fillers. Resilon was developed in an attempt to create an adhesive bond between the solid core material and the sealer. It is designed to be used with Epipheny (Pentron Clinical Technologies, USA), a new resin sealer (Orstavik, 2005; Himel *et al.*, 2006; Schwartz, 2006). The core material is available in conventional and standardized cones and pellets with physical and handling properties similar to gutta-percha (Himel *et al.*, 2006).

2.2.1 (d) Coated Gutta-Percha

Coated-gutta percha (Ultradent) has been developed in an attempt to achieve bonding between the solid core and resin sealer. The uniform layer is placed on the gutta-percha cone and when the layer comes in contact with the resin sealer, a resin bond is formed. The technique calls for use of EndoRez sealer (Ultradent) with this new solid core material (Himel *et al.*, 2006).

2.2.1 (e) Pastes as root canal fillings

The use of paste-type root canal filling is not advocated in contemporary endodontics. Paste can easily be adapted to the most complex internal anatomy. However, their extreme flowability can result in extrusion or incomplete obturation (Liewehr and Johnson, 2002). In addition, most pastes resorb with time, resulting in apical leakage, percolation with a strong possibility of ultimate treatment failure (Gutmann and Witherspoon, 2002). N2 and Biocalex are the examples (Bruder and White, 2002; Roda and Gettleman, 2006).

2.2.2 Endodontic Sealer

At begining it was thought that the sealer played a secondary role by simply cementing (binding, luting) the core filling material into the canal (Ingle and Bakland, 2002). However, a basic concept is that sealer is more important than the core obturating material in providing a fluid-tight seal. The core occupies the space which served as a vehicle for the sealer. Sealer must be used in conjunction with the obturating material regardless of the technique or material used. This makes the physical properties of the sealer important (Walton and Johnson, 2002).

In addition to the basic requirements for a core obturating material, another eleven requirements and characteristics of a good root canal sealer were outlined by Grossman, (1988) and are provided in Table 2.2

Table 2.2 Properties of an ideal sealer

1-	It should be tacky when mix to provide good adhesion between it and the canal wall when set.
2-	It should produce a fluid-tight seal.
3-	It should be radiopaque so it can be visualized on a radiograph.
4-	The particles of powder should be very fine so they can mix easily with the liquid.
5-	It should not shrink on setting.
6-	It should not stain tooth structure.
7-	It should be bacteriostatic or at least not encourage bacterial growth.
8-	It should set slowly.
9-	It should be insoluble in tissue fluids.
10-	It should be tissue tolerant, that is, non-irritating to periradicular tissue.
11-	It should be soluble in a common solvent in case removal of root canal filling becomes necessary.

In addition to this traditional concept of the purpose of root canal filling material, recent ideas have been promoted that a root canal filling material should be able to actively stimulate regeneration of the periodontal connective tissue attachment apparatus, especially after an aggressive treatment procedure or after apical pathosis (Schmalz, 2003).

Both gutta-percha and sealer are used to fill root canal, and each makes its own contribution to achieve the seal. Gutta-percha is dimensionally stable (Wu *et al.*, 2000a), whereas most sealers dissolved over time (Georgopoulou *et al.*, 1995; Kontakiotis *et al.*, 1997). The dissolution of the sealer is probably responsible for the increase in leakage along the root fillings over time (Kontakiotis *et al.*, 1997). Therefore, the amount of sealer should be kept to a minimum and should only be found in a thin layer between the gutta-percha and the wall of the canal (Wu *et al.*, 2000b; De Deus *et al.*, 2003).

Some sealers may cause discolouration of the tooth structure. Partovi *et al.*, (2006) studied the crown discolouration from commonly used endodontic sealers and reported that all sealers caused a degree of tooth discolouration. Parsons *et al.*, (2001) evaluated the coronal discolouration from four root canal sealers; AH 26, Kerr Pulp Canal Sealer, Roths 801 and Sealapex, and concluded that discoloration induced by these sealers produced slight to moderate and generally progressive discoloration over 12 months. The authors reported that AH 26 and Kerr Pulp Canal Sealer are silver-containing sealers; the silver corrodes to a gray-black which likely contributes to the staining, which is analogous to amalgam-stained teeth. Other sealers contain ingredients that are changing chemically with time such as eugenol which oxidizes and darkens with time. Therefore, crowns should be cleaned from sealer remnants to avoid crown discoloration.

Another concern is that heat induction might influence the sealing ability of the sealer (Gambarini and Tagger, 1996; Wu *et al.*, 2004; Beltes *et al.*, 2008). Wu *et al.*, (2004) reported that better seals were obtained by using the backfills with AH 26 sealer than with Kerr Pulp Canal Sealer (Kerr, Romulus, USA). The author reported that the Kerr Pulp Canal Sealer probably had already set (as a result of heat application) before the warm gutta-percha was compacted and that the set sealer was no longer able to act as a sealant. Thus it is important to determine the best sealer for use in combination with the warm gutta-percha.

2.2.2.1 Functions of sealer

Root canal sealers are used in conjunction with core filling materials as stated by Dummer, (1997) for the following purpose:

1- Cementing (luting and binding) the core material into the canal.

2- Filling the discrepancies between the canal walls and the core material.

3- Acting as a lubricant to enhance the positioning of the core filling material.

4- Acting as a bacterial agent.

5- Acting as a marker for accessory canals, resorptive defects, root fractures and other spaces into which the main core material may not penetrate.

2.2.2.2 Classification of root canal sealers

Root canal sealers are divided into groups according to their chemical composition as shown in Table 2.3 (Schmalz, 2003).

Table 2.3 Types of root canal sealers

Sealers commonly used based on	New types of sealers
• Zinc oxide and eugenol • Glass ionomer cement • Calcium hydroxide • Resin • Polyketone	• Composite resins/ dentine bonding agents • Calcium phosphate cements • Silicones • Hydroxyapatite containing sealer

Sealers mixed to a paste and set by chemical reaction. Radio-pacifiers are added, such as precipitated silver or bismuth salts. Binding resins such as staybelite, hydrogenated rosin ester, oleoresin and polymerized resin are added. Some sealers contain antibacterial substances such as thymol iodide and calcium hydroxide. Calcium hydroxide is unlikely to be of therapeutic benefit in eugenol-based sealers as it is chelated by eugenol (Pitt Ford *et al.*, 2002).

2.2.2.2.1 Zinc Oxide- Eugenol

Many Zinc Oxide and eugenol-based sealers are available with some variations from Grossman's original formula (Pitt Ford *et al.*, 2002). Table 2.4 provides some of the more common Zinc oxide-eugenol cements**.**

Table 2.4 Types of Zinc Oxide-eugenol-based sealers (Himel *et al.*, 2006)

• Kerr PCS (Kerr, Romulus, MI, USA)
• Roth (Roth Inc., Chicago, IL, USA)
• ProcoSol (Den-tal-ez, Lancaster, PA, USA)
• U/P-Grossman's sealer (Sultan chemists, Englewood, NJ, USA)
• Endomethason (Septodont, Saint-Maur, France)
• N2 (Agsa, Locarno, Switzerland)
• Bioseal (Ogna, Laboratori Farmaceutici, Milan, Italy)

The eugenol in these sealers is antibacterial, but the material is porous and relatively weak when set. Zinc oxide and eugenol material extruded through the apex will produce an inflammatory reaction in the periapical tissues, and this may last sometime. All Zinc oxide and eugenol are cytotoxic, and have been shown to lead to sensitization (Pitt Ford *et al.*, 2002).

Several studies showed apical leakage around ZnOE sealers that increased with storage time (measured up to 2 years), in thick layers more than in thin layers (Georgopoulou *et al.*, 1995; Kontakiotis *et al.*, 1997). Sealing properties of ZnOE sealers were inferior in comparison to other sealers (Epoxy resin or calcium hydroxide sealers) but better than those of glass ionomer cements (Schmalz, 2003). Cobankara *et al.*, (2002) reported that Sultan sealer (Sultan Chemists, USA) showed significantly more leakage when compared to Roekoseal (Roeko, Germany), Ketac-Endo (ESPE, Germany) and AH Plus (De-Trey, Switzerland) sealers.

2.2.2.2.2 Glass Ionomer Sealer

Glass ionomer cement has the ability to adhere to dentine, and for this reason would appear to be a suitable material for use as an endodontic sealer. On the other hand, Glass ionomer cement has short working time, difficulty in transport to root canal, lack of radiopacity (Noort, 2002) and was generally considered difficult to retreat (Schwartz, 2006). It is cytotoxic while setting and has difficulty in removing from the root canal system when carrying out root canal treatment. Example: Ketac Endo (ESPE, Seefeld, Oberlay, Germany) (Pitt Ford *et al.*, 2002).

2.2.2.2.3 Calcium Hydroxide Sealers

Calcium hydroxide sealers belong to the few materials that apparently stimulate apical healing and hard-tissue formation or root-end closure (Schmalz, 2003). It is also the main component in several pastes which are used as intracanal medicaments in cases of periapical lesions (Beltes *et al.*, 1997). Sealapex (Kerr, Romulus, MI, USA), CRCS (Hygenic Corp. USA) and Apexit (Vivadent, Schaan, Liechtenstein) are examples of commercially available calcium hydroxide-based sealers (Himel *et al.*, 2006).

Leakage studies show inconsistent results with a tendency for less sealing quality compared with other sealers (Schmalz, 2003). Long term exposure to tissue fluid may possibly lead to dissolution of the material when a calcium hydroxide leached out (Pitt Ford *et al.*, 2002).

Figueiredo *et al.*, (2001) studied the tissue response to four endodontic sealers that were implanted in the oral mucosa of white New Zealand rabbits and concluded that the calcium hydroxide- containing sealers had enhanced healing when compared to other sealers.

The disintegration of sealapex indicates that solubility may be needed to increase the activity. In other words, these sealers must dissolve in order to release their calcium hydroxide that's responsible for cementification across the apex and hard tissue formation. But the solubility of these sealers leads to leakage into the exposed canal. Is there a substitute for calcium hydroxide that may have its stimulation effects (stimulate apical healing), but not its drawbacks (solubility that leads to leakage)? The answer may be hydroxyapatite (Ingle *et al.*, 2002a).

2.2.2.2.4 Resin based sealers

The attraction of resin systems is that these materials can readily be formulated in such a way that they maintain a sufficient working time. In addition, these products do not contain any coarse powders so they have a very smooth texture (Noort, 2002). Some resin based sealers are shown in Table 2.6

Table 2.5 Resin-Type endodontic sealers (Orstavik, 2005)

• AH 26 (Dentsply Maillefer, Switzerland)
• AH Plus (Dentsply Maillefer, Switzerland)
• Epiphany (Pentron, USA)
• EndoRez (Ultradent, USA)
• Acroseal (Septodont, Saint-Maur, France)
• Diaket (ESPE, Germany)

2.2.2.2.4.1 AH 26 sealer

AH 26 is an epoxy amine resin–based sealer. Epoxy resin sealers have comparatively good sealing properties, mechanical properties as well as excellent adhesion and adaptation to dentin. After initial volumetric expansion, the AH 26 sealer showed some shrinkage when tested at longer intervals. In general, AH 26 epoxy-resin based sealer showed better sealing ability *in vitro* and *in vivo* than any other tested sealers (Limkangwalmongkol *et al.*, 1991; Miletic *et al.*, 1999; Schmalz, 2003).

The material can initially produce a severe inflammatory reaction if present in the tissue, but this subsides over a few weeks and it is then well tolerated (Pitt Ford *et al.*, 2002). Cytotoxicity of AH 26 is related to the initial release of formaldehyde during the setting reaction. The presence of silver in AH 26 may lead to tooth discoloration due to the formation of black silver sulfide. Some preparations are available without silver and bismuth oxide is added for radiopacity (Schmalz, 2003).

Karadag *et al.*, (2004) found that the AH 26 resin based sealer penetrated into the dentinal tubules better than the glass ionomer sealer Endion, which may be attributed to the smaller size of its particle and its viscosity. They reported that the microstructure of the sealer in the dentinal tubules and the degree of the tubules closure may be the most important factor for a tight obturation. In addition, heat application might increase the flow capacity of the AH 26 sealer (Beltes *et al.*, 2008).

Moreover, AH 26 shows antibacterial activity (Al-Khatib *et al.*, 1990; Heling and Chandler, 1996). Al-Khatib *et al.*, (1990) found that AH 26 was the most active against *Bacteroides endodontalis*. Heling and Chandler, (1996) also found AH 26 within the dentinal tubules, which was shown to have the strongest antimicrobial effect over three other well-known sealers (Pulp Canal Sealer, Sealapex and Ketac-Endo). In addition, Bergeron *et al.*, (2001) reported a significant increase in post retention when AH 26 sealer was used compared with Roth's sealer (zinc-oxide and eugenol sealer).

2.2.2.2.5 Polyketone

The polyketone sealer has good mechanical and sealing properties. It is proved to have acceptable technical properties such as sufficient strength, low shrinkage and good adhesion to dentine. It was reported that the polyketone sealer had lower microleakage scores than the tested sealers (ZnOE sealers and a glass ionomer cement) (Schmalz, 2003). On the other hand, the polyketone sealer is moderately toxic and apparently does not actively stimulate the healing of apical tissue (Schmalz, 2003).

2.2.2.2.6 Composite resins/ dentine bonding agents

Composite resin, dentin bonding agent were tested as root canal sealers in a few studies (Zidan and Eldeeb, 1985; Rawlinson, 1989; Hammond and Meyers, 1992). They were reported able to give good seal with penetration of the resin into the dentinal tubules, although there are apparently difficulties in applying the material into the apical one third of the canal. Removal of the set resin is difficult and thus problems occur when a re-entry is needed (Leonard *et al.*, 1996).

2.2.2.2.7 Calcium phosphate cements

Sugawara *et al.*, (1990) reported that Calcium phosphate cement (CPC) is useful in endodontics as a filler/sealer in root canal treatment. In addition, the authors studied the apical sealing ability of CPC and reported that the CPC formed hydroxyapatite as the final product and resulted in less dye leakage as compared to Grossman's root canal sealer (a zinc oxide-eugenol-based sealer).

CPC adapts closely to root canal walls and sets to a hard mass. Unlike other sealers, moisture in the canal will not decrease the strength of CPC. One of the concerns in using CPC for an endodontic application is the problem of retreatment as it becomes rigid once set (Cherng *et al.*, 2001).

Furthermore, *in vitro* studies have shown that CPC can also seal a furcation perforation (Chau *et al.*, 1997) and could be used as an apical barrier for apexification (Goodell *et al.*, 1997). The results of these studies suggest that CPC has potential to promote the healing of bone in endodontic treatment (Cherng *et al.*, 2001).

2.2.2.2.8 Silicones

Roekoseal (Roeko Dental Products, Langenau, Germany) is a polydimethylsiloxane- or silicon- based sealer (Wu *et al.*, 2002a; Himel *et al.*, 2006). It has been shown that it was less cytotoxic (Bouillaguet *et al.*, 2004) with good long-term sealing ability (Wu *et al.*, 2002a). Wu *et al.*, (2006) found that Roekoseal was dimensionally stable and prevented leakage for at least 1 year. Gencoglu *et al.*, (2003) compared the apical sealing ability of Roekoseal with Grossman's sealer and found that better results were obtained in which Roekoseal was used.

Guttaflow is a new silicon-based sealer. It comes in a unidose capsule and is injected after mixing. The silicon is mixed with gutta-percha powder to form what the company calls a "two in one" cold filling system (Himel *et al.*, 2006).

2.2.2.2.9 Hydroxyapatite containing sealer

Hydroxyapatite, HA is the main biomineral component of human hard tissues (tooth and bone) and its stoichometry is represented by the formula $Ca_{10}(PO_4)_6(OH)_2$. HA is known to be biocompatible, bioactive, osteoconductive, non toxic and non-inflammatory (Chang and Tanaka, 2002; Chow *et al.*, 2004; Oliveira and Mansur, 2007). Its primary use in medicine has been for the reconstruction of nonstress-bearing cranial skeletal defects; however, its properties suggest a potential use as an endodontic retrofill material. These include: radiopacity, ease of manipulation, biocompatibility, antibacterial activity, and the ability to establish an effective apical seal (Mangin *et al.*, 2003).

Although in the last few decades the root canal filling material was considered mainly as an inert filler of the canal space, it is slowly emerging as an active element of the endodontic therapy. The expanding use of calcium hydroxide has prompted investigators to test its application for enhancing the periapical healing. Although the mechanism whereby a calcium hydroxide containing sealer may act is not clear, this compound was added empirically. Other substances that enhance bone apposition have been tested, such as hydroxyapatite, collagen gel and calcium phosphate (Gambarini and Tagger, 1996).

Gambarini and Tagger, (1996) compared the sealing ability of two sealers, Bioseal and conventional sealer using dye penetration method. Both of these sealers are Zinc-oxide eugenol based but the Bioseal contained hydroxyapatite powder additive. Results showed that there was no significant difference between the two sealers and that addition of hydroxyapatite had no adverse effect on the seal.

Sankin apatite type I, Sankin apatite type II, Sankin apatite type III (Sankin Trading Co., Tokyo, Japan) (Telli *et al.*, 1999) and Bioseal (Ogna, Laboratori Farmaceutici, Milan, Italy) (Gambarini and Tagger, 1996) are examples of available HA containing sealers.

2.2.2.2.9.1 Experimental nano-hydroxyapatite sealer

The apatite crystallites in human bone, enamel, dentin and cementum are all extremely small in size and can be considered as nano-structured materials. Because HA is the prototype of biological apatites, which are in nano crystalline forms, extensive efforts have been made to produce synthetic nano HA materials (Chow *et al.*, 2004), which would play a significant role in various biomedical applications such as bone substitute materials, constituent implants and dental materials (Ong *et al.*, 2004).

Recently, synthetic HA was prepared at nano level (1-100 nm) and nano HA particles size is believed to have several advantages over HA particles size in its use in hard tissue formation. This is due to its greater surface area and consequently higher reactivity, which offers better cellular response. In addition nano sized HA is useful as an effective surface modification agent for binding numerous biological molecules (Ong *et al.*, 2004). The nano HA materials are biocompatible due to their chemical and physical nature, the nanometer-sized grains have also been found to increase osteoblast adhesion, proliferation and mineralization (Dolci *et al.*, 2001).

These nano structured HA-based materials are therefore a promising material that may have a future prospect and considerable clinical dental applications. The materials are biocompatible, reactive and have capability to adhere to the dentinal tubules. The