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Root canal Sealer

A project

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بسمِ اللهِ الرَّحمَن الرَّحِيمِ

(وَأَنزَلَ اللَّهُ عَلَيكَ الكِتَابَ وَالحِكمَةَ
وَعَلَّمَكَ مَا لَم تَكُن تَعلَمُ وَكَانَ
فَضلُ اللَّهِ عَلَيكَ
عَظِيمًا)

صدق الله العظيم

(سورة النساء الآية ١١٣)

Dedication

To
My Mother and Father

To
Greatly Support
My Steps…

Introduction

In endodontic practice, the success of root canal therapy mainly depend on achieving a compact fluid tight seal of the apical end of the root canal, so as to prevent the ingress and accumulation of irritants causing biological breakdown of attachment apparatus leading to failure. Root canal sealers along with solid coreor semi-solid core material, to fill voids and to seal root canals during obturation and for entombment of remaining bacteria and the filling of irregularities in the prepared canal.

Several types of root canal sealers are used in endodontic practice with each one having own merits and demerits. Sealers are basically selected based on their sealing ability, adhesive properties, biocompatibility & antimicrobial efficacy (.henstun et .al 2012).

Three dimensional sealing of the entire root canal space with a bio-compatible filling material is a challenging task to be achieved for the success of endodontic treatment. Filling the root canal space is achieved by two main components: Gutta Percha core filling material and root canal sealer. Gutta Percha is the most favorable bio-compatible filling material that can be used to fill the radicular space. But, this material alone is not enough to produce and ensure tight seal of the root Canal system, it is only adapts to the adjacent dentinal walls. However, root canal sealer is necessary to fill the irregularities and minor discrepancies between gutta percha and canal wall. (kumae et.al 2009).

Ideal requirements of endodontic sealer:

Grossman's ideal requirements of endodontic Sealer : **(Henstona et al., 2012)**

1. It should be tacky when mixed to provide good adhesion between it and the canal wall when set.

2. It should make a hermetic seal.

3. It should be radiopaque so that it can be visualized on the radiograph.

4. The particles of powder should be very fine so that they can mix easily with liquid.

5. It should not shrink upon setting.

6. It should not discolour 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 well tolerated by the periapical tissue.

11. It should be soluble in common solvents if it is necessary to remove the root canal filling.

Functions of Root Canal Sealers:

Root canal sealers are used in conjunction with filling materials for the following purposes: **(Garg et al., 2010).**

1. Antimicrobial agent: All the popularly used sealers contain some antibacterial agent, and so a germicidal quality is excreted in the period of time immediately after its placement .

2. Sealers are needed to **fill in the discrepancies** between the filling material and the dentin walls .

3. Binding agent: Sealers act as binding agent between the filling material and the dentin walls .

4. As lubricant: With the use of semisolid materials, the most important function for the sealer to perform is its action of lubrication.

5. Radiopacity: All sealers display some degree of radiopacity; thus they can be detected on a radiograph. This property can disclose the presence of auxiliary canals, resorptive areas, root fractures, and the shape of apical foramen.

6. Certain techniques dictate the use of particular sealer .

Classification

Types of root canal sealer according to the chemical composition :

Endodontic sealer comes in a variety of compositions:

1. Zinc oxide-eugenol based sealer

2. Calcium hydroxide based sealer

3. Resin-based sealer

4. Glass ionomer based sealer

5. Bioceramic based sealer

6. MTA-based sealer

7. Silicon based sealer **(Tyagi et al., 2013)**

1.Zinc oxide-eugenol based sealer:

Early root canal sealers were modified zinc oxide-eugenol (ZOE) sealers based on Grossman or Rickerts's formula that were commonly used throughout the world.

Sealing properties of ZOE sealers were inferior in comparison to other sealers due to the relatively high solubility of the ZOE sealer; so, adhesion between GP and ZOE-Eugenol is cytotoxic and the same has been shown frequently for ZOE with different cell culture systems, especially after mixing, but also in a set state . Even higher cytotoxicity was observed with formaldehyde-containing ZOE sealers, which were classified as highly/extremely cytotoxic **(Tyagi et al., 2013).**

Advantage:

An advantage to this sealer group is antimicrobial activity **(Mickel et al., 2003).**

Disadvantage :

1. They exhibit a slow setting time **(Allan et al., 2001).**

2. Shrinkage on setting.

3. They can stain tooth structure **(Davis et al., 2002).**

4. Solubility.

<u>Eugenol group may be divided into subgroups namely:</u>

a. Silver containing cements :

- Kerr sealer (Rickert, 1931)
- Procosol radiopaque silver cement (Grossman, 1936)

b. Silver free cements :

- Procosol nonstaining cement (Grossman, 1958)
- Grossman's sealer (Grossman, 1974)
- Wach's paste (Wach)
- Tubliseal (Kerr, 1961) .**(Garg et al., 2010).**

1.1. Kerr Root Canal Sealer or Rickert's Formula:

The original zinc oxide-eugenol sealer was developed by Rickert .This is based on the cement described by Dixon and Rickert in 1931. This was developed as an alternative to the gutta-percha based sealers as they lack dimensional stability after setting .

Advantages :

1. Excellent lubricating properties.

2. Greater bulk than any sealer and thus makes it ideal for condensation techniques to fill voids, auxilliary canals an irregularities present lateral to gutta-percha cones .

Disadvantage :

The major disadvantage is that the presence of silver makes the sealer extremely staining if any of the material enters the dentinal tubuli.

Figure (1): Kerr Root Canal Sealer.

1.2. Grossman's Sealer (Grossman, 1974):

Properties:

1. It has plasticity and slow setting time due to the presence of sodiumborate anhydrate.

2. It has good sealing potential.

Disadvantage :

Resin has coarse particle size, so the material is spatulated vigorously during mixing. If it is not done, a piece of resin may lodge on the canal walls.

Figure (2): Grossman's Sealer.

1.3. Wach's Sealer:

Properties :

1. Minimal periapical irritation .

2. It is sticky due to the presence of Canada balsam .

Advantages :

1. It is germicidal . **2.** Less periapical irritation.

Disadvantage :

1. Odor of liquid.

2. Has less lubricating quality.

1.4. Tubliseal (1961):

Slight modifications have been made in Rickert's formula to eliminate the staining property. It has marketed as 2 paste system containing base and catalyst.

Advantages :

1. Easy to mix.

2. Does not stain the tooth structure.

Disadvantages :

1. Irritant to periapical tissue.

2. Very low viscosity makes extrusion through apical foramen.

Indications:

1. When apical surgery is to be performed immediately after filling.

2. Because of good lubricating property, it is used in cases where it is difficult for a master cone to reach last apical third of root canal.

Figure (3) : Tubliseal root canal sealer.

1.5. Medicated variations of ZOE-based sealer :

a- In USA : N2 and RC2B ; While in Europe : Endomethasone and SPAD.

b- Nogenol .

1.5.1. N2 :

N2 was introduced by Sargenti and Ritcher (1961). N2 refers to the so called second nerve. (Pulp is referred to as first nerve).

Composition of N2:

Powder : (Zinc oxide , Lead tetraoxide para , Paraformaldehyde , Bismuth subcarbonate , Bismuth subnitrate , Titanium dioxide , Phenyl mercuric borate).

Liquid: (Eugenol, Oleum rosae ,Oleum lavandulae).

The corticosteroids are added to the cement separately as hydrocortisone powder or Terra-Cortril. The object of introducing formaldehyde within the rootfilling is to obtain a continued release of formaldehyde gas, which causes prolonged fixation and antiseptic action.

Figure (4) : N2 root canal sealer.

1.5.2. Endomethasone:

The formation of this sealer is very similar to N2 composition .

Composition: **Powder -** (Zinc oxide , Bismuth subnitrate , Dexamethasone , Hydrocortisone , Thymol iodide , Paraformaldehyde).

Liquid - Eugenol .

Figure (5): Endomethasone root canal sealer.

1.5.3. Nogenol:

Was developed to overcome the irritating effect of Eugenol . **(Henstona et al., 2012).**

Base is ZnO with Barium sulfate as radiopacifier along with vegetable oil. Set is accelerated by hydrogenated rosin , chlorothymol and salicylic acid.

Figure (6) : Nogenol root canal sealer.

2.Calcium hydroxide-based sealer :

Calcium hydroxide sealers were developed for therapeutic activity. It was thought that these sealers would exhibit antimicrobial activity and have osteogenic–cementogenic potential **(Hargreaves et al., 2016).** The success of calcium hydroxide as a pulp protecting, capping agent and as an interappointment dressing prompted its use also in sealer cement formulations **(Ørstavik, 2005).**

All the calcium hydroxide tested sealers release calcium ions and are able to provide an alkaline medium thus having antimicrobial property **(Omar et al., 2010).** Cytotoxicity appears to be milder than other groups of sealers. Solubility is a concern, leakage of calcium hydroxide–based sealers are not superior to other groups of sealers, In an experimental study on monkey and dog teeth, Sealapex was found to stimulate apical closure by cementum deposition compared with Kerr root canal sealer (ZOE based sealer) when the root filling was 1 mm short of radiographic apex **(Desai and Chandler, 2009).**

Calcium hydroxide based sealers were improved to ensure adequate biological properties and a good sealing of root canal system. It was introduced by Merman in 1920, with a big interest in the 1960s

with generally favorable results. Calcium hydroxide had been selected as a

medication of choice for several clinical situations due to its biocompatibility, stimulation of the formation of mineralized tissue and its antimicrobial action

(Holland, 1999). The success of calcium hydroxide as a pulp protecting, capping agent and as an interappointment dressing prompted its use also in sealer cement formulations (Ørstavik, 2005). All the calcium hydroxide tested sealers release calcium ions and are able to provide an alkaline medium thus having antimicrobial property (Omar et al., 2010).cytotoxicity appears to be milder than other group of sealers. Solubility is a concern, leakage of calcium hydroxide–based sealers are not superior to other groups of sealers, In an experimental study on monkey and dog teeth, Sealapex was found to stimulate apical closure by cementum deposition compared with Kerr root canal sealer (ZOE based sealer) when the root filling was 1 mm short of radiographic apex (Desai and Chandler, 2009).

Calcium hydroxide based sealers were improved to ensure adequate biological properties and a good sealing of root canal system.

The two most important reasons for using calcium hydroxide as a root-filling material are stimulation of the periapical tissues in order to maintain health or promote healing and secondly for its antimicrobial effects. The exact mechanisms are unknown, but the following mechanisms of actions have been proposed:

- Calcium hydroxide is antibacterial depending on the availability of hydroxyl ions .It has a very high pH (hydroxyl group) that encourages repair and active calcification. There is an initial degenerative response in the immediate vicinity followed rapidly by a mineralization and ossification response
- The alkaline pH of calcium hydroxide neutralizes lactic ac osteoclasts and prevents dissolution of mineralized components of teeth. This pH also activates alkaline phosphatase that plays an important role in hard tissue formation
- Calcium hydroxide denatures proteins found in the root canal and make them less toxic.

 Calcium hydroxide activ e calcium-dependent adenosine triphosphatase reaction associated with hard tissue formation.

 Calcium hydroxide diffuses through dentinal tubules communicate with the periodontal ligament space to arrest external root resorption and accelerate healing (Dr. S. Pradeep, 2016).

Example of these products : Apexit Plus , Sealapex , Vitapex , Life , CRCS (Calciobiotic Root Canal Sealer) and MCS (Medicated root canal sealer) **(Henstona et al., 2012).**

2.1. Apexit Plus:

Is a calcium hydroxide based sealer.

Properties:

Biologically balance , easy flowing composition allows the material to adapt well to morphologically complicated canals , minor dimensional change , low solubility, enables good and durable sealing of the root canal **(Salz et al., 2009 ; Desai and Chandler, 2009; Marín-Bauza et al., 2012).**

Figure (7) : Apexit plus root canal sealer.

2.2. Sealapex (Sybron Endo/Kerr):

Is a calcium hydroxide containing noneugenol polymeric sealer that is packaged as two tubes. Sealapex has zinc oxide in the base along with calcium hydroxide and also contains butyl benzene, sulfonamide, and zinc stearate. The catalyst tube has barium sulfate and titanium dioxide for radiopacity, and a proprietary resin, isobutyl

salicylate, and aerocil R792 **(Ingle et al., 2002).**

It appears that Sealapex had a sealing ability comparable with Tubli-Seal and could withstand long-term leakage **(Sleder et al., 1991).**

Holland and De Souza studied Sealapex sealer to see if it could induce hard tissue formation. Sealapex with calcium hydroxide did encourage apical closure by cementum deposition. Closure was also observed in the control groups (5%) and in Kerr Pulp Canal Sealer groups (10%), but was associated with dentin chips that also stimulate cementum formation. Both Sealapex and Kerr Pulp Canal Sealer, when overextended, provoke a chronic inflammatory reaction in the periodontal ligament (PDL) **(Ingle et al., 2008).**

Advantages:

1. Biocompatible.

2. Good therapeutic effect.

3. Extruded material resorb in 4 months.

Disadvantages:

1. Long setting time.

2. Poor cohesive strength.

3. Absorbs water while setting and expands.

Figure (8) : Sealapex root canal sealer.

2.3. Vitapex (NEO Dental International, Inc, Federal Way,WA):

Is a sealer, which was developed in Japan, and contains, not only calcium hydroxide, but also 40% iodoform and silicone oil among other ingredients **(Ingle et al., 2008).**

Figure (9) : Vitapex root canal sealer.

2.4. Calcibiotic Root Canal Sealer (CRCS):

CRCS is a zinc oxide, eugenol-eucalyptol sealer to which calcium hydroxide has been added for its osteogenic effect **(Garg et al., 2010).** CRCS takes 3 days to set fully in either dry or humid environments.

Advantages:

1. Biocompatible. **2.** Takes three days to set. **3.** Stable in nature.

4. Shows little water resorption. **5.** Easily disintegrates in tissues.

Disadvantages: It shows minimal antibacterial activity.

Figure (10) : Calcibiotic Root Canal Sealer.

3. Resin-based sealer:

By far the most successful of the resin-based sealers has been the AH series. The first resin-based sealer has been proposed by Andre Schroeder in Switzerland , in 1954 , and contained epoxy resin and bisphenol **(Ørstavik, 2005).**

Since then, many studies have contributed to the improvement of sealers' properties, leading to the development of an epoxy resin-based sealer with adequate physicochemical characteristics such as Diaket (3M ESPE), AH-26

(Dentsply, DeTrey GmbH, Konstanz, Germany), AH Plus (Dentsply, DeTrey GmbH, Konstanz, Germany) **(Henstona et al 2012).**

Methacrylate resin sealers have been introduced in the beginning of the 21st century, aiming to create "mono-block" by the adhesion of the sealer to the thermoplastic polymer cone and the dentin walls of the root canal. The term monoblock refers to the scenario where in the canal space becomes perfectly filled with a gap-free , solid mass that consists of different materials and interfaces, with the advantages of simultaneously improving the seal and fracture resistance of the filled canals **(Kim et al., 2010).**

It is include four generations:

1. First generation : Hydron.

2. Second generation : EndoREZ.

3. Third generation : RealSeal/Epiphany, Fibrefill.

4. Fourth generation: RealSeal SE/MetaSEAL SE **(Tyagi et al., 2013).**

Resin-based root canal cements are increasingly gaining popularity because they exhibit long-term dimensional stability and do not contain eugenol. However the toxicity of resins and specifically the toxicity and the mutagenicity of resin based endodontic sealers are well documented **(huang et al., 2002).**

3.1. Epoxy resin-based sealer:

3.1.1. Diaket:

Diaket is a polyvinyl resin (Polyketone), a reinforced chelate formed between zinc oxide and diketone. It was introduced by Schmidt in 1951**(Garg et al., 2010).**

Advantages:

1. Good adhesion. **2.** Fast setting. **3.** Stable in nature. **4.** Superior tensile strength.

Disadvantages:

1. Toxic in nature. **2.** Tacky material so difficult to manipulate.

3. If extruded, can lead to fibrous encapsulation.

4. Setting is adversely affected by presence of camphor or phenol (used as intracanal medicaments).

3.1.2. AH-26 (DENTSPLY DeTrey, Konstanz, Germany):

This is an epoxy resin recommended by Shroeder in 1957. Epoxy resin based sealers are characterized by the reactive epoxide ring and are polymerized by the breaking this ring**(Garg et al., 2010).**

Feldman and Nyborg gave the following composition :

Powder : (Bismuth oxide 60 percent , Hexamethylene tetramine 25 percent , Silver powder 10 percent , Titanium oxide 5 percent).

Liquid : (Bisphenol diglycidyl ether).

Is a slow setting epoxy resin that was found to release formaldehyde when setting

(Koch, 1999).

Properties:

1. Good adhesive property. **2.** Good flow . **3.** Antibacterial .

4. Contracts slightly while hardening.

5. The addition of a hardener, hexamethylene tetramine, makes the cured resin inert chemically and biologically.

Advantages of AH-26:

1. High radiopacity. **2.** Iow solubility.

3. Slight shrinkage. **4.** Tissue compatibility.

Disadvantages:

1. Formaldehyde release .

2. Very toxic when freshly prepared but declines rapidly that after 24 hours .

3. The cement has one of the lowest toxicity among sealers , extended setting time [24 hours], and staining .

Figure (11): AH-26 Root Canal Sealer.

3.1.3. AH Plus (DENTSPLY DeTrey):

Is a modified formulation of AH-26 in which formaldehyde is not released **(Leonardo et al., 1999).** The sealing abilities of AH-26 and AH Plus appear comparable **(De Moor et al., 2004).**

AH Plus is an epoxy resin–amine based system that comes in two tubes. The epoxide paste tube contains a diepoxide (bisphenol A diglycidyl ether) and fillers as the major ingredients, while the amine paste tube contains a primary monoamine, a secondary diamine, a disecondary diamine, silicone oil, and fillers as the major ingredients. It exhibits a working time of 4 hours **(Hargreaves et al., 2016).**

Advantages:

1. Half the film thickness **2.** Half the solubility of regular AH26.

3. May be removed from the canal if necessary.

4. In a comparative toxicity study, AH Plus was found to be less toxic than regular

AH-26.

Figure (12) : AH Plus root canal sealer.

3.2. Methacrylate resin sealers :

3.2.1. First generation (Hydron) :

It was appeared in the mid 1970s when scientific foundations behind dentin bonding were at their infancy stage of development. The major component of Hydron was poly[2-hydroxyethyl methacrylate] (poly[HEMA]), which was injected into a root canal and polymerized in situ within the canal space without the adjunctive use of a root-filling material. Hydron became obsolete in the 1980s as subsequent clinical findings were unacceptable **(Hargreaves et al., 2016).**

3.2.2. Second generation (EndoREZ) :

The second generation of bondable sealer is nonetching and hydrophilic in nature and does not require the adjunctive use of a dentin adhesive.

EndoREZ (Ultradent Products Inc., South Jordan, Utah) :

Is a dual-cured radiopaque hydrophilic methacrylate sealer that contains non-acidic diurethane dimethacrylate. The addition of triethyleneglycol dimethacrylate to the sealer composition renders it hydrophilic, so that it may be used in the wet environment of the root canal system and be very effective in penetrating dentinal tubules and forming long resin tags**(Bergmans et al., 2005).**

EndoREZ is recommended for use with either a conventional gutta-percha cone or with specific EndoREZ points (resin-coated gutta-percha). A retrospective clinical and radiographic study evaluating the 10-year treatment outcome of one-visit root canal treatment using gutta-percha and the EndoREZ sealer reported accumulative probability of success of 92.1% after 10 years **(Zmener et al ., 2012).**

Figure (13) : EndoREZ root canal sealer.

3.2.3. Third generation (RealSeal/Epiphany, Fibrefill) :

The third generation self-etching sealers contain a self-etching primer and a dual-cured resin composite root canal sealer. An acidic primer is applied to the dentin surface that penetrates through the smear layer and demineralizes the superficial dentin. The acidic primer is air-dried to remove the volatile carrier and then a dual-cured moderately filled flowable resin composite sealer is applied and polymerized. Provided that these materials are sufficiently aggressive to etch through thick smear layers, the technique sensitivity of bonding to root canals may be reduced when smear layers are inadvertently retained in the apical third of instrumented canal walls.

Third-generation methacrylate resin–based sealers that incorporate the use of self-etching primers became popularized following the introduction of Resilon (Resilon Research LLC, Madison, Connecticut), a dimethacrylate-containing

polycaprolactone-based thermoplastic root-filling material **(Shipper et al., 2004).**

3.2.4. Fourth generation (RealSeal SE/MetaSEAL SE) :

The fourth-generation is functionally analogous to a similar class of recently introduced self-adhesive resin luting cements in that they have further eliminated the separate etching/bonding step **(Radovic et al., 2008).**

Acidic resin monomers that are originally present in dentin adhesive primers are now incorporated into the resin-based sealer/cement to render them self-adhesive to dentin substrates. The combination of an etchant, a primer, and a

sealer into an allin-one self-etching, self-adhesive sealer is advantageous in that it reduces the application time as well as errors that may occur during each bonding step.

3.2.4.1. MetaSEAL SE:

It is the first commercially available fourth-generation self-adhesive dual-curable sealer **(Lawson et al., 2008).**

Composition:

The liquid component of MetaSEAL comprises 4-META, HEMA and difunctional methacrylate monomers.

The powder contains zirconium oxide as spherical radiopaque fillers, silica nanofillers, and a hydrophilic initiator.

The inclusion of an acidic resin monomer, 4-methacryloyloxyethyl trimellitate anhydride (4-META), makes the sealer self-etching and hydrophilic in nature and promotes monomer diffusion into the underlying intact dentin to produce a hybrid layer after polymerization.

According to the manufacturer, MetaSEAL is recommended exclusively for cold compaction and single-cone techniques and supports the use of either Resilon or guttapercha as a root-filling material. The sealer purportedly bonds to thermoplastic root-filling materials as well as radicular dentin via the creation of hybrid layers in both substrates **(Hargreaves et al., 2016).**

MetaSEAL is also marketed as Hybrid Bond SEAL (Sun Medical Co. Ltd., Shiga, Japan) in Japan.

Figure (14) : MetaSEAL SE root canal sealer.

3.2.4.2. RealSeal SE :

It is the simplified dual-cured version of RealSeal and uses a polymerizable methacrylate carboxylic acid anhydride (i.e., 4-META) as the acidic resin monomer **(Babb et al., 2009).**

It contains EBPADMA, HEMA, BisGMA, benzoyl peroxide, tertiary amine, photoinitiators, silane-treated barium borosilicate glass, silica, bismuth oxychloride, Ca-Al-F silicate, tricalcium phosphate as additional components.

It may be used with Resilon cones or pellets using cold lateral or warm vertical techniques, or with RealSeal 1, a carrier-based Resilon obturator system **(Heeren et al., 2012).**

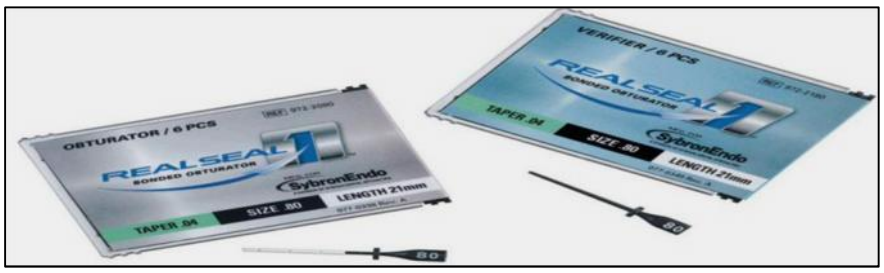

Figure (15) : RealSeal SE root canal sealer.

4.Glass ionomer-based sealers:

Glass ionomer cements used as a root canal sealer, however, have mostly investigated in vitro and their use remains a matter of debate as a result of inconclusive findings on their sealing ability and antimicrobial activity.

GICs considered to be biocompatible and to show some adhesion to dentin, both of which are seen as desirable properties in a root filling **(Ørstavik, 2005).**

Disadvantage: (Hargreaves et al., 2016).

1. They must be removed if retreatment is required.

2. This sealer has minimal antimicrobial activity.

4.1. Ketac Endo sealer (3M ESPE, St. Paul, Minnesota) :

It is a GIC modified in its characteristics by a group at Temple University to be used as sealer into the root canal. It was introduced in dentistry in 1971 by Wilson and Kent as a restorative material. In 1991, it was introduced as

endodontic sealer. It provides adequate chemical, physical and biological properties **(Henstona et al., 2012).**

Composition: Powder (Calcium aluminium lanthanum flurosilicate glass, Calcium volframate, Cilicic acid Pigments).

Liquid (Polyethylene polycarbonic acid/Maleic acid, Copolymer, Tartaric acid, Water).

Advantages:

1. Optimal physical qualities. **2.** Shows bonding to dentin.

3. Shows minimum number of voids. **4.** Low surface tension.

5. Optimal flow property.

Disadvantages:

It cannot be removed from the root canal in the event of retreatment as there is no known solvent for glass ionomer. However, Toronto/Osract group has reported that Ketac- endo sealer can be effectively removed by hand instruments or chloroform solvent followed by 1 minute with an ultrasonic No. 25 file **(Garg et al., 2010).**

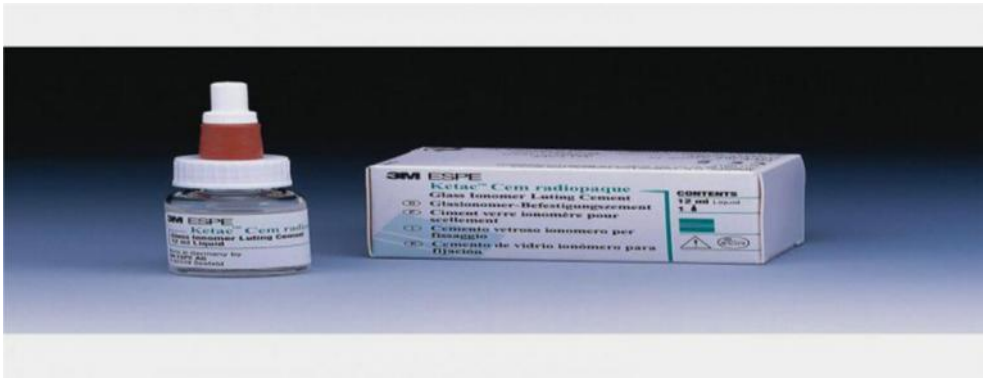

Figure (16) : Ketac Endo sealer .

4.2. Activ GP (Brasseler USA, Savannah Georgia):

Consists of a glass ionomer–impregnated gutta-percha cone with a glass ionomer external coating and a glass ionomer sealer . Available in 0.04 and

0.06 tapered cones, the sizes are laser verified to ensure a more precise fit. **(Hargreaves et al., 2016).**

This single cone technique is designed to provide a bond between the dentinal

canal wall and the master cone (monoblock).

A bacterial leakage study comparing Activ GP/glass ionomer sealer, Resilon/Epiphany, and gutta-percha (GP)/AH Plus demonstrated no statistically significant differences at 65 days **(Fransen et al., 2008).**

Figure (17) : Activ GP root canal sealer.

5. Bioceramic-based sealer :

The introduction of a bioceramic sealer (Endo Sequence BC sealer, Brasseler USA) allows us, to take all the advantages associated with bioceramics and not limit its use to only root repairs and apical retrofills material.

This is possible only because of new nanotechnology developments; the particle size of bioceramic sealer is so fine (less than two microns).

It can actually be delivered with a 0.012 capillary tip with a premixed syringe, thus the need for mixing of the sealer is not required which avoids problems such as insufficient and non homogenous mix. This material was specifically designed as a non toxic calcium silicate cement that is easy to use as a root canal sealer. It is consist of zirconium oxide, calcium silicates, calcium hydroxide, calcium phospahate monobasic, filler and thickening agents. The calcium silicates in the powder hydrate to produce a calcium silicate hydrate gel and calcium hydroxide. The calcium hydroxide reacts with the phosphate ions to precipitate hydroxyapatite and water.

The water continues to react with the calcium silicates to produce additional gel like calcium silicate hydrate **(Koch et al., 2012).**

In 7 days, Endosequence BC Sealer presented the highest rate of Ca2+ release, and this fact might be related with the final setting time of this material that occurs between 7 and 10 days in moist medium. Another interesting fact is that the release of calcium and hydroxyl ions from the calcium silicate – containing material might result in the formation of an apatite layer when it comes in contact with phosphate containing fluids for 2 months. Thereby, formation of this interfacial layer develops a chemical bond between calcium silicate based materials and dentinal walls **(Koch et al., 2012).**

Bioceramics are highly successful endodontic sealers and have several **advantages such as :**

1. Improved biocompatibility .
2. Sealing ability .
3. Have a high pH (12.8) during the first 24 hrs of the setting process make it strongly antibacterial, and an increase in strength of root following obturation.
4. The extreme biocompatibility of bioceramics can also be observed in cases of root repair where there is absence of inflammation and pain or minimal pain following an overfilling during obturation **(Malhotra et al., 2014).**
5. Bioceramics are hydrophilic in nature and have the ability to form Hydroxyapatite , this lead to the formation of a chemical bond between the filling material and dentinal walls, so eliminates the presence of any space between the dentinal walls and sealer which enhances the seal **(Kossev and Stefanov, 2009).**
6. It has dimensional stability and don't shrink upon setting (it actually expands 0.002 percent) and when it is completely set, the material will not resorb **(Koch and Brave, 2009).**

7. Bioceramic sealers are very promising in terms of strengthening the residual root and increase the fracture resistance to a level comparable to that of teeth that have not undergone root canal therapy **(Ghoneim et al., 2011).**

EndoSequence BC Sealer (Brasseler USA) , iRoot SP (Innovative BioCeramix Inc.,Vancouver,Canada), iRoot BP (Innovative BioCeramix Inc.,Vancouver,Canada), Bioaggregate (Innovative BioCeramix Inc.,Vancouver,Canada) are examples of a bioceramic based sealer **(Tyagi et al., 2013).**

5.1. EndoSequence BC Sealer:

EndoSequence BC Sealer is a premixed ready-to-use injectable bioceramic cement paste developed for permanent root canal filling and sealing applications. EndoSequence BC Sealer is an insoluble, radiopaque and aluminum-free material based on a calcium silicate composition, which requires the presence of water to set and harden. EndoSequence BC Sealer does not shrink during setting and demonstrates excellent physical properties. EndoSequence BC Sealer is packaged in a pre-loaded syringe and is supplied with disposable Intra Canal Tips.

Composition: Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents.

Indications for Use:

1. Permanent obturation of the root canal following vital pulp-extirpation.
2. Permanent obturation of the root canal following removal of infected or necrotic pulp and placement of intracanal dressings.

EndoSequence BC Sealer is suitable for use in the single cone and lateral condensation technique. EndoSequence BC Sealer can be applied immediately and introduced directly into the root canal. The working time can be more than 4 hours at room temperature.

The setting time of EndoSequence BC Sealer is dependent upon the presence of moisture in the dentinal tubules. The amount of moisture required for the setting reaction to occur reaches the root canal by means of the dentinal tubules. Therefore, it is not necessary to add moisture in the root canal prior to performing the obturation. Removal of Root Canal Filling: Conventional techniques can be used for the removal of EndoSequence BC Sealer as used in combination with Gutta-Percha Points. Piezo Electric Ultrasonics (with water spray) can also be used.

Figure (18) : EndoSequence BC Sealer.

5.2. iRoot SP (Innovative BioCeramix,Vancouver, Canada):

iRoot SP has been introduced in an attempt to address the inherent problems with existing sealers and biocompatibility particularly when extruded beyond the confines of the root canal.

Calcium silicate sealers include some of the same hydraulic compounds found in Portland cement including tricalcium silicate and dicalcium silicate powder that react with water to form a highly alkaline cement (pH 12) to create a rigid matrix of calcium silicate hydrates and calcium hydroxide. When these sealers set, the dimensional change is less than 0.1% expansion, which help create a barrier that superior sealing ability. The combination of a hydrophilic sealer that is biocompatible with excellent dimensional stability seems ideal, particularly with the potential of obturation materials coming into contact with fluid either apically or coronally potentially salvaging a compromised seal **(Patel , 2016).**

Figure (19) : iRoot SP root canal sealer.

6. MTA- based sealer:

Study by **(Holland et al., 1999)** compared glass ionomer root canal sealer (Ketac Endo) with MTA as a sealer and concluded that MTA induces closure of main canal foramen by new cementum formation with absence of inflammatory cells after 6 months. **(Holland et al., 2001)** Examined influence of the extent of obturation on apical and periapical tissue after filling root canal with MTA and concluded that

It can be used as root canal sealer. This sealer produces calcium hydroxide, which is released in solution and stimulated the formation of hydroxyapatite structures in simulated body fluid .

Advantages :

1. Sealers containing MTA are highly biocompatible and stimulate mineralization **(Gomes-Filho et al., 2009).**

2. They are bioactive, i.e. hard tissue inductive by encouraging differentiation and migration of hard tissue producing cells **.**

3. It modulates cytokinin production **(Taddei et al., 2009).**

4. They form a hydroxyapatite (or carbonated apatite) on the MTA surface and provide biologic seal **(Bozeman et al., 2006).**

5. MTA is a nonmutagenic and non-neurotoxic.

Disadvantages :

1. It may cause discoloration due to release of ferrous ions .

2. Compressive strength is inadequate .

3 . No known solvent can remove it from the root canal during retreatment **(Rautiya et al, 2013)** and extrusion of material outside the root canal is associated with severe pain felt by the patient **(Tyagi et al., 2013).**

Different MTA-based root canal sealers are:

1. ProRoot Endo Sealer (Dentsply Tulsa Dental Specialties, Dentsply/Maillefer, Ballaigues, Switzerland).
2. Fillapex (Angelus).
3. CPM Sealer (EGEO SRL, MTM Argentina SA, Buenos Aires, Argentina).
4. MTA Obtura (Angelus, Angelus Odontologica, Londrina, PR, Brazil).
5. F-doped MTA cements.

6.1. ProRoot Endo Sealer (Dentsply Tulsa Dental Specialities):

ProRoot Endo Sealer is calcium silicate-based endodontic sealer to be used in conjunction with root filling material in either cold lateral warm vertical or carrier-based filling technique.

The major components of the **powder o**f ProRoot Endo Sealer are tricalcium silicate and dicalcium silicate, with inclusion of calcium sulfate as setting retardant, bismuth oxide as radiopacifier and a small amount of tricalcium aluminate. The **liquid component** consists of viscous aqueous solution of water soluble polymer.

It exhibit biocompatibility when in contact with physiologic solution **(Huffman et al., 2009).** There is also release of calcium and hydroxyl ions from the set sealer liquid **(Tay et al., 2007).**

Similar to other calcium silicate containing biomaterial, MTA sealer produce calcium hydroxide on reaction with water. These phenomena may account for in vitro bioactivity of ProRoot MTA sealer.

Microleakage studies of ProRoot MTA sealer showed similar sealing ability to epoxy resin-based sealer superior to zinc oxide eugenol-based root canal sealers when evaluated using fluid filtration system **(Torabinejad et al., 2010).**

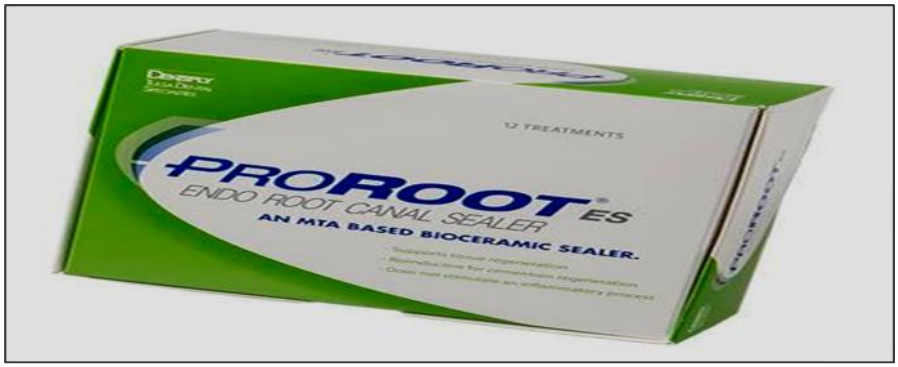

Figure (20) : ProRoot Endo Sealer.

6.2. MTA Fillapex Root Canal Sealer (Angelus):

A MTA endodontic sealer was recently created. According to the manufacturer, its composition after mixture is basically MTA, salicylate resin, natural resin, bismuth and silica . MTA Fillapex is first paste:paste MTA-based salicylate resin root canal sealer, versatile for every obturation method. It delivers easily and without waste, and exhibits excellent handling properties with an efficient setting time

(Kuga et al., 2011).

It has excellent antibacterial properties, as solubility is extremely low (0.1%), thus, it does not erode with time like the other sealers making the root susceptible to microgaps that allow bacteria to re-enter the canal.

It should be only used as endodontic sealer, mainly in endodontic accidents of difficult access, since its physicochemical characteristics differ from gray and white MTA. Notwithstanding, the material presents an alkaline pH similar to that of the clinically and scientifically well- established sealers **(Tanomaru et al.,2007).**

Figure (21): MTA Fillapex Sealer.

6.3. CPM Sealer (EGEO SRL, MTM Argentina SA, Buenos Aires, Argentina):

In 2004, CPM sealer was developed in Argentina , in an attempt to combine the sealing and physiochemical properties of root canal sealer with biological properties of MTA.

Powder consists of fine hydrophilic particles that form a colloidal gel in presence of moisture. The main components are tricalcium silicate, tricalcium oxide,
tricalcium aluminate and other oxides.

Liquid solution consists of saline solution and calcium chloride . It becomes solid and forms a hard sealer in 1 hour **(Scarparo et al., 2010).**

It has good antimicrobial activity and satisfactory radiopacity.Moreover, culture with fibroblast revealed that it is not cytotoxic**(Tanomaru et al.,2007).**

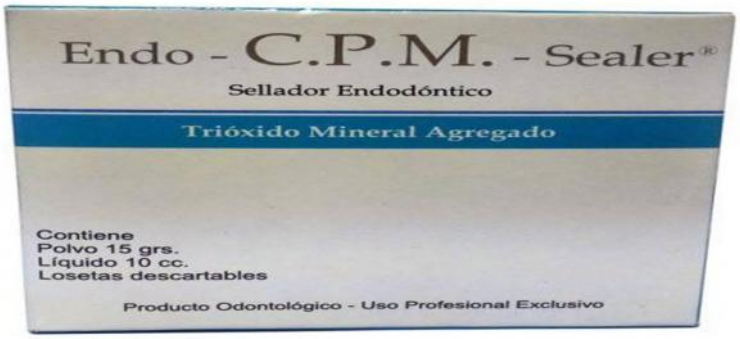

Figure (22): CPM root canal Sealer.

6.4. MTA Obtura :

This sealer was developed by replacing saline with a liquid resin as cure initiator. The composition of the powder in this cement is similar to gray MTA Angelus, consisting of Portland cement clinker and bismuth oxide. The development of MTA Obtura aimed at the achievement of an endodontic sealer combining the biological and sealing properties of MTA Its performance

reproduced the good sealing ability of MTA as repair material **(Namazikhah et al., 2008).**

Study, conducted by **(Bernardes et al., 2010)** MTA Obtura presented the lower flow rate (27.65 mm). Because of this property, MTA Obtura will probably penetrate with more difficulty in ramifications and irregularities of root canal walls than the other sealers tested.

6.5. F-doped MTA Cements:

Composition: **Powder -** White Portland cement, bismuth oxide, anhydrite, sodium fluoride (Carlo Erba, Italy).

Liquid - Consist of Alphacaine SP solution. Sodium fluoride was included in FMTA as an expansive and retardant agent.

Osteoconductive activity is an important property in a sealer for biological response and new bone tissue formation and repair because the extrusion of sealer from the apex is a frequent occurrence in clinical practice. So the fluoride- containing cement revealed a better sealing ability likely because of greater expansion **(Gandolfi et al., 2010).**

Moreover, fluorine ions from the cement may penetrate into the dentine and enhance the mineralization of dentine and may also plug and close dentinal tubules. The setting reaction of the cement involves the continuous formation of hydration products that contribute to reducing the microchannels in the cement bulk **(Girao et al., 2007).**

7. Silicon-based sealer:

Silicone was first introduced as endodontic sealer in 1984.

Advantage : **1.** Non-toxic. **2.** Display comparatively little leakage.

Disadvantage : No antibacterial activity .

RoekoSeal (Roeko, Langenau, Germany) and GuttaFlow are examples of a silicon based sealer. **(Tyagi et al., 2013).**

7.1. RoekoSeal (Coltène/Whaledent) :

Is a polydimethylsiloxane that has been reported to expand slightly on setting **(Ørstavik et al., 2001).**

The manufacturer stated that this silicone-based sealer expands slightly on setting (0.2%) and is highly radiopaque.

the claimed advantages include :

1. Good sealing ability **(Wu M-K et al., 2002).**

2. Excellent biocompatibility **(Miletic et al., 2005).**

However, in a histopathological study on periapical healing in dog's teeth, no differences were noted between RoekoSeal and AH Plus **(Leonardo et al., 2008).**

Figure (23) : RoekoSeal root canal sealer.

7.2. GuttaFlow (Coltène/Whaledent):

It introduced in 2004, is a modification of RoekoSeal. The material is considered to be almost insoluble. It is used with a single master gutta-percha cone, without mechanical compaction, although lateral or vertical condensation are acceptable.

Its flow is significantly better into lateral grooves and depressions in the apical regions of root canals than lateral condensation or warm compaction with AH 26 sealer **(Zielinski et al., 2008).**

Its sealing qualities are similar to lateral compaction or the System B technique with AH 26 **(Kontakiotis et al., 2007).**

GuttaFlow has a working time of 15 minutes and a setting time of about 30 minutes; GuttaFlow FAST has a 5 minute working time and a 10 minute set.

A potential concern is extrusion of material beyond the apex **(Zielinski et al., 2008) ,** although its cytotoxicity is lower than some other sealers.

Figure (24) : GuttaFlow root canal sealer.

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