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REVIEW ARTICLE

Bioactive Materials: A Short Review

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ABSTRACT

In every field of dentistry and medicine, bioactive materials have been widely used. These materials are used for regeneration, repair, and reconstruction in the field of conservative dentistry and endodontics. These materials are used in different forms and composition and act directly on vital tissue, helping in its healing and repair. These materials directly function because of induction of various growth factors and different cells. This article summarizes the types and uses of bioactive materials.

Keywords: Bioactive materials, Biomimetic materials, Glass transition temperature.

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INTRODUCTION

Materials introduced recently mainly concentrate on the bioinductive activity. The terms "bioactive," "bioinductive," "biomaterial," and "biomimetic" are different and are described separately. Bioactive material has the effect on or elicit a response from living tissue, organisms, or cell, such as inducing the formation of hydroxyapatite. Bioinductive property is the capability of a material to induce 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, and function of substances produced biologically(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. The ideal properties or behavior of bioactive material are: Bactericidal or bacteriostatic, sterile, help in reparative dentin formation, and help in maintaining pulp vitality.[1]

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MATERIALS

Calcium Hydroxide[2]

Calcium hydroxide dissociates into calcium and hydroxyl ions. These calcium ions reduce capillary permeability and thus reduce the serum flow and also reduce the levels of inhibitory pyrophosphates that cause mineralization. The hydroxyl ions helps in neutralizing acid produced by osteoclasts maintaining pH for pyrophosphatase activity, leading to increased level of calcium-dependent pyrophosphatase, which reduces the level of inhibitory pyrophosphate and helps in mineralization.

Mineral Trioxide Aggregate[3]

Mineral trioxide aggregate (MTA) was introduced by Torabinejad in 1990. It's a bioactive material, i.e., that is composed mainly of calcium and silicate. Composition of MTA is dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, and tetracalcium aluminoferrite. These calcium silicate–containing materials helps in apatite formation. Mineral trioxide aggregate is used 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 by MTA is not known completely, and more research is needed for understanding this mechanism. However, it was found that MTA was used as a pulp-capping agent as it induces cytologic and functional changes within pulpal cells, resulting in the formation of reparative dentin at the surface of the exposed dental pulp. When placed, it helps in proliferation, migration, and differentiation of odontoblast-like cells that produce a collagen matrix. This unmineralized matrix is then mineralized by osteodentin initially and then by tertiary dentin formation.

Calcium–enriched Mixture Cement[4]

Calcium–enriched mixture cement is also called NEC and was introduced by Asgary. It consists of calcium oxide, silica, and bismuth oxide as the major ingredients. This cement releases both calcium and phosphorus ions, leading to hydroxyapatite formation. It is composed of calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, and calcium chloride.

Biodentine[5]

It is a bioactive material having similar properties like dentin and has a positive effect on vital pulp cells, which helps in tertiary dentin formation.

Doxadent[6]

It is a calcium aluminate product available in a powder liquid form. It can be used as a permanent restorative material. It consists of alumina, calcium oxide, water, zirconium dioxide, 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, resulting in the formation of katoite and gibbsite.

Ceramir[7]

It is a calcium aluminate cement used as a luting agent. It works on the principle of two cements: Calcium aluminate and glass ionomer cement. 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.

Bioaggregate[6]

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

Resin Impregnation with Titanium Oxide (TiO_2)[8]

The TiO_2 nanoparticles can be impregnated in dental resins, such as dental monomers and dentin bonding adhesives. It has been found that with this type of restoration, hydroxyapatite formation is promoted, further enhancing the strength and bactericidal property. These nanoparticles help 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.

MTYA1-Ca filler[9]

It is a resin-based direct pulp-capping agent. It consists of powder (89.0% microfiller, 10.0% calcium hydroxide, and 1.0% benzoyl peroxide) and liquid (67.5% triethyleneglycol dimethacrylate, 30.0% glyceryl methacrylate, 1.0% O-methacryloyl tyrosine amide, 1.0% dimethylaminoethylmethacrylate, and 0.5% camphorquinone).

Tetra Calcium Phosphate[10]

It is a resin-based 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% glyceryl methacrylate, 1.0% O-methacryloyl tyrosine amide, 1.0% dimethylaminoethylmethacrylate, and 0.5% camphorquinone).

Calcium Phosphate[11]

It has properties, such as good biocompatibility, superior compressive strength, and of the ability to form hydroxyapatite over time. It helps in induction of bridge formation with no superficial tissue necrosis and significant absence of pulpal inflammation.

EndoSequence Root Repair Material[12]

It consists of calcium silicates, monobasic calcium phosphate, zirconium oxide, tantalum oxide, proprietary fillers, and thickening agents.

Theracal[13]

It is a light-cured, resin-modified calcium silicate–filled liner insulating and protecting the 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.

Castor Oil Bean Cement[14]

It consists of 81 to 96% triglyceride of ricinoleic acid and is considered a natural polyol containing three hydroxyl radicals and can be used as a pulp-capping material.

APPLICATIONS OF BIOACTIVE MATERIALS AND MOLECULES IN DENTISTRY

Root Canal Therapy[15]

Portland cement or MTA is a bioactive material used for maintaining pulp and periodontal tissue vitality as part of pulp-capping and perforation repair procedures. Mineral trioxide aggregate has replaced calcium hydroxide as the material of choice for repairing injured and broken teeth and is also used as an obturating material after root canal therapy. It helps in apexification.

Tooth Repair and Regeneration[16]

Dentin extracellular matrix proteins (ECMPs) contain growth factors that can promote tooth healing and pulp

regeneration. They can stimulate dental pulp stem cell proliferation, differentiation, and migration to sites of injury. Dentonin (peptide) can stimulate reparative mineralization of the coronal pulp and occlusion of the lumen of the root canal.

The ECMP and Dentonin biomolecules are among the most potent of all the growth factors available for promoting pulp repair and regeneration.

In Dental Surgery and Craniomaxillofacial Reconstruction[17]

Biomaterials, such as Emdogain containing Porcine proteins play an important role in periodontal regeneration after gum disease or injury. Synthetic bone materials are used for maxillofacial and craniofacial reconstruction.

The ideal biomaterial for dental reconstruction should be biocompatible and also able to maintain volume and can be easily shaped.[17] n-Butyl-2-cyanoacrylate is widely used as a tissue adhesive. It is also used for filling and repairing bone defects. This filling material gets fixed in a bone defect more quickly due to the adhesive property of Histoacryl to hard tissue.

Coating of Implants[18]

Metals are often used in dental and medical devices due to their good physical and mechanical properties, such as low density and mechanical resistance.[18] Dental implants are made from titanium alloys and have a coating of hydroxyapatite to promote osteogenesis and bone healing.

Tooth Tissue Regeneration

Some scientists have invented a novel biomaterial (tissue regenerative gel), which can promote the regeneration of tooth tissue.

Hypersensitivity[19]

A novel bioactive glass-ceramic (biosilicate) is applied in hypersensitivity cases. Bioactive glass-ceramic is capable of inducing HCA (hydroxyl carbonate apatite) deposition in open dentinal tubules, and thus occluding the dentinal tubules. Hence, biosilicate may be a new way for treating dentin hypersensitivity.

Biomedical

Stem Cell Therapy[20]

Recent stem cell study has opened up novel potential within science and medicine. New methods of stem cells with bioactive materials are renovate to the function of injured tissue by replacing dead or damaged cells with new and healthy cells.

Dental Tissue Regeneration[21]

Material science conjugated with stem cell biology is important in such advances to move regenerative dentistry from the laboratory to the clinic. A combination of nanostructure materials, such as biomimetic matrices and scaffold and stem cells, will certainly increase the regenerative impact of dental pathological tissues.

Bone Graft[22]

Bioactive materials, such as osteoconductive matrix, which act as scaffold to new bone growth, and osteoinductive proteins, which support mitogenesis of undifferentiated cells combined with osteogenic cells (mesenchymal stem cells), are capable of forming bones in the field of orthopedics.

Drug Delivery[23]

Mesoporous, which are silica based, are widely used in drug delivery and bone tissue engineering.

The adequate combination of the synthesis techniques, additives, and template systems leads to the improvement of materials that combine the bioactive behavior with the drug carrier ability.

Cosmetic Surgery[24]

Collagen is used in soft tissue repair for augmentation in cosmetic surgery.

Tissue Engineering[25]

Gelatin is used as a natural polymer, which is derivative of collagen. Biomolecules released from gelatin are capable of maintaining their biological activity and help them in tissue engineering.

CONCLUSION

This article summarizes the types of bioactive materials and their uses in the field of dentistry and medicine. More study is needed about the materials and their longevity and substantivity. Bioactive materials increase life expectancy and the social obligations to provide a better quality of life. Attention has been paid toward the use of synthetic graft materials in bone repair, bone replacement, dental repair and pulp therapy, bioactive glass and ceramics in hard tissue repair and also proliferation, and nanoparticles in thrombolytic and stem cell therapy.

New implant technologies have led to the design concept of novel bioactive materials. Bioactive materials act as a boon for dentistry, and regeneration of tooth has been made possible by these new materials.

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