Review Article

Root-end Filling Materials – A Literature Review

Tanu Singh[1], Anuraag Gurtu[2], Varnika Saxena[3]

[1]Senior Lecturer, Department of Conservative Dentistry and Endodontics, Bareilly International University, Bareilly, Uttar Pradesh, India, [2]Professor and HOD, Department of Conservative Dentistry and Endodontics, Bareilly International University, Bareilly, Uttar Pradesh, India, [3]Post graduate student, Department of Conservative Dentistry and Endodontics, Bareilly International University, Bareilly, Uttar Pradesh, India.

ABSTRACT

Following endodontic surgery, root-end filling materials are widely employed; however, their influence on neighboring soft tissues is unknown. Exposure of the affected area, root-end excision, and preparation and implantation of root-end filling material are common clinical procedures. This article offers a review of the literature on the materials that have been recommended for clinical usage as root-end filling, as well as the change toward the present materials of choice.

Key words: Amalgam, Glass Ionomer Cement, Bioceramics, Mineral Trioxide Aggregate, Periapical Surgery, Root Canal Treatment

INTRODUCTION

Modern endodontic surgery can reliably treat persistent and recurrent apical periodontitis. Modern microsurgical techniques, unlike traditional surgery, include the use of an operating microscope, ultrasonic tips for precise root-end preparation, and biocompatible root-end filling materials. Reflection of a full-thickness flap, acquiring access to the root apex through an osteotomy, root-end excision, root-end cavity preparation, and sealing off the root canal system with a root-end filling are all operations included in periapical endodontic surgery.[1]

The goal of root-end filling material is to create a hermetic physical seal, preventing microorganisms, or their by-products from egressing from the root canal system into the periradicular tissues. Properties of an ideal root-end filling material:[3,4]

The ideal root-end filling material should be capable of preventing the leakage of bacteria and their by-products by adhering to the dentine walls and sealing the root-end three dimensionally. It should be non-toxic, non-genotoxic, non-carcinogenic, and biocompatible with host tissues and not a cause of any inflammatory reaction. It should be insoluble in tissue fluids, dimensionally stable, unaffected by moisture during setting when set and should be radiopaque.

The ideal root-end filling material should be able to stimulate the regeneration of the periodontium, especially cementogenesis directly over the root-end filling, and easy to use with a long shelf life.

ROOT-END FILLING MATERIALS

Various materials have been suggested and tested for use as root-end filling materials in the quest for a suitable product that fulfills all the ideal requirements.

Amalgam

An amalgam is an alloy of a metal that contains mercury as one of its constituents. In 1884, Farrar is credited with being the first to use amalgam as a root-end filling material.[5] It was the most frequently used retrograde filling material and has served as a benchmark against which other filling materials have been measured.

Amalgam has the advantages of being affordable, readily available, easy to manipulate, radiopaque, and insoluble in tissue fluids.[2,5] Initial microleakage,[6] electrochemical corrosion,[7] induction of inflammation of adjacent periradicular tissues,[8] amalgam tattoo formation,[9] the need for an undercut in cavity preparation, zinc toxicity, delayed expansions, and concerns about mercury introduction into the periradicular tissues are some of its drawbacks as a root-end filling material.

However, amalgam use came into question when SEM studies showed gaps between the amalgam and the root canal wall, and when concerns about mercury toxicity developed (Dorn and Gartner, 1990).

According to Chong and Pitt Ford (2005), the use of amalgam as a root-end filling should now be confined to history.[2]

Gutta-Percha

Bowman invented gutta-percha in 1867 to fill the root canal area. Endodontic gutta-percha is made up of 20% gutta-percha

Corresponding Author:
Tanu Singh, Department of Conservative Dentistry and Endodontics, Bareilly International University, Bareilly, Uttar Pradesh, India.
E-mail: drsainisinghtanu543@gmail.com

as a matrix, 66% zinc oxide as a filler, 11% heavy metal sulfates as radiopacifiers, and 3% waxes or resins as a plasticizer.

When utilized as a root-end filling material, Woo *et al*. found that thermoplasticized gutta-percha with sealer had much less leakage than amalgam.[10]

A proposed strategy for sealing the root-end has been cold burnishing of gutta-percha during root-end resection. However, research reveals that this technique results in much higher leakage than amalgam and intermediate restorative material (IRM).

Because of its poor sealing capabilities, gutta-percha alone should not be used as a root-end filling.

Cavit (3M ESPE, St. Paul, Minnesota, USA)

Cavit is a pre-mixed temporary restorative material made of calcium sulfate that is simple to manipulate and apply to a root-end cavity.[11]

Cavit, on the other hand, is a soluble substance that dissolves when it comes into contact with bodily fluids. As a result, using it as a root-end filler is not recommended.

Glass ionomer Cements

Cavit, on the other hand, is a water-soluble material that dissolves when exposed to human fluids. As a result, it is not a good idea to use it as a root-end filler.

Glass ionomer cements have the benefit of being able to make a chemical bond with dentine and so give a better seal.[11] Initially, they generate a severe inflammatory response that quickly fades.[2] Glass ionomers are slow to set, difficult to handle, and moisture has an unfavorable effect on the setting reaction.[5,11]

Glass ionomer cements cannot be recommended as suitable root-end fillings since it is impossible to verify that the surgical site will be moisture free during the setting reaction.

Reinforced Zinc Oxide-Eugenol Cements (ZOEC)

Because of its good handling properties and satisfactory post-operative results, Nichols recommended zinc oxide-eugenol as a retrograde filling in 196.[2]

ZOEC is more resorbable than amalgam and provides a superior seal. It has strong compressive and torsional strength, low solubility, is radiopaque, and has a neutral pH (Oynick and Oynick, 1978), and the success rate in clinical tests was 75% for amalgam and 95% for ZOEC cement (Dorn and Gartner, 1990).

Early ZOECs, on the other hand, were weak, took a long time to set, and were soluble.[2] As root-end fillings, two variants of ZOEC have been recommended. These are described under (a) and (b) below.

IRM (Dentsply Sirona, York, Pennsylvania, USA)

Polymethyl methacrylate (20% by weight) has been added to the zinc oxide powder in IRM, but the eugenol liquid has not been changed.[2]

Super-ethoxybenzoic acid (EBA) cements

In 1970, Super-EBA was proposed as a retrograde filling. Super-EBA was recommended as a root-end filling by Oynick and Oynick (1978), since it is easy to handle and insert due to its plasticity, adheres to the dentinal walls under moist conditions, has a sufficient mixing time, and sets quickly once in contact with tissues.[12]

When compared to amalgam, gutta-percha, and glass ionomer cement, Super-EBA and IRM showed superior sealing ability, with Super-EBA outperforming IRM.[13-16] On the basis of this evidence, Super-EBA and IRM can be recommended as root-end filling materials.

Bioceramic Cements

Bioceramic materials could be described as biocompatible ceramics that are appropriate for use in the human body. ProRoot mineral trioxide aggregate (MTA) (Dentsply Sirona) was the first bioceramic cement patented for use as a root-end filler, and it is also known as MTA.[17] MTA was created at Loma Linda University in 1993. MTA was found to be superior in studies by Torabinejad *et al*. and Fischer *et al*., with better marginal adaption.

Tricalcium silicate, dicalcium silicate, bismuth oxide, and tricalcium aluminate and calcium sulfate are all present in minor amounts. The chemical make-up is comparable to Portland cement, with the addition of bismuth oxide for radiopacity. MTA is a powder made up of tiny hydrophilic particles that harden when exposed to moisture. When the powder is hydrated, it forms a colloidal gel with a pH of 12.5 that solidifies into a solid structure. The cement takes 4 h to set.[18,19] MTA has a compressive strength of 70 MPa after 21 days, which is comparable to IRM and Super-EBA but far less than amalgam (311 MPa).

MTA Angelus® (Angelus, www.angelusdental.com/Clinician Choice Dental Products Inc., www.clinicianschoice.com) was first introduced in Brazil in 2001 and acquired FDA approval in 2011, allowing it to be sold in the US. MTA Angelus has a faster setting time, comes in containers that allow for more precise dispensing, and has all of the good features of standard MTA. While the original MTA product comes in single-use packets, the newer MTA Angelus comes in air-tight bottles that allow practitioners to dispense a little amount of powder and then reseal the rest of the product in its original container for future use.

It takes roughly 2–3 h to set traditional MTA. MTA Angelus is ready to go in under 15 min. Because doctors may verify that the material is set at the moment of insertion and proceed with their restorative operations without fear of MTA washout, the reduced setting period is sometimes desirable. A decreased concentration of calcium sulfate, the ingredient responsible for the longer setting time in the original formulation, has resulted in a shorter setting time.[20]

Various studies have confirmed the material's superiority, sealability, excellent biocompatibility, cementogenesis, regeneration of the periodontal ligament at the resected root surface, and clinical prognostic superiority over others. Despite these biological advantages, MTA has a granular consistency and a long setting time, making it difficult to handle. It is also been claimed that it discolors the tooth structure around it.

MTA is available in two colors: Gray and white. The first MTA products were gray, and this formulation was the focus of much of the early research. The white form of MTA was launched to the market in 2002 in response to staining problems raised when MTA residues were left in the clinical crown. The difference between the two colors is mostly owing to lower iron, aluminum, and magnesium oxide concentrations in white MTA.[18,19]

Clinical Applications

In the United States, about 24 million endodontic procedures are performed each year, with advanced therapies such as periapical microsurgeries, perforation repairs, and apexification treatments accounting for 5.5% of these procedures. All of these endodontic procedures and some operative procedures have greatly benefitted from the availability of MTA.

The advantages of MTA as a root-end filling are as follows: [21-23]

1. MTA is able to form in a moist environment, such as blood.
2. Numerous experiments on microleakage and marginal adaption have demonstrated MTA's outstanding sealing capabilities.
3. MTA is biocompatible with human tissues and has been found in many cell culture tests to be one of the least cytotoxic materials.
4. When MTA comes into touch with a physiologic solution, hydroxyapatite crystals develop on its surface, indicating that it is a bioactive material.
5. Calcium ions are released by MTA, which react with extrinsic phosphate ions in the environment to create hydroxyapatite. The development of hydroxyapatite on the surface of MTA improves the chemical connection between MTA and dentine and can help the surrounding hard tissues to remineralize.
6. Osteoconductive: MTA and Super-EBA were discovered to be osteoconductive when implanted in bone, since they induced osteogenesis. MTA's ability to promote osteoblastic activity in bone has long been known.
7. Stimulates cementogenesis: Torabinejad *et al.* (1995) found that when MTA and amalgam were utilized as root-end fillings, cementum developed directly over MTA but not over amalgam in a histology examination on beagle dogs.

In a similar histological study carried out on monkeys and in which MTA and amalgam were used as root-end fillings, a thick layer of cementum was found over the MTA that continued over the resected dentine and joined the cementum on the side of the root.

The combination of the physical bond that MTA forms with dentine and the regeneration of cementum results in the formation of a double seal.

8. Antibacterial: When calcium hydroxide is released as a result of hydration, a very alkaline environment is created, which is antibacterial.

Some of the materials that have addressed the limitations of the pioneer material include those set out in the paragraphs.

MTA Plus™ (Prevest Denpro Limited, Jammu, India)

MTA Plus™ is a finer particle mineral trioxide aggregate material than MTA.

A proprietary salt-free polymer gel and water are included in the MTA Plus kit as mixing solutions. MTA Plus is used as a pulp capping cement, a root canal sealer, and a root-end filling substance. Different setting times and physical-rheological qualities can be obtained by utilizing the gel and altering the powder to gel ratio. The gel is designed to resist washout, and the tiny powder particle size makes it easier to handle and apply.

In compared to ProRoot MTA, MTA Plus demonstrated enhanced reactivity and a longer ability to release calcium and raise local pH to alkaline levels.[24]

Biodentine™ (Septodont, Saint-Maur-des-Fosses, France)

Biodentine™ is a "bioactive dentine substitute" made from a synthetic tricalcium silicate-based cement. Biodentine™ is made using "Active Biosilicate Technology™," which produces a pure tricalcium silicate that is devoid of metal contaminants.

The particle size of Biodentine™ powder was found to be significantly smaller than MTA powder. In a triturator, the aqueous solution is combined with the powder within the capsule for 30 s at 4000–4200 rotations/min. The creation of a calcium silicate hydrate gel and the release of calcium hydroxide are the consequences of the hydration reaction.

According to Camilleri *et al.* (2013), calcium carbonate works as a nucleation site for calcium silicate hydrate, resulting in a reduced induction period and, as a result, an initial set in <12 min. The Biodentine™ ultimate setup time was discovered to be 45 min.[25,26]

CONCLUSION

During the 19th and most of the 20th centuries, amalgam was the preferred root-end filling material. Toward the close of the 20th century, reinforced ZOE materials, IRM, and Super-EBA were on the verge of displacing amalgam as the favored root-end filling material. Because of its capacity to appreciate moisture, high sealing ability, and bioactivity and biocompatibility, calcium silicate cement MTA, launched around the turn of the century, outperformed all previous materials tested.

The continuous evolution of calcium silicate materials has resulted in products with improved handling properties and has provided the endodontic field with appropriate and effective repair and root-end filling materials.

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