

Contemporary Endodontic Sealers

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Introduction

Endodontic treatment over goes multiple phases to ensure long term successful outcome. Starting with an accurate diagnosis and treatment planning, through proper debridement and disinfection of the root canal system. Finally maintaining a sterile environment of the pulpal space, by filing its root's with an inert biocompatible material and securing it with a final restoration, a process known as obturation. Accordingly, quality of the seal was shown to be an influencing factor in the long term success of an endodontic treatment, as root canal obturation act as a barrier isolating both periapical tissue and radicular space from ingress of microbial contaminant, and promotes healing as it entombs any remaining pulpal or microbial irritants. (1)(2)

Traditionally, root canal obturation consist of a core material most typically gutta-percha (GP), and some sort of an endodontic sealant to produce a homogenous filling. (3) These Sealers play a major role in obturation by overcoming the physical limitation of the core material, they help to seal minor anomalies, accessory canals and foramina, and fill any voids between root canal walls and core material. (4) Sealers also facilitate placement of core material. (5)(6) While the broader objective of these sealers is to ban microbial ingress, some sort of micro leakage does occur in almost all types of sealant used. (7)

Apart from antimicrobial activities, ideal properties desired in an endodontic sealer were outlined by Grossman. These sealers must be biocompatible or at least non-toxic, insoluble in tissue fluids but dissolve in retreatment solvent, and must display excellent sealing ability. Other include; appropriate adhesion to dentinal walls, bacteriostatic, dimensionally stable, provide adequate working time, radiopaque, and must not stain the tooth. (8) Unfortunately, no available sealer displays all of these properties yet. (9) In light of this, selection of any type of an endodontic sealer could therefore affect treatment outcome. (10-13)

Root canal sealers are available in various quantities and have been grouped in a number of arrangement according to either their chemical composition, usage, or tissue absorbance (14) This paper will touch upon conventional ones and will attempt to introduce contemporary and new ones.

Conventional Endodontic Sealer

Zinc oxide–eugenol (ZOE) sealers have been used for a period of time and proven to be popular among clinicians mainly due to their significant antimicrobial activities. (15) These sealers chemically set's when mixing zinc oxide, the main powder part, with eugenol the liquid portion. They are available in many variations but mainly they are based on Rickert's (16) or Grossman's (3) formulas, with zinc oxide as the primal component. Rickert's sealers are marketed as: Pulp Canal sealer (SybronEndo), Procosol (Procosol, Inc., Philadelphia, Pennsylvania), while Grossman's as: Roth's Sealer (Roth International), Tubli-Seal (SybronEndo), and Wach's Sealer (Balas Dental, Chicago, Illinois), in which all of these ZOE sealers demonstrate shrinkage upon setting (17), tooth staining (18), solubility (19), and a slow setting time. (20) Fast time setting in some of these sealers were extended, while other differ only by adding other ingredients to enhance their properties. Chemicals such as: Canada balsam or rosin were added to improve adhesion, paraformaldehyde for its antimicrobial effect, which all could increase these sealers toxic effect especially when extruded to preiapical tissues. (21) (22) However, ZOE sealers cytotoxicity's do not apparently affect clinical outcome (23) (24) and still produce acceptable results, although their ability to effectively seal were shown to be inferior to other type of sealers. (25)

Contemporary Endodontic Sealer

Conventional ZOE sealers possess their own flaws, they lack the ability to adhere to dentin, thus they are unable to strengthen compromised roots or at least prevent microleakage, which leads to uncertain prognosis. (26-28) Therefore, other approaches were pursued in search for a material with better seal qualities, mainly by increasing adhesion to root canal walls, or substituting the gutta-percha core material with alternatives that are capable of sealing and reinforcing weakened roots by forming a monoblock. (28) This monoblock refers to a root canal filling that function as a single unit consisting of multiple materials that forms a gap-free solid mass and entirely seal the root canal system, which has been advocated to prevent microbial ingress and strengthen the filled roots. (29-31)

Hence, resin monomers were incorporated in endodontic sealers to increase dentinal bonding strength thereby improving the quality of the seal compared to conventional sealers. (26) (28) These include epoxy resin-

based sealers which they have a long history of use, primarily due to their superior ability of adhesion to dentine with lesser rates of solubility when compared to ZOE sealers. (32) (33). Silicon-based sealers reported to be very biocompatible with appropriate sealing abilities, and a potential to form a monoblock. (34-37) And more recently, mineral trioxide aggregate (MTA)-based sealers drew strong interest due to their bioactivity and biocompatibility. (38) (39)

Resin based sealers

These sealers are frequently used among clinicians because of their reliable outcome. (40) They exhibit better flow penetrating dentinal tubules, thereby improving the adhesive bond. (41) These sealers can be classified into: epoxy resin–based and methacrylate resin–based sealers.

AH Plus (DENTSPLY DeTrey, Konstanz, Germany)

AH Plus is a two paste system, based on polymerization reaction of epoxy resin amines.(42) The epoxide paste mainly contains a diepoxide (bisphenol A diglycidyl ether) and radiopaque fillers, the amine paste contains three types of amine, silicone oil, and fillers as the main components. (43) Among different types of sealers available today AH plus is the most widespread and considered as the 'gold standard' endodontic sealer. (44-46) Due to its long-term dimensional stability, biocompatibility, and greater adhesion to dentin this sealer demonstrate better apical seal compared to others which render it to be used as a control material in research. (47) (48) (49) This sealer was shown to have better penetration into root canal irregularities, mainly due to its long setting time and flow ability, thereby increasing its micromechanical bond to root's dentin. (50) However, it lacks the ability to bond with gutta-percha, presumably enabling leakage at this interface. (44)

Methacrylate Resin Sealers

These sealers are driven from advancement in polymer resin technology used in adhesive dental restorative materials. The hydrophilic properties of these materials enable them to penetrate dentinal tubules to which they bond by forming a hybrid layer. (51) Four generations of methacrylate resin–based sealers have been launched to date (52), of which the focus will lay on EndoREZ and the RealSeal system as they dominate the market.

EndoREZ (Ultradent Products Inc., South Jordan, Utah) is a dual-cured self-priming methacrylate sealer based on urethane dimethacrylate (UDMA). (53) Available as a two-component (base and catalysts) with hydrophilic properties and recommended to be used with resin-coated gutta-percha to form a monoblock . (54) (55) Early studies reported that EndoREZ is biocompatible and others found it to react more favorably than AH Plus. (56-60) In contrasts, cytotoxicity of this sealer have been demonstrated in other laboratory and animal studies. (61) (62) It is believed that the UDMA in this sealer formula could be responsible for the cytotoxic effect. (63). EndoREZ was found to be more effective in sealing when compared to ZOE sealers (64), non-difference to AH Plus (65), and sealed better in slightly moist canals. (66) Others reported poor sealing ability due to its higher water sorption and polymerization shrinkage which can lead to formation of gaps in the resin-dentin bond. (67) (55) And others argue that heat and manipulation during compaction could expedite or disturb the developing bond. (68) (69) Nevertheless, favorable clinical performance of this sealer have been reported and it is still being used today. (70) (51)

The RealSeal System (SybronEndo, Orange, CA, USA) consist of a thermoplastic synthetic core material (Resilon) used with the dual cure resin sealer (Epiphany). (71) The Resilon core, handles like gutta-percha, composed of polyester-polymers-based resin, bioactive glass, and radiopaque fillers. (72) The Epiphany sealer is a resin-based sealer composed of bisphenol A-glycidyl methacylate (Bis- GMA), ethoxylate Bis-GMA, UDMA, and hydrophilic difunctional methacylates with radio opaque fillers. (42) In addition, this system incorporates a self-etching primer to facilitate an effective bond between the dentine-sealer interface, while the Resilon core chemically integrates with the Epiphany sealer to form a single entity or a monoblock. (73) Canals filled with this system showed less microleakage than conventional sealers. (72) The relatively good performance of this sealant when compared to gutta-percha/AH Plus was asserted by studies using fluid filtration technique. (74-76) Others using dye testes reported superior apical seal over AH Plus/gutta-percha and similar results to Endosequence BC (a bioceramic sealer), which according to the authors could be due to formation of hybrid layer on dentine. (44) (77). An immediate coronal seal following light cure of this system have been reported which can be advantageous in surgical endodontics. (78) Recent research's indicates that canals filled with Resilon demonstrate higher resistance to fracture and better sealing abilities compared to ones filled with GP and resin-sealers which could allegedly reinforce compromised roots. (29) (30) (79) This root canal sealer was the only one that exhibited intraosseous biocompatibility among other resin based sealers and causes less inflammation upon contact with periapical tissue. (80) (81) In spite of the good properties of this system, concerns to the bonding ability of this sealer have been raised. An electron microscope scanning study reported no difference between AH Plus used with gutta-percha and Resilon/Epiphany with regard to sealer-dentin bond. (52) The ability of the Resilon core to chemically bond to methacrylate-based root canal sealers has also been

doubted due to the inadequate amount of dimethacrylate needed in this composite. (82) Additionally, the high amount of fillers content in Resilon (70% by weight) could leach as a result of degradation and induce cytotoxicity. (42) Furthermore, biodegradation of Resilon by microbial or salivary enzymes could happen through leakage as this material was found to be vulnerable to alkaline and enzymatic hydrolysis. (83) (84)

Silicone based sealers

The initial version of this sealer is marketed as RoekoSeal (Coltène/Whaledent) which reported to expand on setting and promote low leakage. (34) (45) (85) Modification of RoekoSeal by adding fine gutta-percha particles have led to the development of GuttaFlow (Coltène/Whaledent) More recently, GuttaFlow 2 was released as an advancement of the initial GuttaFlow, which have similar components but in altered proportions and supplied in an automix syringe. (86)(87) Also a novel sealer called GuttaFlow bioseal containing calcium silicate particles was launched with intent to stimulate the natural regeneration mechanism. (88) The original GuttaFlow will be presented here as the latest two modifications do not have enough scientific publications yet.

GuttaFlow (Coltène/Whaledent)

GuttaFlow is self-cured, cold flowable gutta-percha sealer, mainly composed of gutta-percha powder, poly-dimethyl-siloxane, and Nano-silver particles as preservatives. (89) (90) Owing its Nano-size particles (less than 30 nm), this sealer is belived to flow readily into the root canal system and fill any space between the canals and the gutta-perca core. (91) Additionally, the ability of Guttaflow to slightly expand (0.2%) after setting resulted in good sealing properties. (92) (93). Furthermore, Guttaflow was shown to be insoluble in tissue fluids (67), and inherently biocompatible when compared with other sealers both in vitro and in vivo. (62) (67) (94-99). Different results were reported by studies evaluating the sealing ability of this sealer with others. In an assessment of coronal leakage, a study using a fluid-transport model, found AH26 used with laterally-compacted gutta-percha or with System B technique to significantly leak more after 12 months than GuttaFlow used with a single cone gutta-percha. (89) Contradicting this finding, another study using the same methods, reports that GuttaFlow was inferior to AH Plus. (100) With regard to microbial leakage studies, one study reports better apical seal with AH Plus over GuttaFlow sealents. (101) While others using lateral condensation with GuttaFlow revealed the best results when compared to AH plus or conventional root canal sealers. (102). (103) The variability between these studies could be attributed to different evaluation methodology. The concern with GuttaFlow is that the residual traces of irrigants could inhibit setting of this sealer. (93)

Bioceramic-Based Sealers

A new category of root canal sealers has recently been prevalent in endodontics, based on the development of bioceramic technology in dentistry. These ceramic material are proposed for tissue repair and regeneration and therefore termed bio-ceramic. Based on their interaction with living tissue they can be classified as bio-active or bio-inert (104) The main advantages of these sealers are thought to be their underlying biocompatibility which lend them to be accepted by surrounding tissue. Additionally, with regards ot obturation, they will not invoke inflammatory response upon contact with periapical tissue. (105) And most notably, their ability to form hydroxyapatite and create an effective bond at the dentine-sealer interface. (106) However, once they set, the difficulty in removing them upon retreatment regarded as a disadvantage of these sealers. (107) they are commercially available according to their main components as:

- Calcium silicate-based sealer (EndoSequence BC Sealer, iRoot SP).
- MTA-based sealer (MTA-Fillapex, Endo CPM sealer, MTA-Angelus, ProRoot Endo Sealer).
- Calcium phosphate-based sealer (Sankin apatite root canal sealer I-III, Capseal I and II).

Calcium silicate-based sealer

This calcium silicate-based sealer is marketed as EndoSequence BC (Brasseler, Savannah, GA, USA) or iRoot SP (Innovative BioCeramix Inc., Vancouver, BC, Canada) in other countries. (28) This sealer is a mixture of nanosphere components mainly calcium silicate (tricalcium silicate, dicalcium silicate), calcium hydroxide, monobasic calcium phosphate, and a radiopacifier similar to white MTA. (108) (109) According to the manufacturer, this sealer employs a water-free thickening vehicles to form a premixed paste ready to be injected, and utilizes dentinal tubules moisture to set via its hydrophilic properties. (109) Additionally, this sealer is insoluble, aluminum-free, and could chemically bound to dentine during the setting process via hydroxyapatite formation. (108) (110) (111) Unexpectedly the bond strength is not affected by the presence or absence of smear layer. (112) (113) In addition, the hydrophilic property of this sealer promote it to expand, thus increasing the total seal of root canal system with the aforementioned chemical bonding. (99) (114) When compared to AH Plus, Epiphany, and MTA Fillapex, iRoot SP exhibited the highest bond strength to root dentin. (115) A study evaluating the fracture resistance of obturated roots, indicates that iRoot SP could potentially strengthen endodontically treated teeth. (116) In terms of apical leakage, iRoot SP similar to AH Plus were found to be

superior than EndoREZ. (117) The high bond strength of this sealer to the dentin walls could render it to be highly difficult to remove, as a study evaluating retreatment of canals obturated with this system, concluded that conventional retreatment techniques could not fully remove this sealer. (118) In contrast, another study reported that this sealer is comparable to AH Plus in terms of removability. (119) This sealer poses excellent antimicrobial properties especially during the first 24 hours of the setting process due to its high pH (12.8). (120) Although this sealer showed some toxicity when freshly mixed (like all other types of sealers), the cytotoxicity decreased over time and has been demonstrated to be biocompatible, thus could potentially serve as a root-end filling. (99) (108) (121) When compared to MTA Fillapex, freshly mixed or set EndoSequence BC sealer showed better cytocompatibility according to an in vitro study evaluating the toxic effect of these sealers on human gingival fibroblasts. (122) On the contrary, iRoot SP was significantly more toxic than ProRoot MTA to the L-929 cells. (123)

MTA-based sealer

These sealers are based on the the widespread successful outcome of MTA products used in surgical endodontic and conservative vital pulpal therapies. (124-126) MTA materials are known for their biocompatibility and excellent sealing capacity. (127) (128) Most significantly they are widely desirable for their bioactivity (129) (130), as they produce calcium hydroxide in solution upon contact with tissue fluids facilitated by their hydrophilicity to form hydroxyapatite. (131-134) However, physical properties of MTA (consistency, coarseness, flow rate and film thickness >50 µm), made it unsuitable to be used as a root canal sealant. (135) Hence, the introduction of MTA-based root canal sealers, all of which they have tricalcium silicate powder in their mixture. (39)

New formulation of this material yielded in creating Endo CPM sealer (EGEO, Buenos Aires, Argentina). This sealer is supplied as powder/ liquid systems mixed in a ration of 4:1, in which the hydrophilic fine powder in the existence of moistness forms a gel mixture. (136) Similarly, MTA Plus (Avalon Biomed, Bradenton, Florida), if which the mixture ratio was adjusted, it can work as a cement or a sealer. (39) Another Sealer of this group is MTA-Angelus/MTA Obtura (Angelus, Londrina PR, Brazil), which mainly contains Portland cement and bismuth oxide to increase it radiopacity, with no addition of calcium sulfate in an attempt to reduce its setting time. (137) ProRoot Endo Sealer (Dentsply Maillefer, Ballaigues, Switzerland) is a new powder/ liquid, calcium silicate-containing sealer designed to be used with a core filling material. The main elements of this sealer powder are tricalcium silicate and dicalcium silicate, with the addition of a setting retardant (calcium sulphate), which reported to enhance this sealer bond strength. (138) Water soluble polymer is added to the liquid part of this sealer to enhance its workability. (139) Another sealer of this group with enhanced consistencies is the MTA-Fillapex (Angelus, Londrina, Brazil), which is the most studied MTA-containing sealer due to its availability. It is available as an auto-mix dual-paste system, in which the paste-catalyst tubes are combined in a mixing tip. The two main components of this sealer are MTA-mixture and resinous components. After mixing, apart from MTA it contains natural resin, salicylate resin, diluting resins, silica nanoparticles, and bismuth trioxide. (140) These added resins could unfavorably affect the sealing ability of this sealer (141), as a study using scanning electron microscopy, found cracks in the resin matrix when exposed to deionized water. (142) Furthermore, this sealer possesses suitable physico- chemical properties, such as good radiopacity, flow, and alkaline pH (143) The manufacturer claims that its sealer has low solubility, excellent radiopacity, great working time, and was easy to handle. (38) However, other reports conflicting results, finding MTA-Fillapex to be highly soluble. (144) Except for an initial cytotoxicity, biocompatibility and antibacterial activity of MTA-Fillapex have been demonstrated. (145) (146) In a study evaluating antibacterial activity, it was found that MTA-Fillapex had a greater bacterial inhibition zone than Endo CPM sealer, which the authors attribute it resin component of MTA-Fillapex. (147) However, studies evaluating the sealing capacity of this sealer are variable. An in vitro study concluded that teeth obturated with MTA-Fillapex experienced more micro-leakage than those with AH Plus or ProRoot MTA. (148) Another study also found it to be inferior to Endo CPM in terms of bond strength to root dentin. (141) While in another study, it showed Fillapex to have less dye leakage than Endo CPM. (145) Whereas when compared to IRoot SP and AH Plus, MTA Fillapex displayed the lowest push-out bond values to root dentine. (149) However, in contrast to IRoot SP, retreatability of MTA-Fillapex was accessible, which could be argued to its inferior bond strength. (150)

In an overview, MTA- based sealers are biocompatible, bioactive and have high bonding strength or at least have similar sealing abilities to epoxy resin-based sealer. (151) (152)

Calcium phosphate-based sealer

The sealers are based on calcium phosphate cement, which it's composition almost resembles bone and teeth minerals, hence It is extremely biocompatible. (153) (154)

Sankin apatite root canal (Sankin Kogyo, Tokyo, Japan) is a powder/liquid sealer based on tetracalcium phosphate, dicalcium phosphate and includes hydroxyapatite. Iodoform was added to type II and III to enhance

antibacterial activity, also bismuth carbonate was added to type III to enhance the sealer radiopacity. (155) This sealer has been shown to be biocompatible with type II and III the most. (156) (157)

More recently, a newly developed calcium phosphate-containing root canal sealer called Capseal. (155) This is also a powder/liquid sealer containing tetracalcium phosphate dicalcium phosphate dehydrate, Portland Cement (gray cement in type I and white cement in type II), and zirconium oxide. Sodium phosphate added to the liquid part to accelerate the setting. (158) (155) Both I & II of this sealer have been reported to be biocompatible and produced less inflammation than AH26, ZOE, and Sankin apatite root sealer. (158-160) Additionally, other report states that Capseal I and Capseal II could promote periapical healing by stimulating osteoblast differentiation from the surrounding periodontal ligaments cells. (161) In a field emission–scanning electron microscope study, this sealer (both type I & II) presented good root canal sealing capability. (155)

Conclusion

Knowledge of root canal anatomy, proper diagnosis and a well carried endodontic therapy is proportional to treatment success. Effective three dimensional obturation is one phase of endodontic treatment that relay on former phases to ensure success.

The Evolution of root canal sealers can be perceived through several approaches, from conventional ones to the most recent trend of bio-materials. Which this later, could change the view of root canal therapy towards mineralization and bio-active centered treatment. Selection of one of these sealer should be judge through the case in the hand of a clinician. Cases with open apices or compromised root clearly will require different approach that others.

New sealers are showing promising results and the in *vitro* evaluations of these materials can be an indicator, further clinical trials are required to properly assess the long term success of these materials.

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