Review Article

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# Materials used for Vital Pulp Therapy: A Review

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## ABSTRACT

**Background**: Pulp is the heart of the tooth and every attempt should be made to restore its heartbeats. Advancements in the knowledge of pulpal responses and material science, has contributed significantly to the development of range of materials, to be used for vital pulp therapy. Selection of an ideal material for dentin-pulp protection may be very confusing. The aim of this review is to summarize various vital pulp therapy materials currently available with their advantages and short comings.

**Keywords:** Vital PulpTherapy, Calcium Hydroxide, Bioceramics, Biomaterials Based Scaffolds.

## INTRODUCTION

Prognosis of vital pulp therapy depends not only on selecting the right case and right technique but also on selecting the right pulp capping material and providing a bacterial tight coronal seal. Materials used range from synthetic materials to use of biomaterials.

An Ideal material should :(1)

- Maintain pulp vitality
- Resist the forces under restoration
- Should be bactericidal or at least bacteriostatic
- Provide bacterial tight seal
- Should be radiopaque
- Should be sterile
- Adhere well to dentine and restorative material
- Stimulate reparative dentine formation

Advances in understanding of pulpal biology has triggered the development of biomaterials to be used for vital pulp therapy.

### 1. CALCIUM HYDROXIDE

It was introduced by Herman in 1920, as a pulp capping agent to stimulate pulpal recovery. It is the most widely used pulp capping material having the longest track record. It has a unique potential to induce mineralization even in tissues which are not programmed to be mineralized.(2) It has a high pH 9 – 12. It releases $Ca^{2+}$ and $OH^-$ ions, which causes activation of alkaline phosphatase activity, stimulating dentin bridge formation and giving antibacterial property.(3)(4) Sciaky and Pisanti found that calcium present in mineralized tissue does not come from calcium hyrdroxide but from the blood supply.(5)

However, calcium hydroxide has certain disadvantages as:

Lack of bonding, dissolution over time, incomplete bridge formation i.e. presence of tunnel defects, necrosis of tissue immediately adjacent to it (Fig.1) and pulp obliteration.(6)(7) It causes internal resorption in primary teeth, because it is very toxic initially and destroys the predentin internally.(8)

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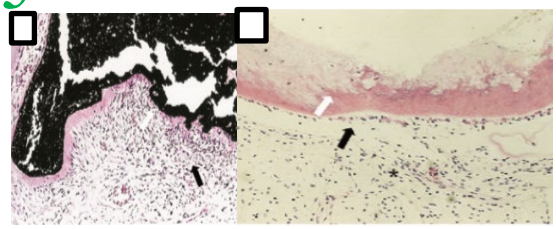

Fig 1a: Dentinal bridge formation with calcium hydroxide and MTA after 60 days of direct pulp capping.

(A) Ca(OH)2 shows irregular and Incomplete hard tissue bridge and chronic inflammatory infiltrates in the pulp(Black arrow)

(B) MTA shows irregular but complete hard tissue bridge (white arrow), odontoblast layer in contact with bridge (Black arrow) and normal pulp(*).

Calcium hydroxide is available in various forms, having different vehicle – aqueous, viscous or oily. Hard setting formulation is preferred as it release hydroxyl ions slowly causing less damage to the pulp.(1)


Fig 1b: Representative commercially available calcium hydroxide.

**2. BIOCERAMICS**

Ceramic materials that are specially developed for use as medical and dental implants are called Bioceramics. They include Alumina, Zirconia, Calcium silicate, Calcium oxides, Calcium phosphates, Calcium carbonates, Bioactive glasses, Glass- ceramics or Hydroxyapatite.

Bioceramics are broadly classified as: 9)

**Bioinert:** non-interactive with biological systems (Alumina, zirconia)

**Bioactive**: show interfacial interactions with surrounding tissue (bioactive glasses, bioactive glass ceramics, hydroxyapatite, calcium silicates)

**Biodegradable**: soluble or resorbable, eventually replaced or incorporated into tissue (Tricalcium phosphate, Bioactive glasses).

**Bioceramics used in endodontics are broadly divided into**

**Calcium silicate based – Cements**- Portland Cement, Mineral trioxide aggregate (MTA), Biodentine (Septodont, France), Theracal LC (Bisco) **Sealers** - Endo CPM Sealer (EGO SRL, Buenos Aires, Argentina), MTA Fillapex (Angelus, Brazil), BioRoot RCS (Septodont, France), TechBiosealer (Profident, Kielce, Poland).

**Calcium phosphates based** - tricalcium phosphate/ hydroxyapatite based

**Mixture of calcium silicates and calcium phosphates** - iRoot BP, iRoot BP Plus, iRoot FS (Innovative Bioceramix Inc., Vancouver, Canada), EndoSequence BC Sealer (Brasseler, Savannah, GA, USA)/ Total Fill, Bioaggregate (Innovative Bioceramix Inc., Vancouver, Canada), Ceramicrete (developed at Argonne National Lab, Illinois, USA), Calcium Enriched Mixture (BioniqueDent, Tehran, Iran)(10)

All bioceramic materials used for pulp therapy are biocompatible, bioactive - inducing dentinal bridge formation at the exposure site, hydraulic, radiopaque, achieves good hermetic seal, have high pH (around 12) and thus are antibacterial and act by releasing calcium and hydroxide ions. Bioceramics sets by hydration, forming hydrated calcium silicate gel and calcium hydroxide which is released over time. Its biological integration is due to the ions of Ca, which form hydroxyapatite in contact with phosphate ions present in body. (10) Fig. 2 shows interaction of representative bioceramic material with the surrounding tissue, stimulating hard tissue formation. (11)

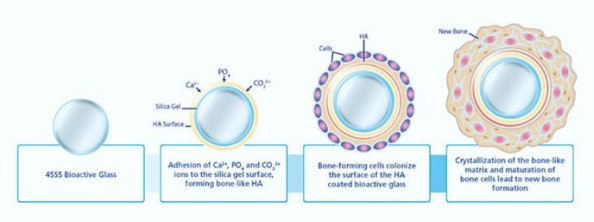


Fig 2: Surface reaction of Bioactive Glass, representing osteoconductive nature of bioceramics

**Few commonly used bioceramics in endodontics are:**

**a. Mineral Trioxide Aggregate (MTA)**

It is a medical grade version of Portland cement and bismuth oxide. It is the first bioceramic material introduced by Torabinejad in 1993, at Loma Linda University, California.(12) It is considered to be a bench mark against which other materials are compared. Its composition includes: (1)

**Powder**

- Tricalcium silicate
- Dicalcium silicate
- Bismuth oxide
- Tri Calcium aluminate
- Tetra Calcium AluminoFerrrite (present only in grey MTA)
- Calcium sulfate dihydrated
- Traces of free crystalline Silica, Calcium oxide, free Magnesium oxide, Potassium and Sodium sulfate compounds

**Liquid**

- Distilled water

Setting reaction of MTA is as follows: (10)(13)
$2(3CaO.SiO_2) + 6\ H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$
Tricalcium silicate + water → Calcium silicate hydrate + Calcium hydroxide
$2(2CaO.SiO_2) + 4\ H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2$
Dicalcium silicate + water → Calcium silicate hydrate + Calcium hydroxide
$3CaO.Al_2O_3 + CaSO_4 + H_2O \rightarrow 3CaO.Al_2O_3.3CaSO_4.3H_2O$
Tricalcium aluminate + gypsum + water → Ettringite

During the initial stages, calcium silicate hydrate is formed; coating the cement particles with calcium silicate hydrate prevents further reaction. Tricalcium aluminate dissolves and reacts with the calcium and sulphate ions present in the liquid phase to produce ettringite that also precipitates on the cement particle surface. The initial phase is followed by a dormant period wherein the hydrate coating on the cement grains prevents further hydration. The dormant period lasts for 1–2 h, and is a period of relative inactivity. Following the completion of the dormant period, setting of the cement proceeds to the acceleration stage wherein the hydration process accelerates again. The rate of tricalcium silicate hydration increases and more calcium silicate hydrate gel is formed. Hydration of dicalcium silicate also increases at this stage. Sulphate ions are depleted and monosulphate forms from ettringite. Crystalline calcium hydroxide also precipitates from the liquid phase.(10)

MTA has many advantages like:

- Biocompatibility
- It causes more predictable, faster & thicker hard tissue barrier formation in comparison to calcium hydroxide
- Less pulpal inflammation
- Releases bioactive dentin matrix proteins
- Osteo-conductive and Osteo-inductive
- Good Sealing ability
- Hydrophilic – sets hard in presence of water & presence of blood has little impact on it's properties
- Alkaline (12.5) in nature
- Exhibits significant antimicrobial activity.

It has a few shortcomings as well like:

- Poor handling characteristics
- Grey MTA causes tooth discoloration
- Long setting time ( 2 hrs 20 minutes) so requires two step procedure

Series of MTA products are available in market with variation in composition, handling properties and setting time. Newer MTA has less setting time eg. MTA plus gel: 55+/- 5 mins, MTA angelus :15 mins (decrease in calcium sulfate), Retro MTA: 180 sec (3mins,zirconia, no heavy oxides)


Fig 3: Few commercially available MTA products

**b. Biodentine (Septodont, Saint Maur des Fosses, France).**

Similar to MTA, except for the presence of calcium carbonate in powder, which acts as nucleation site and calcium chloride in liquid which accelerates the setting reaction. It is 2nd generation bioceramic material which does not cause discoloration of tooth due to presence of zirconium oxide.

Composition of Biodentine includes:(14)

**Powder**

- Tricalcium silicate
- Dicalcium silicate
- Calcium carbonate
- Zirconium oxide
- Calcium oxide
- Iron oxide

**Liquid**

- Calcium chloride
- Hydro soluble polymer and water


Fig 4: Commercially available biodentine.

Biodentin is available in form of capsules, where in 5 drops of liquid has to be added and put in amalgamator for 30secs, at 4200rpm.

Distinguishing features of Biodentin includes:

- Less setting time (Initial : 9-12 minutes, Final: 45 minutes )
- Good handling characteristics compared to MTA
- Good mechanical properties , eg. Compressive strength is 200 Mpa at 24 Hrs which is greater than MTA (40 MPa at 24 hrs)
- Can be used as interim restoration
- Less radiopaque than MTA (3.5 Vs 7.1mm of AL)
- More dense than MTA as less water is required for mixing.
- Shows slight setting expansion thus achieving good seal
- Biodentin is less difficult to remove as it is like dentin, and only ultrosonics are used near the orifices.

**c. Theracal LC (Bisco Inc., Schaumburg,IL,USA)**

It is a light cured, resin modified calcium silicate filled, premixed liner. It has a higher calcium releasing ability and lower solubility than either ProRoot MTA or Dycal. It can be cured to a depth of 1.7 mm, preventing untimely dissolution.(15) Its physical properties are stronger and it has high radiopacity. But it is opaque and whitish in colour, thus may show through translucent composite affecting shade of final restoration.(16)


Fig 5: Theracal LC

Next group of materials are **Mixture of Calcium Silicate and Calcium Phosphate:**

**d. Endosequence (ERRM; Brasseler, Savannah, GA).**

It is recently being introduced and is available as paste in preloaded syringes and also in a moldable putty form. Its composition includes:(16)

- Calcium silicates
- Monobasic calcium phosphate
- Zirconium oxide
- Tantalum oxide
- Fillers and thickening agents.


Fig 6: Endosequence

It has a good working time of 30 minutes. Setting time is more, 4 hrs after coming in contact with moisture. Sealing ability of endoseqence was significantly less when compared with MTA. (17) Whereas antibacterial activity and biocompatibility was found to be equivalent to MTA.(18)(19)

**e. Bioaggregate (Verio Dental Co. Ltd., Vancouver,Canada)**

Bioaggregate is a nano particle size formulation, similar to MTA, except for the presence of Tantalum oxide for radioopacity and elimination of aluminium.

It is composed of:(20)

- Tricalcium silicate,
- Dicalcium silicate,
- Calcium phosphate,
- Amorphous silicone dioxide and
- Tantalum oxide

It has a longer setting time of 4 hrs.

It is more biocompatible, has better sealing ability, higher fracture and acidic resistance than MTA. (21)(22)


Fig 7: Bioaggregate.

**f. Calcium Enriched Mixture (CEM) (BioniqueDent, Tehran, Iran)**

It is a newer generation of bioceramic with nano particle size 0.5 – 2.5 microns, smaller than dentinal tubules, thus precipitates within the dentinal tubules. It provides good seal, has less film thickness and more flow compared to MTA.

It is composed of:

- Calcium oxide
- calcium phosphate
- Calcium carbonate
- Calcium silicate
- Calcium sulfate
- Calcium chloride.

Fig 8: Calcium enriched mixture (CEM, BioniqueDent).

Its advantages over MTA include, shorter setting time( 50 mins), does not cause tooth staining, Induces a thicker dentinal bridge with less pulp inflammation, has better handling characteristics, does not adhere to instrument and has surface characteristics like human dentin.(23)

Research in regenerative dentistry, is evaluating experimental pulp capping materials, where in various growth factors are added to scaffolds/ bioceramics. These materials are proposed to induce natural dentinogenesis. Various natural scaffolds such as collagen, chitosan,alginate,etc. and synthetic scaffolds such as hydroxyapatite, tricalcium phosphate,self assembling peptide hydrogels,etc. have shown experimental differentiation of odontoblast like cells and dentin bridge formation.(24)

**BONE MORPHOGENIC PROTEIN (BMP)**

BMP is a member of transforming growth factor Beta.(TGF-β). BMP-2, 4, and 7 play a role in the differentiation of adult pulp cells into odontoblasts during pulpal healing.(25) Hu et al. has found that only TGF-β 1-enhances reparative dentin

formation.(26) However, there is a possibility of unexpected side effects or immunological problems with the use of growth factors. Also the appropriate dose response is not known, to avoid uncontrolled obliteration of pulp chamber.

**Platelet rich fibrin (PRF)**

In order to get autologous growth factors, PRF is investigated as a pulp capping material. Autologous venous blood (10ml) is collected without anticoagulants, centrifuged at 3000 rpm for 10mins, fibrin clot is collected, pressed and applied directly on exposed pulpal tissue. Growth factors and cytokines which are trapped in the fibrin meshes are slowly released in a controllable manner and over the long duration stimulating differentiation of odontoblast like cells and dentin bridge formation. Disadvantages associated with it include lack of sealing ability, thus has to be covered with bioceramic material.(24)

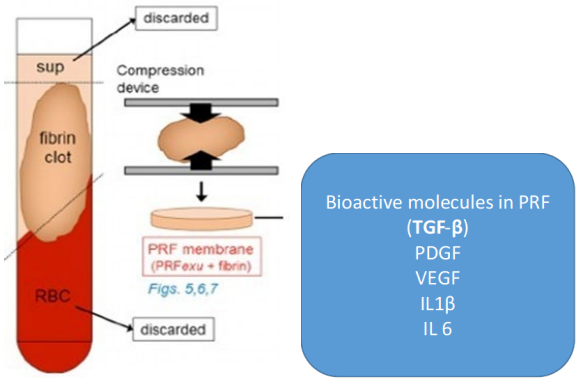


Fig 9: Formation of PRF Membrane.

## CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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