



Manoeuvring Bioactive Materials in Dentistry- A Review

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ABSTRACT

Bioactivity refers to bio-inductive activity. The materials which induce such activity are bioactive materials. These materials induce a reaction from living tissue. Bioactive materials have a role in the promotion of the healing process, repair, maintaining the vitality of pulp, etc. The material should be sterile, bacteriostatic and bactericidal in nature. Bioactive materials are used in dentin remineralization, maintaining long-term restorations bonded with cement, and repairing intra-bony lesions. A biomaterial is a substance, external layer or assembly that interconnect with an organic system. Biognosis- an analysis of, structure or uses of biologically generated materials, their mechanisms and processes for the formation of likely products by artificial mechanisms that mimics natural structures. A biomaterial is a substance, external layer or assembly that interconnect with an organic system. These materials differ in their form and function and composition. Bioactive substances function works due to the inauguration of growth initiators and multiple cells. It aids in "growth, immigration, and distinction of odontoblast-like cells producing tissue matrix. Bioactive matrix form an outer layer of an apatite-like substance in association with inorganic phosphate solution. Bioactive materials like calcium hydroxide, mineral trioxide aggregate, biodentin, etc., are commonly used in routine practice. As these materials have multiple purposes, this review focuses to highlight newer materials in the category of bioactivity and their implications in dentistry particularly.

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INTRODUCTION

Bioactivity of the materials used in dentistry mainly refers to its bio-inductive activity. Terms like

"bioactive", "bio-inductive", "biomaterials", and "biomimetic" refers to this activity. The bioactive material is a material that induces a reaction from living tissue, like the formation of hydroxyapatite. It acts on vital tissue, promoting healing, repair. It also has a role in the maintainance of pulp vitality. In dentistry, it has a role in regeneration, repair and reconstruction. Ideally, the material should be sterile. It should be bacteriostatic and bactericidal. Bio-inductivity refers to the ability of a material to produce a biological response. "Biomaterial is a substance, external layer or an assembly that interconnect with an organic system." "Biognosis- an analysis of, structure or uses of biologically generated materials, its mechanisms and processes for the formation of likely products by artificial mechanisms that mimics natural structures (Bhushan

et al., 2015).” Bioactive matter acts due to inauguration of different development initiators and cells. Such materials may produce an apatite-like product with inorganic phosphate solution. They help in remineralization, long-term bonded restorations, and intra-bony defects. Bioactive materials act by producing hydroxyapatite as it contacts with “phosphate-containing” physiological liquid. Apatite production is initiated with an interaction of Ca_2^+ released from the material with phosphates. These materials induce cellular changes in pulpal tissue and result in the production of reparative dentin at the surface of exposed pulp in vital pulp therapy. It aids in “growth, immigration, and distinction of odontoblast-like cells producing tissue matrix.” This non mineralized ground substance is mineralized by osteo-dentin at first and later by the formation of tertiary dentin (Hegde *et al.*, 2017). These bioactive materials also have a role in endodontic therapies. They lead to periodontal and periapical healing and thus improves the outcome of the endodontic treatment. The main purpose of this review is to appraise various “bioactive materials” and their implications in dentistry.

MATERIALS AND METHODS

CALCIUM HYDROXIDE [$\text{Ca}(\text{OH})_2$]

$\text{Ca}(\text{OH})_2$ is snowy, odourless dust. It was developed by Hermann in 1930. It has good biological properties like antibacterial effects and the ability to decrease osteoclastic activity and induce mineral tissue formation (O'Brien, 2009). Apexification, the treatment for non vital teeth with open apex, is commonly treated with $\text{Ca}(\text{OH})_2$. It dissolves organic tissues and passivates bacterial endotoxins (Mahalaxmi, 2013). It breaks into “Ca ions and OH ions”. The Ca_2^+ reduces “penetrability” and decreases “flow of serum” and thus decreases the level of “repressive pyrophosphatases”, causing calcification. OH^- ions neutralizes acidity by “osteoclasts”. The basic pH of the material, i.e. 11, is due to the release of hydroxyl ions. It causes an increase in levels of “calcium-pyrophosphatase”, decreasing the levels of “repressive pyrophosphate”, and thereby promotes calcification (Hegde *et al.*, 2017).

Uses

1. Conservative procedures- direct and indirect pulp capping.
2. Endodontics
 - a. Pulpotomy.
 - b. Apexification.

- c. Management if resorption.
 - d. Management of traumatized teeth.
 - e. Intracanal medicament.
 - f. Endodontic sealer.
3. Pediatric dentistry- as pediatric obturating material (Anusavice *et al.*, 2013; O'Brien, 2009).

Mineral Trioxide Aggregate

Discovered by “Mahmoud Torabinejad” (1993) “Loma Linda University” (Sonarkar and Purba, 2015). It mainly constitutes “calcium and silicate”. It mainly comprises “di-calcium silicate, tri-calcium silicate, tri-calcium aluminate, gypsum, and tetra-calcium-alumino-ferrite”. Initially, only Grey MTA was introduced (Hegde *et al.*, 2017). White MTA was introduced in 2000 to eliminate discoloration and esthetic problems (Anusavice *et al.*, 2013). It has been observed histologically that MTA leads to the formation of new cementum in periradicular tissue area and a low inflammatory response with bridge formation in the pulp space (Peter *et al.*, 2015). It forms an “apatite-like” sheath on its uppermost layer when it contacts with physiologic liquid or with activated tissue fluids. MTA dissolve in tissue fluids releasing “Ca, Si, Bi, Al, and Mg”. Calcium is the most dominantly released. It leads to the precipitation of hydroxyapatite (HA). This reaction continues beside the dentinal wall. As MTA is placed in root canals, it gradually dissolves and HA seals the space of MTA and dentin. This reaction results in the formation of a chemical bond that seals between the MTA dentin interface (Peter *et al.*, 2015).

Uses

In primary teeth

- a. Pulp covering.
- b. Partial removal pulp.
- c. obturation.
- d. Root puncture repair.
- e. repair of root defect.

In permanent teeth

- a. Pulp covering.
- b. Partial removal of pulp.
- c. Perforation puncture.
- d. Defect repair.
- e. Repair in fracture - Horizontal and Vertical.
- f. Apex filling.
- g. Root end blockade.
- h. Coronal barrier for regenerative endodontics.

i. As a root canal sealer ([Anusavice et al., 2013](#); [O'Brien, 2009](#); [Peter et al., 2015](#)).

Calcium Enriched Mixture Cement

It was introduced by "Asgary in 2006". It is a "new root canal cement", which was further named as a "Calcium-empowered mixture". It is a "water dependent cement" mainly comprising of "CaO, CaPO₄, CaCO₃ Ca-si, CaSO₄, CaCl₂". The cement leaches both "calcium and phosphorous" and leads to the formation of appetite crystals. CEM has pH and increased flow, similar to MTA. In the contrary, it has reduced manipulating time, film size, and lower cast than MTA. "Asgary et al." stated that this cement initiate dentinogenesis after direct pulp capping and pulpotomy and in apexogenesis. It also induces cemento-genesis after perforation repair or surgery.

Uses

1. As root-end filling biomaterial.
2. For resorption.
3. For root filling teeth ([Anusavice et al., 2013](#)).

Biodentin

Biodentin was introduced by Septodont in the year 2011. It is a rapidly-setting calcium silicate based material ([Hegde et al., 2017](#)). It was introduced as a "bioactive dentin replacement material" with properties likely that of dentin. The material stimulates tertiary dentine formation by activation of pulpal cells. It is composed of a "combination of calcium and zirconium dioxide as a radiopacifer". In contact with dentine, biodentin leads to the formation of the tag-like structures, namely the "Mineral Infiltration Zone," which may contribute to adhesive properties. Calcification is in the form of "osteodentine" ([Asgary et al., 2009](#)).

Uses

1. For enamel placement.
2. For dentin placement.
3. For Deep carious lesions.
4. Pulp covering
5. Pulp partial repair.
6. Root perforation repair.
7. Furcation repair.
8. Repair resorption.
9. Repair of external resorption.

10. Apex blockede.

11. Retrograde surgery ([Anusavice et al., 2013](#); [Sonarkar and Purba, 2015](#)).

Bioaggregate

First nanoparticulate mineral cement introduced. Bio-Aggregate is a fine white hydraulic cement-like powder. It is composed of contamination-free bioceramic nanoparticles. It is similar to MTA in its composition. It is an insoluble, radiopaque, and aluminium-free material mainly formed of calcium. As an aluminium-free formulation, it stimulates the proliferation of PDL fibroblasts and helps in periodontal regeneration ([Hegde et al., 2017](#)).

Uses

1. Vital pulp therapy.
2. Formation of the calcific barrier at the apex in cases with an open apex.
3. Resorption of root.
4. Perforation of root.
5. Retrograde material ([Hegde et al., 2017](#)).

Endosequence Root Repair Material

It is ca-si material. It is mainly available in paste or putty form. It comprises "calcium-phosphate monobasic, Ca silicates, zirconium-oxide and tantalum-oxide". It is a hydrophilic bioceramic, insoluble, radiopaque material. It is an aluminium free material with high pH. It sets and hardens in the presence of moisture. It initiates tissue fluid results in the precipitation of apatite crystals ([Hegde et al., 2017](#)).

Uses

1. Direct or indirect pulp capping.
2. Formation of apical hard tissue barrier.
3. Internal resorption.
4. Radicular Perforation.
5. Retrograde filling material.

Bioactive Root Canal Sealers

It comprises of a "mixture of various calcium-silicates, tantalum-oxide, fillers". It forms a tight seal in gutta-percha (GP), sealer, and dentin. These sealers have antibacterial property because of its high pH ([Hegde et al., 2017](#)).

Eg. "BC Sealer(Brasseler USA); iRoot SP (Innovative BioCreamixInc), is an injectable root repair material (Bhushan *et al.*, 2015).

Bio Root Rcs

It is a "Mineral-based material". It has a tricalcium, silicate setting system. The powder is mainly composed of "zirconium oxide as radiopacifier and a watersobtion polymer for adhesion enhancement". The liquid consists of "water, calcium chloride as a setting modifier and a water reducing agent". It stimulates physiological mineralization. It creates a nidus for the repair of periapical tissues. It has bioactive properties, including safety, oxyapatite formation, mineralization, high pH and sealing properties (Hegde *et al.*, 2017).

Bioactive Luting Agents

Modification of bioactive chemically bonded cement of which Ceramic has been used most commonly in restorative dentistry. It is a "calcium-aluminate" based material. It is used for cementation. It acts on the mechanism of calcium-aluminate and GIC. Glass ionomer component has advantages like Low pH, modified flow and setting method, initial adhesiveness to the tooth structure, early strength. Calcium aluminate help to; increased strength and retention time, biocompatibility, blocking of tooth material gap, apatite formation, lack of degradation, stable basic cement pH (Hegde *et al.*, 2017).

Uses

1. Cementation of the prosthesis.
2. Cementation of gold intracoronal and extra coronal restoration.
3. Luting of the secondary retentive matrix.
4. Cementation -zirconia or alumina crowns.

Doxadent

It is "calcium-aluminate cement". It is marketed as a powder and liquid system. It is mainly composed of "alumina, calcium-oxide, H₂O, zirconium-dioxide, and the alkali-oxides". On mixing powder and liquid, calcium-aluminate gets dissolved in water and form "calcium, aluminium and hydroxyl ions", which leads to the formation of "katoite and gibbsite" (Bhushan *et al.*, 2015).

Resin Impregnation with Titanium Oxide

The titanium oxide nanoparticles are incorporated in dental monomers and dentin bonding adhesives. This promotes hydroxyapatite formation and enhances the strength and bactericidal property of the restoration.

The nanoparticles incorporated seals the marginal gaps and re-mineralizes both enamel and dentin. Thus, it reduces the chances of secondary caries formation (Bhushan *et al.*, 2015).

MTYA1-CA Filler

It is composed of resin. It is available in powder and liquid system. Powder consists of "89.0% micro filler, 10.0% Ca(OH)₂, and 1.0% benzoyl peroxide".

Liquid is formed of "67.5% tri ethylene glycol dimethacrylate, 30.0% glyceryl methacrylate, 1.0% O-methacryloyl tyrosineamide, 1.0% dimethylamino ethyl methacrylate, and 0.5% camphor-quinone". It forms a dentine bridge without the formation of a necrotic layer.

It was found of having good physical properties and was not inferior to "Dycal" histopathologically (Bhushan *et al.*, 2015).

Uses

As a direct pulp capping agent.

Tetracalcium Phosphate

It is a resinous material. It is composed of "powder: 89.0% microfiller, 10.0% calciumhydroxide, 1.0% benzoylperoxide and a liquid : 67.5% triethyleneglycol di-methacrylate, 30.0% glyceryl-methacrylate, 1.0% o-methacryloyltyrosineamide, 1.0% dimethylaminoethylmethacrylate, and 0.5% camphor-quinone" (Bhushan *et al.*, 2015).

Uses

As a direct pulp capping agent.

Calcium Phosphate

Available in the form of paste, cement, ceramics and scaffold. It consists of " tetra calcium phosphate and dicalcium phosphate'. It helps in "biological and pathological mineralization". It induces dentin barrier generation with no necrosis of superficial tissue. This eliminates pulpal inflammation.

Also known as hydroxyapatite cement. It is composed of one acidic and one basic calcium phosphate compound. It was introduced by ADA Paffenbarger Research Center (Bhushan *et al.*, 2015; Rudagi and Rudagi, 2012).

Uses

1. As coatings on various materials to enhance its bioactivity.
2. Used to fill and heal bone defects.
3. Used in combination with scaffolds in regenerative procedures.

Theracal

It is a “light-cured, resin-modified calcium silicate filled liner”. It insulates and protects the dentin pulp complex. It has a property of higher calcium release and low solubility (Bhushan *et al.*, 2015).

Uses

1. Pulp capping.
2. As base/liner material.

Application of Bioactive Materials in Conservative Dentistry and Endodontics

Root Canal Therapy

1. “Portland cement or Mineral Trioxide Aggregate” is used for vital pulp therapy and repair of perforation.
2. “Mineral trioxide aggregate” is also used as an obturating material.
3. It is used in cases of the open apex.

Tooth Repair and Regeneration

1. ECMPs contain developmental factors promoting tooth healing and regeneration of pulpal tissue.
2. “Dentonin” (peptide) can induce reparative mineralization of pulp.
3. “Novel biomaterial” promote the regeneration of tissue of the tooth.

Hypersensitivity

1. A “novel bioactive glass-ceramic” used in the treatment of hypersensitivity.
2. It induces HCA (hydroxylcarbonateapatite) deposition tubules of dentin and thus occluding them.

Biomedical

Stem Cell Therapy

Stem cells, in combination with bioactive materials, alter injured tissue function by replacing damaged cells with healthy cells.

Dental Tissue Regeneration

A combination of biomimetic material and scaffold and stem cells add additive effect in its regenerative impact on pathological tissues.

Tissue Engineering

1. Gelatin is a natural polymer.

2. It is a form of collagen.

3. Biomolecules released from gelatin maintain their botanical activity and help in tissue regeneration (Bhushan *et al.*, 2015; Manoj *et al.*, 2018).

CONCLUSIONS

From this review, it can be concluded that bioactive materials are used in numerous clinical indications like “pulp capping, pulpotomy, root ending filling, repair of root resorption, repair of root perforations, and apexification”. Materials like “Calcium hydroxide & MTA” are still used effectively due to their bioactive potential. Recent materials such as “Bioaggregate, Biodentine, Endosequence Root Repair Material, I Root BP, and BP Plus” are also gaining popularity. Now bioactive cement can also be used as lining and bases “(Biodentine)” and as luting cement for crown and bridge. Newer mechanisms for adhesion, integration, and sealing of dentin are being developed using bioactive technology, and these materials will closely resemble natural teeth in more ways than one and will change the future of restorative dentistry.

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Conflict of Interest

The authors declare that they have no conflict of interest for this study.

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