



ENDOSEQUENCE ROOT REPAIR MATERIAL (ERRM): A LITERATURE REVIEW

Dentistry

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ABSTRACT

Bioceramics are biocompatible ceramic material specifically developed to be used in medical and dental fields to repair and reconstruct diseased or damaged part. Since 1990's MTA is a widely used bioceramics in dentistry. ERRM, a new bioceramic endodontic material available in pre-mixed syringes, is demonstrated to be an effective material for various endodontic treatments with similar properties to MTA. It has good antimicrobial properties with superior osteo/odonto induction potential. ERRM and iRoot can be effectively used as root repair material in various procedures such as perforation repair, furcation repair, retrograde filling material, vital pulp therapies (pulp capping, pulpotomy), as well as in regenerative procedures. Apart from this ERRM also promotes root formation hence, can be used in regenerative procedures (apexogenesis and apexification). This review of literature is focused on the properties and clinical applications of the new bioceramic material, Endosequence Root Repair Material (ERRM).

KEYWORDS

Endosequence Root Repair Material (ERRM), iRoot BP, regeneration, endodontics, bioceramics, root repair material.

INTRODUCTION:

Regenerative endodontics, a biological procedure, carried out in immature permanent teeth with trauma or deep dentinal caries with or without pulpal exposure, in order to replace the damaged tissue with healthy tissues along with continued root development with apical foramen closure. Materials used for regenerative procedures should have the capability of inducing the mesenchymal stem cells to differentiate into the desired cell type and produce the desired effect.¹ Bioceramics are ceramic compounds, specifically designed to be used in regenerative procedures. Its superior properties like excellent biocompatibility, anti-bacterial properties, ability to induce a regenerative response in an organism makes it an suitable material for regenerative dentistry. They are homogenous, inorganic, non-metallic material that includes alumina and zirconia, bioactive glass, glass ceramics, coatings and composites, hydroxyapatite, and resorbable calcium phosphates in dentistry for various procedures like root resorptions, perforations, retrograde fillings, pulpotomy, apexification. There are numerous bioceramics available in the market- MTA, BioAggregate, Biodentin, Endosequence Root Repair material (ERRM). MTA is the gold standard bioceramic material used since decades. Also, various authors in the literature suggested ERRM as an alternative material for regenerative procedures.^{2,3,4} This literature review presents an overall properties and applications of ERRM/iRBP in dentistry.

Endosequence Root Repair Material:

ERRM, a new bioceramic aluminium free material, introduced in recent decades as a modified version of MTA, to improve its handling properties and clinical outcome. ERRM holds an excellent alternative for MTA because of its superior anti-microbial efficacy, biocompatibility, and improved physical properties.⁵

No tooth discoloration has observed using this material because it contains zirconium oxide for its radiolucency, not bismuth oxide as in MTA. ERRM is a ready-to-use white hydraulic premixed putty material which is a totally a synthetic calcium-silicate-based cement. It is also available as iRoot SP, iRoot FS (iRFS), iRoot BP, and iRoot BP Plus (iRBP).⁴

Composition and uses ERRM:

According to the instruction manual, it is composed of tricalcium silicate, zirconium oxide, tantalum pentoxide, dicalcium silicate, calcium sulphate, calcium phosphate monobasic, and filler agents. According to the manufacturer, the application of ERRM includes

root-end fillings, apexification, pulpotomy, and indirect or direct pulp capping.⁵

Setting Time:

It is commercially available in premixed syringes which is carried to the desired tooth using a sterile plastic instrument. ERRM is a hydrophilic material and requires the presence of water to set and harden. The setting reaction is initiated instantly as the cement comes in contact with water/ moisture that eliminates the need for complete isolation which is difficult to achieve in children. iRBP sets in two hours⁶ whereas ERRM reaches its initial set at 61.8 ± 2.5 minutes and final set at 208 ± 10.0 minutes. iRFS has the fast-setting time reaches its initial set at 18.3 ± 2.6 minutes and final set within 1 hour.⁷

Properties of ERRM:

1. Tissue Regeneration:

Dental pulp is a highly vascular loose connective tissue, consists of predominant odontoblasts and undifferentiated mesenchymal cells. In response to an injury, the undifferentiated mesenchymal cells differentiate into odontoblasts-like cells and forms reparative dentin near the injured site.⁸ The alkaline phosphatase activity represents an early marker for odonto/osteogenic differentiation as it plays an important role in the formation hydroxyapatite crystals. The association of alkaline phosphatase (ALP) activity level with dentin mineralization is well documented in the literature. iRBP is shown to have the highest ALP activity which is constantly upregulated throughout the culture period (1 – 7 days) with its highest activity (CCK-8 assay) during days 3, 5, 7 than MTA. This represents the highest mineralization of iRBP to MTA.⁹ SEM and CLSM showed excellent adhesion and attachment of different human cells over the surface of set cement similar to MTA which represents the greater biocompatibility of iRBP.

The odonto/osteogenic potential of iRBP was found to be similar to MTA. iRBP triggers the odonto/osteogenic differentiation of BMMSC (Bone Marrow Mesenchymal Stem Cells) by promoting gene expression and protein levels of dentin sialo phosphoprotein (DSPP), osterix (OSX), osteopontin (OPN), and runt-related transcription factor-2 (RUNX-2). It induces BMMSC via MAPK and autophagy pathways.⁵ The iRBP induced the mRNA expression of specific odontoblastic markers (OC, DSP, DMP-1).⁹

2. Cytotoxicity:

ERRM contains zirconium oxide and iRBP contains tantalum oxide

for its radioopacity instead of barium oxide as in MTA to eliminate the toxic effect of barium oxide. However, the cytotoxic property of iRBP was found to be similar to MTA.¹⁰

3. Effect On Blood Exposure:

The exposure of the material to blood is inevitable when used as a medicament in certain procedures like direct pulp capping, pulpotomy, apexogenesis, perforation repair. Studies have proved the negative effects of dental material on blood exposure. This is because, the albumin, the plasma protein and other constituents of blood occludes the dentinal tubules and adversely affects the hydroxy apatite formation. With no exception ERRM required more than 48 hours to set in the presence of blood.¹¹ However, the push bond strength of ERRM decreased immediately after its exposure to blood but, significantly increased after 72 hours.¹²

4. Anti-microbial Efficacy:

The antimicrobial effect of iRBP was found to be significantly higher compared to MTA-HP (Mineral Trioxide Aggregate- High Plasticity). iRBP inhibits the growth of *Enterococcus faecalis*, the most prevalent micro-organism responsible for both primary and secondary infection of teeth. In addition, it also inhibits gram-positive cocci-*Staphylococcus aureus*, *Streptococcus mutans*, and superior antimicrobial activity against *Enterococcus faecium*, *Peptostreptococcus anaerobius*, and *Candida albicans* than MTA-HP. It showed no antibacterial effect against *Porphyromonas gingivalis* and *Actinomyces israelii*.¹³ Another study concluded that the iRBP has a similar anti-microbial effect as MTA against *Enterococcus faecalis* and *Candida albicans* but it does not possess an inhibitory effect on *Enterococcus faecalis*.¹⁴ ERRM is proved to be effective against ten strains of *Enterococcus faecalis*.¹⁵

5. pH:

iRoot BP is strongly alkaline in nature with higher initial pH measurements at 5 minutes and 60 minutes (12.1 ± 0.14 and 11.9 ± 0.25). At this higher alkaline pH, the hydroxyl ions affect the cell membrane and the enzymatic activity of the micro-organisms.¹³ However, the iRBP releases markedly higher concentrations of calcium and silica in acidic environment (pH 5.4) than in physiologic environment (pH 7.4).¹⁶ An acidic environment reduced the surface microhardness of ERRM.

6. Porosity:

Porosities formed in the endodontic material space for bacterial growth resulting in microleakage thereby failure of root canal treatment in permanent teeth. Operator-related factors such as the type of mixing and physical properties of the material are reasons for porous formation. The premixed ready to use root canal sealer ERRM has significantly lesser porosity than grey-MTA and white-MTA.⁷ iRBP demonstrated a similar degree of porosity as conventional MTA.¹⁷

7. Sealing Ability:

Sealing property of ERRM is enhanced over time, featuring the least leakage on day10 and 28. Whereas the ERRM showed similar dye penetration as MTA when used to furcation repair suggesting that it could be a desirable alternative for MTA in root-end filling material.^{18,19} However, the ERRM putty showed good marginal adaptation to the root canal walls similar to MTA than ERRM paste.²⁰

8. Dentinal Tubule Penetration Of Root Canal Sealers:

A hermetic seal prevents reinfection in the root canals after treatment which can be achieved by the penetration and interaction of the sealer in dentinal tubules. iRoot SP displayed a greater area of penetration than MTA. Extremely smaller particles with less than two microns in size and high viscosity of iRoot SP attributes to its penetration into the dentinal tubules. Further, iRoot SP undergoes 0.2% expansion while setting.²¹

9. Microhardness:

ERRM, the set material exhibited lowest microhardness on day one with a gradual increase over 28 days but reached similar to MTA on 4th day.⁷

10. Fracture Strength:

The fracture strength of ERRM is similar to MTA-Plus and MTA Angelus. ERRM showed better fracture resistance when placed in the coronal one-third^{22,23} (as in regenerative endodontic procedures) or in the apical one-third²⁴ (as in retrograde filling material). The mean

fracture strength value for ERRM is 17.65 ± 4.28 MPa.²³

11. Compressive Strength:

The compressive strength is significantly higher than MTA in ERRM on 7th day (107.4 ± 31.1 MPa) and 28th day (176.6 ± 22.0 MPa). The strength was reduced after saline contact (40-45 MPa) at 7 days. No significant differences were found between grey-MTA, white-MTA and iRFS.⁷

12. Push Bond Strength:

A tooth repair material encounters dislocation forces such as condensation forces, mastication forces. Shortly after perforation repair, the material might dislodge from the tooth while mastication because of the longer setting time. In general, ERRM proved to have superior push bond strength at 2 months than at 1 week.²⁵ Exposure of blood has positive effect on push bond strength.²⁶ ERRM exhibited lower push bond strength when used as a root canal sealer for placing the fiber post.²⁷

13. ERRM with 2% TAP incorporation:

Triple Antibiotic Paste (TAP), known for its anti-microbial efficacy, is widely used in lesion sterilization and tissue repair. The most commonly used TAP is the combination of metronidazole, ciprofloxacin, and doxycycline/ minocycline. Doxycycline/ minocycline tends to react with the available free calcium ions and forms chelates thus, compromising the effectiveness of apical plugs formed by ERRM. Thibodeau B and Trope M suggested cefaclor as an alternative for doxycycline.²⁸ ERRM incorporated with 2% triple antibiotic paste (ciprofloxacin, metronidazole, and cefaclor) demonstrated the highest calcium ion release from the apical plug than ERRM alone.²⁹

Clinical Application In Dentistry:

1. Pulp capping/ Pulpotomy: (tertiary dentin formation)

An ideal material for pulp therapy must have biocompatibility, anti-microbial property and it should heal the pulpal wound by facilitating reparative dentin formation. iRBP enhances reparative dentin formation. iRBP has the ability to induce the formation of reparative dentin when used as a pulpotomy or direct pulp capping medicament. iRBP as an indirect pulp capping effectively remineralizes the affected dentin in 4 weeks after the partial/complete excavation of infected dentin.^{30,31,32} The effect of iRBP as a pulp capping and pulpotomy material was investigated in wistar rats (in-vivo). iRBP enhanced the proliferation of human dental pulp cells in-vitro.³¹

iRBP as a direct pulp capping agent, induced reparative hard dentin formation immediately below the exposed area in all the specimens on the fourth-week observation. Whereas in the MTA group only hard tissue formation was observed only in three-quarters of the specimens. The newly formed reparative dentin in the iRBP group was similar to primary dentin with dentinal tubule-like structures coupled with polarized odontoblasts like cells aligned along with the layer.³¹ Micro CT analysis of tertiary dentin demonstrated superior compactness of dentinal tubules. Besides, the structure of tertiary dentin demonstrated with 3-D micro-CT analysis and histological evaluation showed homogenous dentin without defects.³² Moreover, the adjacent pulp tissue appeared to be normal without inflammatory cells.³¹

As a pulpotomy medicament, the iRBP resulted in the formation of a layer of hard tissue in the root canal at one-week observation and a thick layer of dentin bridge, in the fourth-week observational period, that completely sealed the canal orifice with polarizing odontoblasts like cells immediately below the dentin bridge.³¹

2. Partial Pulpotomy:

An ex-vivo study conducted by Azimi et al³³ demonstrated pulp inflammation, calcific bridge formation, and dentin bridge appearance using iRBP and ProRoot MTA was similar. The calcific bridge was evaluated under microscope on day 42 that revealed a layer of flat cells behind the calcific bridge. Complete calcific bridge formation was seen in 58% of specimens and incomplete bridge formation in 42% of specimens. The calcific bridge was permeable with tubular (25%), and atubular (67%) appearance. Tunnel defect was observed in 8% of specimens. Investigation of the cells in the inflammatory infiltration showed dominant mononuclear white blood cells with a complete absence of poly morpho nuclear cells. However, partial pulpotomy using iRBP was more sensitive to cold.³³

3. Apexogenesis:

The thickness of calcific bridge revealed a significantly thinner calcific bridge in iRBP than in CaOH. The dentin wall thickness and the root length were similar to the Calcium Hydroxide as well as when compared with the adjacent normal teeth. The survival rate of partial pulpotomy using iRBP was 90.4% at the end of 24 months.³⁴

iRBP pulpotomy is a suitable alternative for calcium hydroxide pulpotomy to induce root formation in traumatized young permanent teeth with complicated fractures. iRBP exhibited a 100% of clinical and 99% of radiographic success rate. Radiographically, dentin bridge formation was appreciated in 92.3% of cases.³⁵ Even though, the duration for complete root formation and the thickness of dentin bridge was not assessed in this study, other studies have proven the regenerative effect of iRBP.

4. Maturogenesis:

The hydraulic calcium silicate cements induce apatite formation after interacting with physiologic phosphate ions.^{25,36,37} iRBP is an excellent regenerative material that can induce root formation even in teeth undergoing apexification procedure. This was accidentally found and first reported by Nagarajan S et al.³⁸ Maturogenesis with the closure of apical foramen was observed in a non-vital immature mandibular premolar treated using iRBP. iRBP apexification was performed in mandibular premolar (45) which presented with a developmental anomaly, dens evaginatus. In the follow-up visit, surprisingly the radiographic evaluation revealed a continuation of root development beyond the apexification level with normal periodontal ligament and lamina dura, at 6-month follow-up. iRBP holds a promising future for regenerative procedures.³⁸ This provides strong evidence of regenerative property of the material. It could be hypothesized that when the material contacts the mesenchymal cells, it induces them to differentiate into odontoblasts like cells.

5. Pulpotomy In Deciduous Dentition:

iRBP as a pulpotomy medicament for deciduous teeth showed a success rate of 92.5% with complete calcified dentin bridge formation within one year. iRBP possesses an additional advantage of no tooth discoloration in treated teeth. The time taken for the procedure was significantly lesser than MTA.³⁹

6. Root End Filling Material:

There is a direct contact existing between the root repair material and the periapical tissue. The primary aim of a root canal repair procedure is sealing of infected/damaged root canals permanently thereby, promoting healing of root canals and surrounding periapical tissues. Hence, the material must have an excellent sealing ability, radioopacity, and the ability to set in a wet environment. Endodontic microsurgery is performed in post-treatment apical periodontitis. iRBP yields promising results as a retrograde filling material. In retrospective studies, 94.4% and 92% success rates were reported using iRBP.^{40,41}

CONCLUSION:

Eliminating the foci of infection is the primary goal of endodontics. As such, a good endodontic material should possess superior antimicrobial properties against root canal pathogens. ERRM possess antimicrobial properties similar to MTA. iRBP Plus is an operator-friendly material exhibiting higher sealing ability and least apical leakage than MTA with similar fracture strength suggesting that it could be a viable alternative for MTA when used in regenerative procedures. The pre-mixed ERRM and iRoot paste eliminate the difficulties in handling the material. Heretofore, iRBP Plus is the only material with the capability of inducing root formation in a non-vital teeth without additional procedures like inducing blood (revascularization) or placement of scaffolds (Platelet rich plasma, platelet rich fibrin). Another advantage is no discoloration is reported using ERRM and iRBP. The application of ERRM is not limited to root repair as it is proved to induce tissue regeneration in apexification and apexogenesis. Studies have proved the effectiveness of the new bioceramic material in various dental therapies.

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