ENDODONTIC REPAIR FILLING MATERIALS: A REVIEW ARTICLE

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ABSTRACT

The emergence of Mineral Trioxide Aggregate (MTA) as endodontic repair filling material has generated a lot of interest due to its superior sealing ability and biocompatibility. Although MTA possesses superior sealing ability to traditional endodontic repair filling materials, such as calcium hydroxide, but it has poor handling characteristics. A novel endodontic repair filling materials with similar chemical composition, but improved handling characteristics, was recently developed. Recently, BioAggregate repair filling materials is claimed as biocompatible material and promotes cementogenesis and forms a hermetic seal inside the root canal. More recently, Biodentine and EndoSequence endodontic repair materials introduced to the market. Both materials have recommended for perforation repair, apical surgery, apical plug, and pulp capping. This article focused about physical properties of endodontic repair filling materials.

Key Words: Endodontic repair filling materials, Ideal requirements of filling materials

INTRODUCTION

An ideal endodontic repair material should provide an impervious seal, be dimensionally stable, radio-opaque, nonresorbable, nontoxic and well tolerated by the periradicular tissues.

In addition, an ideal material should be bactericidal or bacteriostatic. Various materials have been used for root repair, including amalgam, Cavit, zinc oxide-eugenol, intermediate restorative material (IRM), composite resins carboxylate cements, zinc phosphate cements and glass ionomers. However, none of them are ideal for the special conditions and requirements of root repair. This review article will focus in many traditional and recent endodontic repair materials.[1]

IDEAL REQUIREMENT OF ENDODONTIC REPAIR MATERIALS

- It should provide adequate seal.
- It should be biocompatible.
- It should have ability to produce osteogenesis and cemento-genesis.
- It should be bacteriostatic, and radiopaque.
- It should also be beneficial to use a resorbable matrix in which a sealing material can be condensed.
- It should be relatively inexpensive.
- It should be non-toxic, non-cariogenic and easy to place.

1. Gutta Percha:

Gutta Percha was introduced by Bowman in 1867. It is the most popular and most commonly used core filling material in endodontics. It is a trans-isomer of polyisoprene, existing in alpha and beta crystalline forms. Friedman described its composition as consisting of 20% gutta-percha matrix, 60% zinc oxide filler, 11% heavy metal sulphates as radioopacifiers and 3% waxes as plasticizers. Gutta percha is known to have a poor sealing ability as it has to be used with a sealer during root canal obturation. Use of gutta-percha as a root-end filling material is no longer recommended owing to the advent of newer materials with significantly enhanced properties.[2]

2. Amalgam:

Silver Amalgam has been in use as a root-end filling material since 1884 (Farrar 1884 in Gutmann and Harrison 1999). Amalgam remains a standard to which all other materials are compared. It is readily available, easy to handle and manipulate, and is radio-opaque. But, there are many disadvantages that have been recognized which include marginal leakage, secondary corrosion, moisture sensitivity, and safety issues due to mercury toxicity. A study by Tanzilli et al suggested that amalgam gives a poor seal when used as a retrograde filling material. But, the use of amalgam with 4-methacryloxy trimellitate anhydride bonding agent is shown to reduce microleakage. Electrochemical corrosion products of amalgam were reported to be responsible for failure of root-end fillings.A study of tissue response to various root-end filling materials done by Chong et al in 1997 showed that all roots filled with amalgam showed moderate or severe inflammation. Scattering of excess amalgam particles during placement of the root-end filling can lead to corrosion of the implanted material and cause unsightly amalgam tattoos. Many clinical studies have shown poor outcomes with amalgam root-end fillings and amalgam can no longer be considered as the ideal root-end filling material.[3]

3.Polycarboxylate cements:

Introduced by Smith in 1968, Zinc polycarboxylate cement consists of a powder which contains zinc oxide, magnesium oxide, bismuth and aluminium oxides, stannous fluoride. The liquid is and aqueous solution ofpolyacrylic acid or a copolymer of polyacrylic acid with other carboxylic acids like itaconic acid. The cement is believed to act with calcium ions through carboxyl groups on the surfaces of enamel and dentin. The bond strength to enamel is greater than in dentin. The sealing ability of polycarboxylate cement, as shown by Barry et al using dye penetration methods is inferior to amalgam.[2]

4. Cavit:

Cavit was introduced as a temporary filling material made of zinc oxide and zinc sulphate without eugenol. Evaluation of the sealing ability of amalgam, Cavit and glass ionomer cement was done to reveal that Cavit had a better seal than amalgam but the seal was inferior to that of amalgam.[4]

5. Zinc Oxide Eugenol Cements:

Zinc-oxide eugenol cements are among the most commonly used and recommended root-end filling materials. ZOE cements, in order to improve their physical properties was subjected to various modifications.[5]

6. Super EBA:

Here, there is a substitution of part of the eugenol liquid with ortho-ethoxybenzoic acid (EBA) and addition of alumina to the powder. Super-EBA was developed in the 1960’s, it was originally manufactured by Staines in England. This contained a powder component with 60% zinc oxide, 34% silicon dioxide, 6% natural resin, and a liquid component with 62.5% ortho-ethoxy benzoic acid and 37.5% eugenol. The

Harry.J.Bosworth Co. used the same liquid component and replaced the silicon dioxide in the powder with 34% alumina. Super EBA shows high compressive strength, high tensile strength, neutral pH and low solubility. A comparative study of the solubility of some root-end filling materials done by Poggio et al in 2007 showed that IRM, Super-EBA and MTA showed no signs of solubility in water. It has also been shown to have good sealing characteristics. An in vitro microleakage study done by Yaccino et al in 1999 suggested that fast set or regular set super-EBA used in various consistencies may be acceptable as root-end fillings. It adheres well to tooth structure even in moist conditions. Reports show a good healing response to super-EBA with minimal chronic inflammation at the root apex. But, super-EBA is radioluscent and technique sensitive. The eugenol content of super-EBA may be a source of irritation to the tissues.[6]

7. IRM:

IRM is zinc oxide eugenol cement modified by addition of 20% polymethyl methacrylate by weight to the powder. the effect of IRM as a root-end filling placed in teeth prior to replantation was observed by Pitt Ford et al in 1994 and the tissue response was found to be less severe than that to amalgam. Eugenol in IRM may have an affinity for poly methyl methacrylate which reduces its release into the tissues, thereby reducing the cytotoxicity. Zinc oxide eugenol cements, IRM and super-EBA were analysed for their release of zinc and eugenol by Al-aseed et al in 2008. Eugenol release from IRM by this leached component analysis was obviously higher than from Super-EBA because of the comparatively higher content of eugenol. But this higher release of eugenol did not increase its cytotoxicity; super-EBA was more toxic. So, the release of zinc may be the main cause of toxicity due to ZOE cements. IRM was shown to have a better seal than amalgam or super-EBA. IRM showed good anti-bacterial activity against S.*aureus*, E.*faecalis*, P.*aeruginosa*.[7]

8. Glass Ionomer Cement:

Glass ionomer cement was introduced as a new restorative material in the early 1970s. They are based on the reaction of ion-leachable, acid soluble calcium fluoro aluminosilicate glass particles with polyalkenoic acid. They possess adhesive properties forming a chemical bond with dentin, and have a significant fluoride releasing property. Resin-modified glass ionomer cements were first described by Antonucci et al to improve physical properties and handling characteristics. They contain a monomer such a Hydroxyethyl methacrylate (HEMA) or bisphenol-A-glycidyl methacrylate (bis-GMA) along with a photo-initiator such as camphoroquinone. Glass ionomer cements induce an intense inflammatory response which resolves and the inflammation is replaced by bone. Silver-reinforced glass ionomer cements were also tried which showed a good tolerance but it released more amounts of silver which caused discolouration similar to amalgam and the corrosion products were cytotoxic. Generally, glass ionomers are slow setting, awkward to handle and are very sensitive to moisture contamination. Using them in a surgical field only amplifies this problem. Resin-modified glass ionomers - Vitrebond as a potential root-end filling material improved the handling properties and had a good adaptation and sealing ability. The sealing ability of light-cured glass ionomer cements was significantly better than that of amalgam and also slightly better than conventional glass ionomer cements. In vitro studies showed a good antibacterial effect and low cytotoxicity. In a comparative study of tissue response to amalgam, Vitrebond and Kalzinol in an experimental model of infected root canals, Vitrebond and Kalzinol showed a tissue response considerably more favourable than amalgam root-end filling, even in the short term. After one week, the overall best tissue response was to Vitrebond, followed by Kalzinol. These are easier to handle and light-curing helps control the setting reaction, but, maintenance of a dry field during placement still presents a challenge as it may interfere with the dentin bond.[8,9]

9. Composite Resins:

Use of composite resins along with dentin bonding agent is also used to produce a leak-resistant seal. Rud et al have shown excellent long term clinical success with Retroplast composite resin root-end fill and Gluma dentin bonding agent. But, presence of a dry field during placement is important. Conventional composite resins contain a polymerizable organic matrix, inorganic fillers and a silane coupling agent. TEGDMA, bis-GMA and UDMA have been detected in aqueous extracts and formaldehyde can liberate over a long time period. These components may be the reason why the material exhibits highly anti-bacterial effects against P.*gingivalis*, P.*intermedia*, P.*endodontalis*, F.*nucleatum*. Enamel matrix derivatives (EMD) coated on surfaces of root dentin is known to promote periodontal regeneration. Periapical biopsies of teeth with composite resin retrograde fillings have shown deposition of cementum and reformation of periodontal ligament over the resin fillings. An experiment done to evaluate the adherence of enamel matrix derivatives on root-end filling materials was done to compare amalgam, IRM and Composite resin. High amounts of EMD were found to adhere to the composite resin. This could be an explanation for the periodontal regeneration seen with composite resin fillings.[10]

10. Compomers:

Compomers which are poly-acid modified composite resins were developed to combine the fluoride releasing property of glass ionomer cements with the mechanical properties of composite resins. The setting reaction is an addition polymerization which is light-initiated, similar to composite resins. The monomer contains acidic functional groups and the material sets via a free radical polymerization reaction. It does not bond to tooth structure like glass ionomer cement but need a bonding agent like composite resins. Compomers may release fluoride in the first few days after polymerization due to the presence of ion-leachable glass fillers, similar to glass ionomer cements. In a study done to compare silver amalgam and compomer as retrograde filling materials, a histological study of the samples involving retrograde filling with amalgam in animal models revealed average biocompatibility with limited bone formation and moderate inflammation. The compomer group showed greater inflammation showing its low biocompatibility but also showed greater root cementum growth. Other studies with an in vivo intraosseous implantation in rabbit showed that it has a good biocompatibility as Super-EBA. Gingival tissues appear to adhere to the material, allows fibroblasts to reform around the root apex in which compomer root-end filling is placed. Dyract has been shown to have good anti-bacterial effects against P.*gingivalis*, P.*intermedia*, P.*endodontalis* and F.*nucleatum*. the release of residual monomers and additives after polymerization may be the reason for the anti-bacterial effect. The results of an electrochemical study of the sealing ability of super-EBA, MTA and Dyract-flow showed that the sealing ability of Dyract-flow is equal to that of super-EBA and MTA. [11, 12]

11. Titanium screws:

A study of titanium screws as retrograde fillings was done to compare it with amalgam. Bacterial penetration was seen readily on the first day in the amalgam fillings but bacteria penetrated the titanium screw seals after 2 to 7 days. Titanium screws appeared to produce a tighter seal than amalgam.[13, 14]

12. Diaket:

Diaket, which is normally used as a root canal sealer has been used as a root-end filling when mixed to a thicker consistency. As a root canal sealer, it was shown to be tolerated by the tissues. Stewart in 1958 showed that Diaket is impervious to methylene blue dye and does not dissolve or absorb in the presence of periradicular tissue and fluids. As a root-end filling, diaket is shown to have superior sealing qualities when compared to amalgam. Diaket also shows a good healing response characterized by bone apposition, reformation of periodontal ligament and deposition of new cementum.[15, 16]

13. Ceramicrete :

Ceramicrete is an inorganic phosphate ceramic binder material used to encapsulate radioactive and hazardous wastes. It is a self-setting phosphate ceramic that sets using an acid-base reaction to form a potassium magnesium phosphate hexahydrate ceramic matrix phase. Its mechanical properties were improved by adding calcium silicate whiskers to produce a phosphosilicate ceramic material. A ceramicrete based dental or bone material was introduced which had hydroxyapatite powder and cerium oxide radioopaque fillers. This material is biocompatible and radioopaque. The material is also known to release calcium and phosphate ions during setting. An in vitro study was done to evaluate the Ceramicrete based material as a root-end sealing material. This study used a ceramicrete-based powder mixed with deionized water. This study showed that ceramicrete had a radioopacity similar to root dentin, and the sealing ability was higher compared to a SuperEBA and ProRoot MTA group. This excellent apical seal was attributed to its impervious nature and also the use of an acidic MgH2PO4.H2O solution as a conditioner to remove the smear layer which is believed to have improved the adaptation of ceramicrete with the dentin. On immersion of the set ceramicrete material in a Phosphate containing fluid (PCF), there was formation of Dicalcium phosphate dihydrate (DPCD) or hydroxapatite on the surface. This is due to the reaction of calcium disilicate from the ceramicrete material with the phosphate from the PCF. Thus, ceramicrete shws potential bioactivity. A comparison of the root-end seal achieved using Ceramicrete, Bioaggregate and White MTA was done to study the prevention of glucose penetration. Both Bioaggregate and Ceramicrete showed similar sealing ability to MTA, with Ceramicrete showing significantly better results than Bioaggregate.[17]

14. Metal-modified glass ionomer cements

Silver glass-ionomer cement is a product of sintering pure silver to aluminosilicate. It has the properties like bonding to dentin, radiopacity, rapid set and ease of delivery. Due to these properties it has also been used for perforation repair. Zvi Fuss et al, evaluated the sealing ability of silver glass ionomer cement (Chelon silver) in treating furcation perforations in vitro and compared it with amalgam. Results have shown that perforations repaired with Chelon Silver leaked significantly less than those repaired with amalgam and their leakage was lower than that of the intact pulp chamber group though this difference was not significant. . Studies found that resin-modified glass ionomer cement provided a better seal than amalgam or Cavit and was superior to the conventional, chemically set glass ionomer cement and composite resin when used to seal furcation perforations.[18]

15. Decalcified Freezed Dried Bone (DFDB)

DFDB chips are biocompatible, relatively nontoxic, easy to obtain, easy to use, relatively inexpensive, easy to manipulate, completely degrades during the repair process and acts as an excellent barrier against which filling material could be placed. When packed into the bony defect they mix with the blood present and "weld" together into a solid mass to completely fill the defect. In a study by Hartwell et al., he found both positive and negative findings associated with the use of DFDB as a perforation repair material. The positives include the excellent clinical and radiographic findings at the end of 6 months. All teeth exhibited normal appearing periodontal soft tissues, absence of any periodontal pockets or furcation defects and absence of inflammation in 85% of samples. The negative findings included absence of new bone formation and epithelial growth in all specimens.[12]

16. Calcium Hydroxide

Since its introduction by Herman in 1920's, it was used for a wide range of purposes in both conservative field and endodontics. It is a substance that is biologically compatible with pulpal and periodontal tissues. By composition calcium hydroxide consists of a base paste and catalyst paste. Base paste consists of 1-methyl trimethyl enedisalicylate, Calcium sulphate, Titanium dioxide, Calcium tungstate orbarium sulphate and Catalyst paste consists of Calcium hydroxide, Zinc oxide, Zinc stearate, Ethylene toluene, Sulphonamide. P Bogaerts et al., used calcium hydroxide as matrix and Super EBA as the material for perforation repair. It lead to good clinical results with positive outcome . In another study by Clovis Monteiro Bramante et al., specimens dressed with calcium hydroxide paste plus iodoform for perforation repair showed necrosis at the site of perforation and different levels of cementum hyperplasia.[14]

17. Mineral trioxide aggregate

Mineral trioxide aggregate is commonly employed material with wide range of uses. Since its introduction by Mahmoud Torabinejad in 1992 it gained a wide role and emerged as a widely accepted material for various purposes. MTA consists of fine hydrophilic particles of Tricalcium silicate, Tricalcium aluminate, Tricalcium oxide, Silicate oxide, calcium sulphate dihydrate, tetracalcium aluminoferrite and small amounts of mineral oxides (bismuthoxide) . It has a mean setting time of 165±5 minutes. MTA stimulates cementoblasts to produce matrix for cementum formation and is biocompatible with the periradicular tissues thus shows a superior sealing ability when used for perforation repair. When Amalgam, IRM and mineral trioxide aggregate were tested for repair of experimentally created root perforations; results showed that the MTA had significantly less leakage than IRM or amalgam. According to Weldon JK et al., the combination of MTA and Super-EBA provided a more rapid seal than MTA alone.[16]

18. Biodentine

Biodentine is a calcium silicate-based bioactive material. It is a powder liquid system, powder composed of Tri-calcium silicate, Di-calcium silicate, Calcium carbonate and oxide, Iron oxide, Zirconium oxide. Liquid consist of Calcium chloride, Hydro soluble polymer. It is easy to handle owing to its ease of manipulation and a short setting time approximately 12 minutes, has high alkaline pH and is a biocompatible material makes it a favourable material for perforation repair. In a study by Guneser et al.,, Biodentine showed considerable performance as a perforation repair material even after being exposed to various endodontic irrigants as compared to MTA.[16, 17]

19. EndoSequence

EndoSequence is a bioceramic material. Bioceramics refers to the combination of calcium silicate and calcium phosphate. It is composed of calcium silicates, zirconium oxide, tantalumoxide, calcium phosphate monobasic and filler agents. It has a working time of more than 30 minutes and a setting reaction initiated by moisture with a final set achieved in approximately 4 hours. It is produced with nanosphere particles that allow the material to enter into the dentinal tubules and interact with the moisture present in the dentin. This creates a mechanical bond on setting and renders the material with exceptional dimensional stability, along with this the material has superior biocompatibility characteristics due to its high pH Endosequence root repair material simulates tissue fluid, phosphate buffered saline and results in precipitation of apatite crystals that become larger with increasing immersion times concluding it to be bioactive. In a study by Jeevani et al., Endosequence showed better sealing ability when compared to MTA and Biodentine as furcation repair materials.[18, 19]

20. Bioaggregate

Bioaggregate is a bioceramic material composed of tricalcium silicate, dicalcium silicate, calcium phosphate monobasic, amorphous silicon di oxide and tantalumpent oxide . It induces mineralized tissue formation and precipitation of apatite crystals that become larger with increasing immersion time ssuggesting it to be bioactive. It has comparable biocompatibility and sealing ability to MTA. In a study by Hashem et al., concluded that MTA is more influenced by acidic pH than Bioaggregate when used as perforation repair material.11

21. New endodontic cement

"New endodontic cement (NEC)" a bioactive material consisting of different calcium compounds was later termed as Calcium Enriched Mixture (CEM). It is composed of calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, calcium hydroxide, and calcium chloride. It has a setting time of less than 1 hour and sets in aqueous medium. It is composed of different calcium compounds, it produces greater amount of calcium and phosphate ions which most likely forms hydroxyapatite in higher concentrations and this would make CEM cement preferable as a furcal perforation repair material in close proximity to the exposed periodontium. Asgary et al. observed cementogenesis and periodontal regeneration when CEM was used as perforation repair material.[20]

CONCLUSION

Recent progress in endodontic repair filling materials is reviewed for possible replacement the traditional endodontic repair filling materials. The existing literature review exhibited a solid base about new endodontic repair filling materials, namely; Biodentine, EndoSequence, BioAggregate, for possible replacement calcium hydroxide and MTA as an endodontic material.

Although major developments were noted in endodontic repair filling materials that can improve physical properties for endodontic applications, further studies are needed to improve their properties which may improve the function and increase life span in clinical uses.

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