Bioceramic Based Sealers: A Review Article

Abstract: Endodontic sealers play an important role in controlling endodontic infection and preventing leakage of nutrients and reinfection of the root canal. A variety of endodontic sealers is available including zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin, and bioceramic based sealers. Bioceramic based sealers are ceramic products that are designed particularly for medical and dental applications. These sealers include alumina, zirconia, bioactive glass, glass ceramics, hydroxyapatite, and calcium phosphates. New generation of endodontic sealers has been produced based on calcium silicate as MTA Fillapex, EndosealMTA, Total Fill BC Sealer, EndoSequence BC Sealer, iRoot SP, Endo CPM sealer, MTA-Angelus and ProRoot Endo Sealer.

Keywords: Sealers, Bioceramic, Hermetic seal, Ceramic.

INTRODUCTION

The objectives of root canal treatment are elimination of infection from the root canal and prevention of its reinfection by filling and sealing the root canal space (Cagliani, M. M., et al., 2005). Although chemomechanical preparation significantly reduces the number of microorganisms in the root canal, 40–60% of root canals still remain positive for bacterial presence after this treatment (Bystrom, A., & Sunqvist, G. 1985). Thus, endodontic sealers play an important role in controlling endodontic infection and preventing leakage of nutrients and reinfection of the root canal (Kapralos, V., et al., 2018).

The main functions of root canal sealers are (i) sealing off of voids, patent accessory canals, and multiple foramina, (ii) forming a bond between the core of the filling material and the root canal wall, and (iii) acting as a lubricant while facilitating the placement of the filling core and entombing any remaining bacteria (Kaur, A., et al., 2015).

A variety of endodontic sealers is available including zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin, and bioceramic based sealers (Al-Haddad, A., & Che Ab Aziz, Z. A. 2016). Bioceramic based sealers are ceramic products that are designed particularly for medical and dental applications. These sealers include alumina, zirconia, bioactive glass, glass ceramics, hydroxyapatite, and calcium phosphates (Hench, L. L. 1991).

Bioceramic based sealers are categorized into two groups of calcium silicate based sealers (Mineral Trioxide Aggregate (MTA) based and non MTA based) and calcium phosphate based sealers (Al-Haddad, A., & Che Ab Aziz, Z. A. 2016). Also, another categorization of bioceramic based sealers is available in two groups of bioactive and bioinert materials due to their interaction with the close, alive tissues (Best, S. M., et al., 2008).

New generation of endodontic sealers has been produced based on calcium silicate as MTA Fillapex, EndosealMTA, Total Fill BC Sealer, EndoSequence BC Sealer, iRoot SP, Endo CPM sealer, MTA-Angelus and ProRoot Endo Sealer.
HISTORY

The first bioceramic material used for root canal obturation was described in 1984 (Krell, K.F., & Wefel, J.S. 1984). The forerunners of modern bioceramic materials were calcium phosphate sealers like Sankin apatite root canal sealers (I, II and III) (Sankin Kogyo, Tokyo, Japan) and experimental sealers known as Capsel (I and II) (Al-Haddad, A., & Che Ab Aziz, Z. A. 2016). A new era of bioceramic materials started in the mid-1990s when bioceramic materials based on MTA were introduced firstly as root repair cements (Haapasalo, M. et al., 2015). Those were mainly Portland-derived cements like ProRoot MTA (Dentsply Tulsa, Tulsa, OK, USA), which have been used as root-end filling materials, and root repair and pulp capping materials (Parirokh, M., & Tainbinejad, M. 2010). Because of their dense consistency, these cements are not easy to place in root canals (Ber, B. S. et al., 2007), therefore, bioceramic based root canal sealers have recently been developed (Zhang, W., Li, Z., & Peng, B. 2009; & Loushine, B. A. et al. 2011). The first sealer based on MTA was MTA Fillapex (Angelus, Londrina, Brazil), introduced onto the market in 2010. This sealer is composed mainly of a salicylate resin matrix, silica, and MTA (40%).

MECHANISM

There are two major advantages associated with the use of bioceramic materials as root canal sealers. Firstly, their biocompatibility prevents rejection by the surrounding tissues (Koch, K., & Brave, D. 2009). Secondly, bioceramic materials contain calcium phosphate which enhances the setting properties of bioceramics and results in a chemical composition and crystalline structure similar to tooth and bone apatite materials (Ginebra, M. P. et al., 1997), thereby improving sealer-to-root dentin bonding. However, one major disadvantage of these materials is in the difficulty in removing them from the root canal once they are set for later retreatment or post-space preparation (Cherng, A. M. et al., 2001). The exact mechanism of bioceramic-based sealer bonding to root dentin is unknown; however, the following mechanisms have been suggested for calcium silicate-based sealers:

- **Diffusion of the sealer particles into the dentinal tubules (tubular diffusion) to produce mechanical interlocking bonds (Zhang, W. et al., 2009).**
- **Infiltration of the sealer’s mineral content into the intertubular dentin resulting in the establishment of a mineral in filtration zone produced after dematuring the collagen fibres with a strong alkaline sealer (Han, L., & Okiji, T. 2011; & Atmej, A. R. et al., 2012).**
- **Partial reaction of phosphate with calcium silicate hydrogel and calcium hydroxide, produced through the reaction of calcium silicates in the presence of the dentin’s moisture, resulting in the formation of hydroxyapatite along the mineral in filtration zone (Zhang, H. et al., 2009).**

The biological and physical properties of bioceramic-based root canal sealers were reviewed based on the ideal root canal sealer properties as described by Grossman (Grossman, L. 1982), as in the following list:

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 discolor 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.

**Table 1: Composition of calcium silicate based sealers**

<table>
<thead>
<tr>
<th>Sealer</th>
<th>Manufacturer</th>
<th>Sealer contents</th>
<th>Some Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fill BC Sealer</td>
<td>FKG Dentaire, La-Chaux-de-Fonds, Switzerland</td>
<td>premixed single syringe which contains calcium silicates, calcium phosphate monobasic, zirconium oxide, tantalum oxide and thickening agents</td>
<td>Insoluble, radiopaque, aluminum free, hydrophilic, ready to use calcium silicate and resin based material developed for permanent root canal filling</td>
</tr>
<tr>
<td>iRoot SP</td>
<td>Innovative BioCeramix Inc., Vancouver, Canada</td>
<td>calcium silicate, calcium phosphate, calcium hydroxide, niobium oxide and zirconium oxide</td>
<td></td>
</tr>
<tr>
<td>Ortho MTA</td>
<td></td>
<td>Powder (Tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetra calcium alumino ferrite, free calcium oxide, bismuth oxide) and Liquid (deionized water)</td>
<td></td>
</tr>
<tr>
<td>Ortho MTA–PBS Paste</td>
<td></td>
<td>(Ortho MTA mixed with phosphate-buffered saline) is a root canal obturation material.</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Manufacturer/Origin</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
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<tr>
<td>DiaRoot Bioaggregate</td>
<td>DiaDent Group International, Burnaby, BC, Canada</td>
<td>Tricalcium silicate, dicalciumsilicate, tantalum pentoxide, calcium phosphate monobasic, amorphous silicon oxide</td>
<td>is considered as a modified version of MTA, with the advantage of being aluminum free in composition</td>
</tr>
<tr>
<td>EndoSeal</td>
<td>EndoSeal, Maruchi, Seoul, Korea</td>
<td>Sodium oxide, calcium oxide, potassium oxide, magnesium oxide, iron oxide, aluminium oxide, titanium dioxide, zirconium oxide, silicone dioxide</td>
<td>Bismuth oxide is replaced with zirconium oxide as the radiopacifier in EndoSeal</td>
</tr>
<tr>
<td>Endo-CPM</td>
<td>Egeo, Buenos Aires, Argentina</td>
<td>The same composition of MTA, except for the addition of barium sulfate and calcium chloride</td>
<td>a sealer in two forms of powder or liquid</td>
</tr>
<tr>
<td>MTA Plus</td>
<td>-</td>
<td>- a recent Hydraulic Calcium Silicate Cement mixed with a polymer gel and proposed as an endodontic sealer</td>
<td>Has improved reactivity and a prolonged ability to release calcium</td>
</tr>
<tr>
<td>MTA Fillapex</td>
<td>Angelus, Londrina, PR, Brazil</td>
<td>natural resin, salicylate resin, diluting resin, bismuth trioxide, nanoparticulated silica, pigments and MTA</td>
<td>is a paste-catalyst MTA containing resin based bioceramic sealer which is developed as a paste or paste sealer in a formulation that allows its appropriate insertion into the root canal as a conventional endodontic seal</td>
</tr>
<tr>
<td>Endosequence BC sealer</td>
<td>Brasseler USA, Savannah, GA, USA</td>
<td>(injectable form) a premixed calcium phosphate silicate-based sealer</td>
<td>needs natural canal moisture for setting reaction</td>
</tr>
<tr>
<td>NeoMTAPlus</td>
<td>Avalon Biomed</td>
<td>powder and a water-based gel</td>
<td>When the powder to gel ratio is low, a sealer type consistency is obtained for these two materials</td>
</tr>
<tr>
<td>Quick Set2</td>
<td>Avalon Biomed Bradenton, FL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ProRoot Endo Sealer</td>
<td>DENTSPLY Tulsa Dental Specialities</td>
<td>calcium sulphate, dicalcium silicate, tricalcium silicate, bismuth oxide, and a bit of tricalcium aluminate Liquid (viscous aqueous solution of a water soluble polymer)</td>
<td></td>
</tr>
</tbody>
</table>

**PHYSICO-CHEMICAL PROPERTIES**

**Radioopacity**

Radioopacity, a well-known characteristic of endodontic sealers, should exist in any root canal filling materials with a certain degree in order to evaluate the quality of root filling function (Malka, V. B. et al., 2015). Two methods of standard discs and tissue simulator were used to evaluate radio opacity in one study which indicated that it was higher in AH Plus than MTA Fillapex and Endo CPM.35 Radioopacity of Endo CPM sealer was 6 mmAl (Guerreiro-Tanomaru, J. M. et al., 2009). Also, radioopacity of MTA Fillapex and AH-Plus were 3.9 and 18.4 mmAl respectively (Viapiana, R. et al., 2014). Xuereb, M. et al., (2015), found the value of 10.8 and 4.3 for radioopacity of Endosequence BC and MTA Fillapex sealers. However, another study demonstrated the radioopacity of Endosequence BC sealer and AH Plus to be 3.84 and 6.90 mm Al respectively. The radioopacity of Endoseal was lower than AHPlus.

**Setting Time**

The ANSI/ADA Specification number 2 requires that the setting time of a sealer shall be within 10% of that stated by the manufacturers (Marín-Bauza, G. A. et al., 2012). The final setting time was determined to be 85.66 (±6.03) minutes for Biodentine and 228.33 (±2.88) minutes for MTA (Kaup, M. et al., 2015). Endosequence BC Sealer required at least 168 hours to reach the final setting using the Gilmore needle method, and its microhardness significantly declined when water was included in the sealer (Camilleri, J., & Mallia, B. 2011). Endosequence BC sealer and MTA Fillapex could not be set in dry condition within 3 days whereas they set in contact with the physiologic solution (HBSS) (Xuereb, M. et al., 2015). The setting time values for Endosequence BC Sealer and MTA Fillapex in moist conditions were 22.3 and 19.3 minutes respectively(Xuereb, M. et al., 2015).These results are in contrast with another study, finding that the setting time of these materials is 2.7 hours. When there are minimal amounts of fluids in contact with the materials, dry conditions are not valid in vivo. An equivalent of 20 cm water pressure investigating the hydraulic conductance of dentin.
Dentin permeability is mainly caused by the dentinal tubules present. Permeability in dentin can be reduced by the apposition of tertiary dentin, the deposition of crystalline calcium phosphate, or the presence of the smear layer and coagulation products.

Solubility
Solubility is the mass loss of a material during a period of immersion in water. The solubility of a sealer should not be superior to three percent by mass based on specification number 57 of ANSI/ADA (2000). The solubility of both iRoot SP and MTA-Fillapex was high (20.64% and 14.89%, respectively), which are not fulfill ANSI/ADA requirements (Viapiana, R. et al., 2014; & Amoroso-Silva, P. A. et al., 2014). Amoroso-Silva (2014) showed MTA Fillapex sealer possess a higher solubility and quantity of gaps in the dentin/sealer interface when compared to the AH Plus sealer. Nevertheless, in another study, the solubility of MTA-Fillapex and EndoSequence BC, were in line with ISO 6876/2001. MTA-Angelus also has low solubility (Amoroso-Silva, P. A. et al., 2014) because of an insoluble matrix of crystalline silica within itself that preserve its integrity even in the presence of water. The solubility and water absorption increased significantly over time for both MTA Fillapex and AH Plus in 1 to 28 day period. MTA Fillapex had a higher solubility that guttaflow (Dudeja, C. et al., 2015). MTA Fillapex and EndoSequence BC sealers have a higher solubility than AH Plus. Solubility and disintegration of MTA Fillapex are lower than AH Plus. The solubility of AH Plus and MTA Angelus agreed with ANSI/ADA’s requirements, whereas iRoot SP, MTA Fillapex, and Sealapex were unlike ANSI/ADA’s protocols (Amoroso-Silva, P. A. et al., 2014). Morphological changes in both outer and inner surfaces after the solubility test were observed in SEM/EDX analysis of all sealers (Amoroso-Silva, P. A. et al., 2014). Similar solubility, but a higher dimensional change of Endoseal was observed between Endoseal and AH Plus.

Calcium Release
For calcium ion release test, mostly, high release of calcium was indicated in the sealers in three hours assessment and by decreasing values over time. In contrast to AH Plus, iRoot SP, MTA Fillapex sealers showed high levels of Ca (2+) ion release (Amoroso-Silva, P. A. et al., 2014). Calcium release of MTA Fillapex was superior than guttaflow (Viapiana, R. et al., 2014) and inferior than iRoot SP (de Miranda Candeiro, G. T. et al., 2012). EndoSequence BC Sealer had high tendency to release calcium ions than AH plus sealer. The highest leaching of calcium ion was exhibited by EndoSequence BC Sealer followed by MTA Fillapex (Xuereb, M. et al., 2015). Phosphorus was leached in solution in higher quantities in EndoSequence BC Sealer compared with MTA Fillapex, which exhibited a negative value, indicating that there was the uptake of phosphorus from the solution rather than leaching (Xuereb, M. et al., 2015).

pH, alkalinizing activity and correlation with antibacterial properties
Zhang et al. (2011) tested the antibacterial activity of iRoot SP sealer in vitro against E. faecalis found that iRoot SP showed a pH value of 11.5 even after setting, but its anti bacterial effect was greatly diminished after seven days. EndoSequence BC Sealer has also been shown to have high pH (>11) (Zhang, H. et al., 2009) iRoot SP showed more pH value than MTA Fillapex (de Miranda Candeiro, G. T. et al., 2012). The pH value of the Endo CPM was higher than that of MTA Fillapex (>11); however, the bacterial inhibition zone produced by MTA Fillapex was greater than that produced by Endo CPM (Duarte, M. A. H. et al., 2003). Antibacterial activity of MTA Fillapex was related to the existence of resin as the main factor. However, the ability to maintain antibacterial activity after setting even with their primary high pH was observed in any of the sealers (Duarte, M. A. H. et al., 2003). The value of pH was slightly higher for MTA-Angelus than ProRoot (Silva, E. J. et al., 2013). MTA Fillapex has higher alkalinity and pH than AH Plus (Zhou, H. M. et al., 2013) and higher alkalinizing activity than guttaflow (Dudeja, C. et al., 2015). MTA Fillapex sealer had the lowest pH at 3 and 24 hours approximately 7.5 and increasing PH values over time. Higher alkalinity, was observed in Endoseal when compared to AH Plus. EndoSequence BC Sealer pH values greater than AH Plus sealer (Zhang, H. et al., 2009). Dudeja stated that initial dressing of calcium hydroxide followed by obturation with Gutta-percha and iRootSP and MTA Fillapex sealers may be considered as an alternative treatment modality for inflammatory resorption and it is beneficial when compared to the long-term calcium hydroxide application (de Miranda Candeiro, G. T. et al., 2012). The reason for this phenomenon is calcium ion release performed by bioceramic sealers. Also, MTA based sealer demonstrate higher pH values than resin based sealers, MTA, calcium enriched mixture (CEM) cement, and Portland cement generated more alkalinity and the pH of 9.47-10.80.

Flowability, film thickness and dimensional stability
Flow determines the ability of sealers for filling the irregularities, and it is the viscosity that determines the flow characteristics. According to ISO 6786/2001, a root canal sealershould have a flow rate of not less than 20mm. MTA Fillapex had flowability higher than 20 mm and a film thickness lower than 50 μm. MTA Fillapex was significantly more flowable than AH Plus by the results of Zhou H et al., (2009) and Silva EL et al., (2013) Others stated similar flow, film thickness and inferior compressive strength of MTA Fillapex when compared to AH Plus sealers. Flow of Endoseal was higher than AH Plus. Ako, they were a similarity between MTA Fillapex and EndoSequence BC sealers (Raja, J., & James, J. R. 2014). Film thickness of MTA Fillapex is higher than both AH Plus and EndoSequence BC sealer (Raja, J., & James, J. R. 2014). EndoSequence BC Sealer (Zhang, H. et al., 2009)
showed flow according to ISO 6876/2001 recommendations. The flow test revealed that BC Sealer and AH Plus presented flow of 26.96 mm and 21.17 mm respectively (Zhang, H. et al., 2009).

**CONCLUSION**

Bioceramic-based root canal sealers show promising results as root canal sealers. However, discrepancies in the results of these studies reveal that these sealers do not fulfill all of the requirements demanded of the ideal root sealer. The biocompatibility and biomineralization effect of these sealers might allow them for alternative uses in direct pulp capping and root end filling. Further studies are required to clarify the clinical outcomes associated with the use of these sealers.

**REFERENCES**


