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Bioactive Materials: A Review

Dr.Pradnya V. Bansode[1], Dr.Seema D. Pathak[2], Dr.M. B. Wavdhane[3], Dr.Vaibhav Lohate[4]

[1](Head of Department, Professor, Department of Conservative Dentistry and Endodontics, GDC and Hospital, Aurangabad/MUHS, India)

[2](Professor, Department of Conservative Dentistry and Endodontics, GDC and Hospital, Aurangabad/MUHS, India)

[3](Associate Professor, Department of Conservative Dentistry and Endodontics, GDC and Hospital, Aurangabad/MUHS, India)

[4](MDS Student, Department of Conservative Dentistry and Endodontics, GDC and Hospital, Aurangabad/MUHS, India)

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ABSTRACT : Bioactive materials have evolved over the past few decades. Since then bioactive materials have been used widely in the fields of Dentistry and Medicine . In modern dentistry, there is a great interest in the application of these materials for restorative and endodontic treatments . These materials acts on the vital tissues by contributing in it's healing and repair.In conservative dentistry, the term "bioactive" refers to the ability of a material to form hydroxyapatite crystals on its surface. These materials have antimicrobial action which has great impact on the protection from recurrent caries and bacterial microfiltration. These materials havebiocompatibility , bioactivity and rheological properties , due to whichthese can be good alternatives as root canal fillers in endodontics. Also we can use them as drug delivery vehicles and as scaffolds in pulp tissue engineering . This article focuses on types and applications of bioactive materials .

Keywords : Bioactive materials , MTA , Nanoparticles.

I. INTRODUCTION :

The evolution of Dentistry is closely associated with the advancements in dental materials and their applications[1] . Currently, there is a change in the behaviour of dental materials, going from being passive biomaterials without having positive or negative reaction in the body to those having constant bioactivity with a positive and expected reaction, which causes cellular stimulation or antimicrobial activity [2] . Initially ideal restorative materials were thought to be the one which were biologically inert and hence biocompatible [1].

The terms "bioactive," "bioinductive," "biomimetic," and "biomaterial" are distinct and have been described separately. Bioactive material is the material which have the ability to affect or elicit a response from living tissue, organisms or cells such as inducing the formation of hydroxyapatite crystals,hydroxycabonate, etc[3, 4] .

The capability of a material to induce a response in a biological systemis known as bioinductive property . Any matter, surface, or construct that interacts with biological systems is called as biomaterial . Biomimetics is the study of formation, structure, and function of substances that are produced biologically(such as silk / conch shells) and biological mechanisms and processes (such as protein synthesis /mineralization) for the purpose of synthesizing similar products through artificial mechanisms that resembles natural structures. The ideal characteristics of bioactive material are: bactericidal or bacteriostatic effect , sterile environment thatpromotes the reparative dentin formation and maintains the vitality of pulp [3] , [4] .

CLASSIFICATION OF BIOACTIVE MATERIALS :

I] Bioactive materials are classified into 2 groups based on cellular response.[1] :

CLASS A : OSTEOPRODUCTIVE MATERIALS.

When a material elicits both an intracellular and extracellular response at its interface , Class A bioactivity occurs **.** 45S5 bioglass is good example of osteoproductive material , these materials shows both osteoproductive and osteoconductive properties[1] .

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GROUP B: OSTEOCONDUCTIVE MATERIALS .

Osteoconductive bioactivity occurs when a material shows only an extracellular response at its interface.These materials provide a biocompatible interface along which bone migrates. Synthetic hydroxyapatite (HA) is a good example of osteoconductive materials[1] .

II] We can also classify the bioactive materials in Dentistry depending on their intervention with the tissues[2] .

i) RESTORATIVE :

The incorporation of these bioactive agents plays a protective therapeutic role in dental restorations by inducing the mineralization of the collagen mesh and the fossilization of metalloproteinases . Incorporation of these bioactive fillers in the restorative materials induces the formation of apatite crystals[2] .

ii) REMINERALIZE :

The gain of calcified material in the dental structure that was previously lost by demineralization caused by acids and a decrease in the pH of bacterial metabolism is referred as remineralization . Bioactive materials plays a fundamental role in remineralization process by ionic exchange , generating supersaturation of the fluids that lead to ionic precipitation in demineralized tissues and the formation of amorphous calcium phosphate with the growth of hydroxyapatite crystals [2] .

iii) DESENSITIZING :

Bioactive glasses have been accepted as desensitizing agents in the treatment of dental hypersensitivity . Bioactive glass reacts with artificial saliva to form apatite hydroxycarbonate crystals within collagen fibers that are similar to the mineral phase of human hard tissues. These deposits occlude the open dentinal tubules resulting in desentization[2] .

iv) ANTIBACTERIAL :

The components of bioactive materials have the ability to generate an alkaline medium, with a pH between 8 and 9 which favors bacterial inhibition reducing the formation of secondary caries , for example : incorporation of Methacryloyloxy-dodecylpyridinium bromide (MDPB) monomers creates a long-lasting antibacterial effect without compromising mechanical properties such as strength and biocompatibility[2] .

II. DISCUSSION

MATERIALS :

1) Calcium Hydroxide :

In 1920 , Calcium hydroxide was described for application in Dentistry by Hermann . Properties of calcium hydroxide derive from its ionic dissociation into calcium and hydroxyl ions[5] . The calcium ions reduces the capillary permeability which in turn reduces both serum flow and levels of inhibitory pyrophosphates which ultimately causes mineralization. Acids produced by osteoclasts are neutralized by hydroxyl ions which further maintain optimum pH for pyrophosphatase activity leading to increase the level of calcium-dependent pyrophosphatase which reduces the levels of inhibitory pyrophosphate and helps in mineralization[3,4,6].

2) MTA :

In 1990 , Mineral trioxide aggregate (MTA) was introduced by Torabinejad .It is a bioactive material whichis mainly composed of calcium and silicate. Dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, and tetracalciumaluminoferrite are the major components of the MTA . These calcium silicate–containing materials elicits apatite crystal formation. Exact mechanism of formation of dentinal bridge by the MTA is not known and more research is needed for understanding this mechanism. However, MTA can be used as a pulp-capping agent as it induces cytologic and functional changes within pulpal cells which results in the formation of reparative dentin at the surface of the exposed dental pulp. When placed , MTA helps in proliferation, migration, and differentiation of the odontoblast-like cells that produce a collagen matrix. This unmineralized matrix is initially mineralized by osteodentin and then by formation of tertiary dentin.

MTA is used in vital pulp therapy, apexification and apexogenesis, regenerative procedures and repair of injured tooth. Also these materials can be used as a obturating material in root canal therapy , as root-end filling material in apicoectomy procedures as well as for correcting procedural errors in endodontics [1,3,4,7,8] .

3) Calcium – enriched Mixture Cement (CEM) :

Calcium–enriched mixture cement is also called Novel Endodontic Cement (NEC) and was introduced by Asgary. The major ingredients of CEM are calcium oxide, silica, and bismuth oxide . Other components are calcium carbonate, calcium

silicate, calcium sulfate, calcium chloride.This cement releases both calcium and phosphorus ions which leads to hydroxyapatite crystal formation[3,4,9,10]. It is proven that CEM is able to produce hydroxyapatite with its endogenous as well as exogenous ions sources[10].

4) Biodentine :

It is a bioactive material that shows similar properties like dentin and it has a positive effect on vital pulp cells which helps in formation of tertiary dentin[1,3,4,11] . As this material has good handling properties associated with its biological, mechanical and physical properties we can use it as a pulp capping agent and bulk restorative material at the same time[11] .

5) Calcium phosphate :

This cement has properties such as good biocompatibility along with superior compressive strength, and its transformation into hydroxyapatite crystal over time[3,4]. It has the ability to stimulate the pulp to form hard tissue in direct contact with the cement, which suggests the possibility of its use as a pulp-capping agent [12].

6) Tetracalcium phosphate :

It is a resin-based cement which is used as direct pulp-capping agent[3,4] . In comparison to other calcium phosphate cements , tetracalcium phosphate (TTCP) has a higher solubility and has greater basic property[13] .

7) Bioaggregate :

Bioaggregate is a calcium silicate material available in powder and liquid form which can be used for pulp capping and apexification . Also it can be used as a root perforation repair material, root end filling material[1,3,4 ,14].

8) Endosequence root repair material :

It is a calcium silicate material , available in paste or putty form . It mainly consists of calcium silicates, monobasic calcium phosphate, zirconium oxide, tantalum oxide and proprietary fillers .The applications are similar to that of bioaggregate[1,3,4,14,15].

9) Doxadent :

It is a calcium aluminate product. It is used as restorative material . It is available in a powder liquid form. After mixing powder with liquid , water dissolves the calcium aluminate powder, leading to the formation of calcium, aluminium, and hydroxyl ions, resulting in the formation of katoite and gibbsite. Calcium aluminate component in this cement is reported to contribute to increased strength and retention over time , biocompatibility , sealing of tooth material interface , bioactivity-hydroxyapatite crystal formation , lack of solubility and development of a stable basic cement pH[1,3,4,14].

10) Ceramir :

It is a calcium aluminate cement which is used as a luting agent . These calcium aluminosilicate cements are fast-setting , acid-resistant, bioactive cements[16]. It basically works on the principle of two cements: calcium aluminate cement and glass ionomer cement. It is used in luting of permanent crowns and fixed partial dentures, inlays and onlays, metal and cast dowel and cores, and high-strength all-zirconia or all-alumina crowns[1,3,4,14].

11) Resin Impregnation with Titanium Oxide (TiO2) 8 :

TiO2 nanoparticles can be impregnated in dental resins, such as dental monomers and dentin bonding agents . These nanoparticles help in remineralization of enamel as well as dentin by restoring the marginal gaps, it also promotes hydroxyapatite formation . It has combined features of bioactivity and bactericidal effect which reduces the incidence of secondary caries [3,4,17].

12) Theracal :

It is light-cured , pulp-capping material composed of resin and calcium silicate . It has higher calcium releasing ability and lesser solubility when compared with ProRoot MTA and Dycal. It can be cured to the depth of 1.7 mm . It can be used in direct and indirect pulp capping , as a base or liner under amalgams , composites and other cements[3,4,18].

13) MTYA1-Ca filler :

Niinuma A. developed MTYA1-Ca which is resinous material containing calcium hydroxide. It is available in the powder and liquid form . Powder contains microfiller, calcium hydroxide and benzoyl peroxide and liquid contains triethyleneglycoldimethacrylate, glyceryl methacrylate, O-methacryloyl tyrosine amide, dimethylaminoethylmethacrylate and camphorquinone . Its is used as direct pulp capping agent[3,4,19].

14) Sol-gel-derived Ag-BG :

Sol-gel derived bioactive glass-ceramic (BG) containing silver ions (Ag) is bioactive material having antibacterial and regenerative properties[3,20].

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15) iRoot BP :

iRoot BP is a calcium silicate material available in paste or putty form. It is a injectable root repair material[14].

16) Castor Oil Bean Cement (COB) :

Recently, a material based on a polymer derived from the castor oil plant i.e. Ricinus communis was introduced into endodontics . This material is called as castor bean polyurethane cement (COB) .It is composed of 81–96% triglyceride of ricinoleic acid, and is considered as a natural polyol containing three hydroxyl radicals. This cement have antibacterial properties and is compatible with living connective tissues . Also It has the potential to facilitate tissue healing due to which it can be used as pulp capping material[3,4,21] .

17) Nanoparticles :

Nanoparticle improve the quality of the products by adding various functional groups to it. There are different types of nanoparticles used in dentistry like nanocarbon, nanosilica,nanozirconia,nanohydroxyapatite , silver nanoparticles, chitosan based nanoparticles, copper based nanoparticles, zinc based nanoparticles, titanium oxide nanoparticles and nanoparticles of amorphous calcium phosphate (ACP). Silver is the frequently used NPs, used in various products in different form, which is followed carbon and ion oxides (TiO_2). Nanoparticles are used as dental filling materials, to treat hypersensitivity, for prevention of caries, in vital pulp therapies, as a drug delivery system and as a coating over dental implant surface[22].

Applications Of Bioactive Materials And Molecules In Dentistry

1. **Bioactive materials can be used in vital pulp therapy :**

Bioactive materials are used for maintaining vitality of the pulp and periodontal tissues. These materials arecapable of stimulating specific biological responses via biochemical and biophysical reactions that result in the formation of an hydroxyapatite layerand helps In pulpal tissue repair.

2. **In apexogenesis and apexification :**

These materials can be used in apexogenesis which is indicated in teeth with vital pulp and open apex while apexification is indicated in teeth with necrotic pulp.

3. **In repair of endodontic procedural errors :**

Root perforations can occur during root canal therapy , post space preparation and also as a result of the extension of an internal resorption into the periradicular tissues.Surgical repair of these perforations is indicated whenrepair fails with intracanal approach or if the perforations can not be accessed through the access cavity.

4. **As root end filling materials :**

The use of MTA as root-end filling material is associated with significantly less inflammation, cementum formation over MTA, and regeneration of the periradicular tissues .

5. **As obturating materials :**

MTA can be used as obturating material in root canal therapy due to its capacity to prevent bacterial leakage and ability to form effective seal [1,3,4,23].

6. **For repairing injured and broken teeth :**

MTA has replaced calcium hydroxide as the material of choice for repairing injured and broken teeth. Also we can use biodentine , bioaggregate , and calcium silicate cement to repair the injured tooth.

7. **In regenerative procedures :**

These materials have ability to stimulate dental pulp stem cell proliferation, differentiation, and migration. Dentonin (peptide) can stimulate reparative mineralization of the coronal pulp which result in occlusion of the lumen of the root canal. The ECMP and Dentonin biomolecules are one of the most potent of all the growth factors available for promoting pulp repair and regeneration[4,24].

8. **To treat hypersensitivity**:

Bioactive glass reacts with artificial saliva to form apatite hydroxycarbonate crystals within collagen fibres which are equivalent to the mineral phase of human hard tissues. These deposits occlude the dentinal tubules and thus helps to reduce hypersensitivity[2].

9. **In craniomaxillofacial reconstruction :**

In craniofacial surgery , augmentation and reconstruction can be done by using bioactive materials .These materials are superb for craniofacial reconstruction , also they are not hampered by long-term resorption but they do not demonstrate significant bony ingrowth. This filling material gets fixed in a bone defect more quickly due to the adhesive property to hard tissues[4,25].

10. For coating of Dental implants:

Dental implants are made from titanium alloys commonly Ti6Al4V . These implants have a coating of hydroxyapatite to promote osteogenesis and bone healing[4,26].Also TIO2 nanoparticles, zirconia nanoparticles and silica nanoparticles are used to coat the dental Implant surface[22].

11. In stem cell therapy

Stem cells are a natural choice for cell therapy due to their pluripotency and self renewal capacity. Creating reserves of undifferentiated stem cells and driving their differentiation to a lineage of choice in an efficientmanner is critical for the ultimate clinical success[27]. Stem cells with bioactive materials are used to restore the injured tissue byreplacing dead or damaged cells with new and healthy cells[4].

12. In bone grafting:

Commonly used ceramic bioactive alloplastic bone grafting materials include hydroxyapatite and beta-tricalcium phosphate, which forms chemical bond with bone tissue. Bioactive and osteoconductive properties of a resorbable bioactive glass can be used in subantral augmentation procedures after sinus elevation[4,28] .

13. In drug delivery

Drug delivery systems based on the concept in which biocompatible materials play a vital role in the release of drugs into aim tissues of the oral cavity with minimum adverse effects. Bioactive materials can be used as carriers in biocompatible drug delivery systems. These are commonly prepared in some forms such as particulate complex, fibres, microspheres, gels, hydrogels, and injectable systems[29].

14. In cosmetic surgeries

Ideal biomaterials have properties of regeneration , degradation, long lasting effect and remodelling. They are safe and have dynamic balance between regeneration and degradation . Due to these properties regenerative bioactive materials provides promising results in the field of plastic surgery[30].

15. In tissue engineering

Bioactive materials are capable of imitating the human tissue structure because of their physical and chemical resemblance. Due to their unique characteristics these materials specially chitosan based materials can be used as potential materials in tissue engineering[31].

III. CONCLUSION :

This article summarizes different types of bioactive materials and their uses in the field of Dentistry and Medicine. More research is needed about the materials and their longevity and substantivity. Bioactive materials increase the life expectancy and social obligations to provide a better quality of life . These materials can be considered as boon to Dentistry because of their regenerative potential

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