Root end filling materials — A review
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ABSTRACT

The main objective of all endodontic procedures is to obtain a hermetic seal between the periodontium and root canal foramina. When this is not possible by an orthograde approach, root end filling technique is used. Numerous materials have been suggested for root-end filling. This article reviews on the suitability of various root end filling materials from past to present.

Key Words: Root-end filling materials, hermetic seal, biocompatibility, microleakage.

Introduction

Most endodontic failures occur as a result of leakage of irritants from pathologically involved root canals. When non-surgical attempts prove unsuccessful or are contraindicated, surgical endodontic therapy is needed to save the tooth. The root-end filling material should provide an apical seal to an otherwise unobturated root canal or improve the seal of existing root canal filling material and be biocompatible with the periradicular tissues.

The complexity of root canal systems, inadequate instrumentation and presence of physical barriers may necessitate surgical endodontic therapy in some cases. Once the root-end preparation has been completed, a suitable root-end filling material is inserted. According to Gartner and Dorn¹ an ideal material to seal the root-end cavities should prevent leakage of microorganisms and their by-products into the periradicular tissues. It should also be non-toxic, non-carcinogenic, and biocompatible with the tissue fluids and dimensionally stable. The presence of moisture should not affect its sealing ability. For practical purposes, it should be easy to use and be radio-opaque, to be recognized on the radiograph.

Throughout the dental history, a wide variety of materials have been used for retrograde fillings. Although a plethora of materials are available, no material has been found that fulfills all or most of the properties for ideal retrograde filling material. Given below is the list of materials that have been or are currently being used as retro-grade filling materials.

Metals such as gold-foil, silver posts, titanium screws, tin posts, amalgam (with and without bonding agent) and gallium alloy are some of the solid, commonly used retro-filling materials.

Cements and sealers such as ZnOE Cement IRM, Super EBA, cavit, zinc-polycarboxylate, zinc phosphate and glass ionomer cements, mineral trioxide aggregate, calcium phosphate cement and bone cement have also been employed for retro-fillings.
Other commonly used materials are composite resin (with and without bonding agent) and gutta-percha.

The less commonly used materials are laser, citric acid demineralization, ceramic inlay, teflon, mixture of powdered dentin & sulfathiazole and cyanoacrylates.

Based on review of literature on scientific evaluation and clinical usage, the following are the commonly used root end filling materials.

**Amalgam**

It is the most extensively used retro-filling material from past seven decades, but one of the first reports of placing it as a root-end filling subsequent to resection is attributed to Farrar (1884). Later Rhein (1897), Faulhaber & Neumann (1912), Hippels (1914) and Garvin (1919) extolled the use of root-end amalgam fillings. Amalgam is easy to manipulate and has good radio opacity. It is non-soluble in tissue fluids and marginal adaptation as well as sealing improves as amalgam ages due to formation of corrosion products. High copper zinc free amalgam is preferred. Use of Amalgambond, a 4-META bonding agent with amalgam significantly reduces the microleakage of amalgam retrofillings². Compatibility studies have demonstrated that freshly mixed conventional silver amalgams are very cytotoxic due to unreacted mercury³, with cytotoxicity decreasing rapidly as the material hardens.

Amalgam has few limitations which include initial marginal leakage, corrosion, tin and mercury contamination of periapical tissues, moisture sensitivity of some alloys, need for retentive undercut preparation, staining of hard and soft tissues and technique sensitivity¹.

**Gutta Percha**

Until the development of thermoplasticized gutta-percha, the placement of gutta percha as a root-end filling material was not advocated. Orthograde gutta-percha root canal obturation that is associated with apical surgery is burnished after apicectomy with either cold or hot burnisher. Its adaptation to root dentin walls can also be accomplished with the use of solvents, excavators, scalpels and burs. Abdal and Retief in their study observed that heat sealed gutta-percha provides a better seal as compared to Amalgam, IRM and Super EBA⁴. It is reported that a better seal can be obtained with thermoplasticized gutta-percha than amalgam with and without varnish⁵-⁷.

Due to it’s porous nature, it absorbs moisture from surrounding periapical tissue and expands initially, which is followed by contraction at a later stage. This may result in poor marginal adaptation and increased micro leakage.

**Zinc Oxide Eugenol (ZOE) and Reinforced ZOE Cements**

The use of ZOE as a root-end sealing agent in periradicular surgery has had limited documentation. Newer modifications of ZOE compounds, such as IRM and Super EBA provide a better apical seal. IRM is zinc oxide-eugenol cement reinforced by addition of 20% polymethacrylate by weight to the powder⁸. Studies reveal that IRM seals better than non zinc amalgam⁹. Super EBA is zinc oxide-eugenol cement modified with ethoxybenzoic acid to alter the setting time and increase the strength of the mixture⁸. Super EBA has much better physical properties than ZOE. It showed high compressive strength, high tensile strength, neutral pH, and low solubility. Even in moist conditions Super EBA adheres to tooth structure. Super EBA adheres well to itself and can be added incrementally as necessary but IRM does not. Reports showed a good healing response to super EBA with minimal chronic inflammation at the root apex¹⁰. EBA demonstrates virtually no leakage¹¹-¹². Super EBA and IRM showed less leakage as compared to silver amalgam¹³.
Super EBA provides a better seal, when compared with amalgam as a root-end filling material\textsuperscript{14-15}. Based on the above studies, the use of EBA as a root-end filling material is promising.

Cavit

It is a Zinc oxide based temporary filling material. Cavit is soft when placed in the tooth and subsequently undergoes a hygroscopic set after permeation with water, giving a high linear expansion (18\%). This rationalizes its use as a root-end filling material. Cavit has been shown to exhibit greater leakage than IRM\textsuperscript{16}. It is found to be soluble and quickly disintegrates in tissue fluids. Biocompatibility studies with Cavit are in conflict, showing it to be both toxic\textsuperscript{17} and non-toxic\textsuperscript{18}. Keeping these studies in mind, the use of Cavit as a root-end filling material cannot be advised.

Gold Foil

First reports of its use as a root-end material is attributed to Schuster in 1913 and Lyons in 1920. It exhibits perfect marginal adaptability, surface smoothness and tissue biocompatibility. Implants of gold foil produce only mild tissue reaction\textsuperscript{19}. When compared to IRM, composite resin, amalgam and glass ionomer, gold foil was least toxic\textsuperscript{20}. Gold Foil was found to be the best apical sealing material as far as the improvement in biting force is concerned\textsuperscript{21}. Leakage studies in root-end preparations have indicated minimal or no leakage. The routine use of gold foil as a root-end filling material does not appear practical because of the need to establish a moisture free environment, careful placement and finishing. However its use in isolated cases can be justified.

Polycarboxylate cement

It was introduced by Smith in 1968. The zinc polycarboxylate cement consists of a powder having modified zinc oxide with fillers and a liquid comprising of aqueous solution of polyacrylic acid which, when mixed and hardened, forms a cement of zinc oxide particles dispersed in a cross linked structureless matrix of zinc polycarboxylate. The pH of the cement is approximately 1.7, which rapidly increases as the cement sets. Despite their initial acidic nature, minimal irritation has been reported to the dental pulp when placed on adjacent dentin\textsuperscript{22} or used as a direct pulp cap\textsuperscript{23}. Polycarboxylates placed in root canal systems or beyond the confines of root apex show a varied periradicular tissue response. Apical leakage studies have indicated that polycarboxylates, when used as root-end fillings, leak at levels significantly greater than amalgam or gutta-percha.

Based on their poor sealing ability and uncertain periradicular tissue response, the use of polycarboxylate as root-end filling material is highly questionable. Further evaluation may be warranted.

Zinc phosphate cement

Rhein in 1897 used zinc phosphate cement along with gutta-percha to seal the root canal system prior to root-end resection. In 1941 Herbert recommended zinc phosphate mixed with powdered thymol as a root-end filling material following root-end resection. As previously discussed, the root-end filling material should be nonirritating, not inhibit healing, and exhibit minimal, if any, leakage or solubility. Since zinc phosphate does not fulfill these criteria, it is not indicated as a root-end filling material.

Glass Ionomer Cement (GIC)

Glass ionomers are formed by the reaction of calcium–alumino-silicate glass particles with aqueous solutions of polyacrylic acid. It bonds physico-chemically to dentine. Biocompatibility studies have shown evidence of initial cytotoxicity with freshly prepared samples, with decreasing toxicity as setting occurs. It is easy to handle and does not cause any adverse histological reaction in the periapical tissue\textsuperscript{24,25}. 
Sealing ability of GIC was adversely affected when the root end cavities were contaminated with moisture at the time of placement of cement\textsuperscript{26}. Marginal adaptation and adhesion of glass ionomer cements to dentin have been shown to improve with the use of acid conditioners and varnishes\textsuperscript{27}. Light cure, resin reinforced GIC was used as a retrograde filling material by Chong et al\textsuperscript{28}. It showed least microleakage due to less moisture sensitivity, less curing shrinkage and deeper penetration of polymer into dentin surface.

Newer glass ionomer cements containing glass-metal powder have been reported to have less leakage\textsuperscript{29} and showed no pathologic signs. Their use as root-end filling materials is promising and further evaluations are warranted.

**Composite resin**

Composite resins due to their cytotoxic or irritating effects on pulp tissue have received minimal attention as root-end filling materials. The cytotoxic effects are a function of the evaluative methods employed, and, when the agents are properly used, the cytotoxic effects were substantially decreased or eliminated\textsuperscript{30}. McDonald and Dumsha compared composite with a dentin bonding agent, composite alone, cavit, amalgam, hot burnished gutta percha, and cold burnished gutta percha and found that composite with dentin bonding agent showed least amount of leakage followed by composite alone when both of these were placed directly on resected root surface\textsuperscript{31}. These findings suggest that the preparation of a root-end cavity may be obviated.

Light cure composite resin showed significantly lower apical leakage than amalgam and ketac-silver\textsuperscript{32}. Rud et al\textsuperscript{33} applied Gluma \textit{in vivo} to cases requiring periradicular surgery and compared it to cases treated with root-end amalgam fills. Gluma exhibited complete healing in 74\% of the cases as compared to amalgam which showed in only 59\% of cases.

The proper use of dentin bonding agents and composite resin may play a significant role in enhancing the final root-end filling and the benefits of their use warrant further evaluation.

**Mineral Trioxide Aggregate (MTA)**

It was developed at Loma Linda University, CA, U.S.A in 1993. This cement contains tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide and other mineral oxides forming a hydrophilic powder which sets in presence of water. The resultant colloidal gel solidifies to a hard structure within 4 hours. Initially the pH is 10.2 which rises to 12.5 three hours after mixing. It is found to be more opaque than EBA and IRM. MTA provides superior seal when compared with Amalgam, IRM and Super EBA\textsuperscript{34}. Adamo et al\textsuperscript{35} compared MTA, Super-EBA, Composite and amalgam and found statistically no significant difference in the rate of microleakage but studies of Torabinejad et al and Fischer et al proved MTA to be superior as compared to Super EBA and IRM\textsuperscript{36}. The marginal adaptation of MTA was better with or without finishing when compared to IRM and Super EBA\textsuperscript{37}. MTA, when used as a root-end filling material, showed evidence of healing of the surrounding tissues\textsuperscript{38-40}. Most characteristic tissue reaction of MTA was the presence of connective tissue after the first postoperative week\textsuperscript{41}. Studies have shown that osteoblasts have favorable response to MTA as compared to IRM and amalgam. With longer duration, new cementum was found on the surface of the material\textsuperscript{42}. In a two year follow-up study with MTA as root-end filling material resulted in a high success rate\textsuperscript{43}. Such studies support further development of MTA to reduce the long setting time and difficulty in manipulation for use as a root-end filling material.

**Calcium Phosphate Cement (CPC)**

Developed by ADA-Paffenbarger Dental Research Center at the United States National
Institute of Standards & Technology, CPC is a mixture of two calcium phosphate compounds, one acidic and the other basic. Commonly known as hydroxyapatite cement, it is composed of tetracalcium phosphate and dicalcium phosphate reactants. These compounds, when mixed with water, react isothermally to form a solid implant composed of carbonated hydroxyapatite. The final set cement consists of nearly all crystalline material, and porosity is in direct ratio to the amount of solvent used. It is as radio opaque as bone. When combined by dissolution in moisture, even blood, CPC sets into hydroxyapatite. It demonstrates excellent biocompatibility, does not cause a sustained inflammatory response or toxic reaction. Its compressive strength is greater than 60 MPa and has shown to maintain its shape and volume over time. An in vivo monkey study found new bone formation developing immediately adjacent to CPC. CPC implants are resorbed slowly and are replaced by natural bone in an approximate 1:1 ratio in an osteoconductive manner. CPC seems to be quite promising as a retrograde filling material but it is yet to get approval from the United States Food and Drug Administration.

Laser

Laser applications for dental practice has been a research interest for the past 25 years. First laser, the Ruby laser was developed by Miaman in 1960. Application of laser in endodontics was introduced by Weicham in 1971. Studies show that the effects of laser irradiation are dependent on wavelength specificity and energy density. By varying a number of parameters (Pulse mode, irradiation time, frequency and energy outputs), several types of lasers are indicated for use in various fields of dentistry. Clinical investigations into LASER, used for apicectomy began with the CO₂ laser. Later Nd:YAG, Er:YAG and Ho:YAG lasers were used. The most promising wavelength has been the Er:YAG at 2.94 micrometers. Komori et al. compared CO₂, Nd:YAG, Er:YAG and Ho:YAG and found that Er:YAG was superior, it showed root surfaces devoid of charring. Clinically it’s use improved healing and diminished post operative discomfort. There have been no reports on clinical use of this laser for apicectomy.

The use of laser for apicectomy procedure has some merits, but it takes more time to perform when compared to more conventional methods.

Rest of the materials enlisted in this article has received brief mention in the dental literature for use as root-end filling materials following periradicular surgery. Little substantiation exists for the use of some of these materials, while others require further evaluation to determine the long term efficacy of their use.

Conclusion

The endodontic surgeon should consider using materials, which have been biologically and clinically evaluated and which give evidence of long term success. The root-end filling materials should provide a hermetic seal, should be non-toxic, non-carcinogenic, biocompatible and dimensionally stable. Based on review of literature, it appears to date that the existing root-end filling materials do not possess ideal characteristics, but studies have revealed that MTA and Super EBA are superior to other retro-grade filling materials.

References:


