Bioactive materials in conservative dentistry

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Abstract
Bioactive materials have been used in every field of dentistry and medicine. These materials are broadly used in the field of conservative dentistry for regeneration, repair and reconstruction. These materials are available in different form and composition that acts directly on vital tissue inducing its healing and repair. These materials directly function because of induction of various growth factors and different cells. Thus, this article describes various bioactive materials, the form in which they are available and its uses.

Keywords: Bioactive materials, biomimetic substances, conservative dentistry, repair/regeneration

Introduction
Recently introduced materials mainly concentrate on the bioinductive activity. The terms bioactive, bioinductive, biomaterial and biomimetic are different and have been defined separately. Bioactive material is defined as a material that has the effect on or eliciting a response from living tissue, organisms or cell such as inducing the formation of hydroxyapatite. The bioinductive property is defined as the capability of a material for inducing a response in a biological system. Biomaterial is defined as any matter, surface or construct that interacts with biological systems. Biomimetics is the study of formation, structure or function of biologically produced substances and materials (such as silk or conch shells) and biological mechanisms and processes (such as protein synthesis or mineralization) for the purpose of synthesizing similar products by artificial mechanisms that mimic natural structures. These definitions thus describe the difference between each term.

The ideal properties of bioactive material are; bactericidal and bacteriostatic, sterile, stimulate reparative dentine formation, sterile and maintain pulp vitality. The various bioactive materials are calcium hydroxide, mineral trioxide aggregate (MTA), calcium-enriched mixture (CEM), Biodentine, Inert material (isobutyl cyanoacrylate and tricalcium phosphate ceramic), Active BioACTIVE restorative material, Pulpdent (composite resin that are more bioactive and release more fluoride than glass ionomers), MTYA1-Ca filler, tetracalcium phosphate (TTCP), sol-gel-derived bioactive glass (BAG) ceramic containing silver ions (Ag-BG), calcium phosphate, novel endodontic cement (NEC), endo sequence root repair material.

Uses of bioactive material
1. It can be used as pulp capping material
2. Used for permanent restorations
3. It can be used for dentinal tubule occlusion. Huaxi-BAG-ceramic (HX-BGC) a BAG ceramic material can be an effective material for reducing dentine permeability and thus can be used for the treatment of dentinal hypersensitivity.
4. Bioactive materials such as BAG act as scaffold and helps in regeneration of bone tissue. The other material that is advanced composite modified with Ag-BG and natural ECM have improved properties for tooth regeneration.
5. It promotes tooth remineralization and has been found that both BAG and casein phosphopeptide-amorphous calcium phosphate are effective in remineralizing.
Materials

Calcium hydroxide
Calcium hydroxide dissociates into calcium and hydroxyl ions. These calcium ions reduce capillary permeability thus in turn reducing the serum flow and reducing the levels of inhibitory pyrophosphates that cause the mineralization. The hydroxyl ions neutralize acid produced by osteoclasts maintaining optimum pH for pyrophosphatase activity leading to increase level of calcium-dependent pyrophosphatase which reduced the levels of inhibitory pyrophosphate and causing mineralization.[13]

MTA
MTA introduced by Torabinejad in 1990. It’s a bioactive material that is mainly composed of calcium and silicate. Major content of the mixture is dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, and tetracalcium aluminoferrite.[14] These calcium silicate containing materials have a common characteristic of apatite formation.[15] This is a material of choice for vital pulp therapy, apexification and apexogenesis, correcting procedural errors as well as for root-end filling material in apicoectomy procedures.

The exact mechanism of dentinal bridge formation when MTA is used is not known completely and detailed research should be carried out for understanding this mechanism. However, it was found that when MTA was used as a pulp capping agent it induces cytologic and functional changes within pulpal cells, resulting in formation of fibrodentine and reparative dentin at the surface of mechanically exposed dental pulp. When placed it causes proliferation, migration and differentiation of odontoblast-like cells that produce a collagen matrix. This formed unmineralized matrix is then mineralized by osteodentin initially and then by tertiary dentin formation.[15]

CEM[8]
It is also known as NEC and was introduced by Asgary.[16] It consists of calcium oxide, whereas calcium oxide and silica in Portland cement and calcium oxide, silica, and bismuth oxide in MTA are the major ingredients.[17] This cement releases both calcium and phosphorus ions leading to hydroxyapatite production.[18,19] It is also known as CEM. It is composed of calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, and calcium chloride.

Biodentine
It is a bioactive dentin replacemental material having similar properties of dentin and has a positive effect on vital pulp cells stimulating tertiary dentin formation.[20]

ActiveBioACTIVE restorative material[46]
It is a composite resin that is bioactive and release more fluoride than glass ionomers. It contains bioactive resin matrix, a shock absorbing resin component and BAG fillers that have similar properties of tooth.

MTYA1-Ca filler[3]
It is a resinous direct pulp capping agent. It consists of powder (89.0% microfiller, 10.0% calcium hydroxide and 1.0% benzoyl peroxide) and liquid (67.5% triethylene glycol dimethacrylate, 30.0%glycerylmethacrylate,1.0%O-methacryloyl tyrosine amide, 1.0% dimethyaminoethylmethacrylate and 0.5% camphorquinone).[5,11]

TTCP[60]
It can be used for biomedical purpose as it contains biodegradable poly(lactide) composite that was incorporated with more basic filler for biomedical applications. It was proved that it reduces inflammation and allergic effect resulting from acidic substances.

Sol-gel-derived Ag-BG[27]
It is a Ag-BG having antibacterial and regenerative properties.

Calcium phosphate
It has properties such as good biocompatibility, superior compressive strength, and its transformation into hydroxyapatite over time. It induces bridge formation with no superficial tissue necrosis and significant absence of pulpal inflammation.[22]

Endo sequence root repair material
It consists of calcium silicates, monobasic calcium phosphate, zirconium oxide, tantalum oxide, proprietary fillers and thickening agents.[23]

Monomers
It was found that HEMA-BisGMA-TEGDMA resin with antimicrobial agent as quaternary ammonium salt monomer 2-methacryloyloxyethyl dodecyl methyl ammonium bromide was an effective pulp capping material for vital pulp preservation and treatment of deep caries.[24]

HX-BGC
It is novel BAG-ceramic available in powder form and containing SiO$_2$,P$_2$O$_5$,CaO,Na$_2$O,SrO. It was used to reduce dentine permeability and works by the property of occluding dentinal tubule.

Theracal
It is a light cured, resin modified calcium silicate filled liner insulating and protecting dentin-pulp complex. It can be used in direct and indirect pulp capping, as a protective base/liner under composites, amalgams, cements, and other base materials. When this material was compared with ProRoot MTA and Dycal, it was found that calcium release was higher and solubility was low.[25]

Castor oil bean cement
It consists of 81%-96% triglyceride of ricinoleic acid, and is considered a natural polyol containing three hydroxyl radicals and can be used as a pulp capping material.[26]
Doxadent

It is a calcium aluminate product available in powder liquid form. It can be used as a permanent restorative material. It consists of alumina, calcium oxide, water, zirconium oxide and other alkali oxides. When powder and liquid are mixed water dissolves the calcium aluminate powder leading to the formation of calcium, aluminum and hydroxyl ions leading to the formation of katoite and gibbsite.[27]

Ceramir

It is calcium aluminate cement used as a luting agent. It works on the principle of two cements they are calcium aluminate and glass ionomer cement.[27] This cement helps in luting of permanent crowns and fixed partial dentures, gold inlays and onlays, prefabricated metal and cast dowel and cores, and high-strength all-zirconia or all-alumina crowns.[28,29]

Bioaggregate

It is a calcium silicate material available in powder and liquid form. This can be used for pulp capping, apexification, root resorption, root perforation and root end filling material.[27]

Endosequence root repair material

It is also a calcium silicate material available in paste or putty form. The applications are same as bioaggregate.[27]

iRoot BP

It is also a calcium silicate material available in paste or putty form and is an injectable root repair material.[27]

Resin impregnation with titanium oxide (TiO₂)

The TiO₂ nanoparticles can be impregnated in dental resins such as dental monomers and dentin bonding adhesives. It has found that with this type of restorations hydroxyapatite formation is promoted further enhancing the strength and bactericidal property. These nanoparticles helps in remineralization of both enamel and dentin by restoring the marginal gaps. Thus, because of this property it reduces the incidence of secondary caries and other properties of implant surface.[30]

Conclusion

Bioactive materials can be considered as boon to dentistry because of its regeneration potential.

References

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