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The Advent of Bioactive Materials in Dentistry: A Review

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ABSTRACT

Bioactive materials are revolutionizing oral health care and the quest for newer materials is never ending especially in the field of dental science. Research on biomaterials intensely involves interdisciplinary contributions from several major areas and requires extensive knowledge in medical science, materials science, biochemistry, biomedical engineering and clinical science. They are broadly used in the field of conservative dentistry and periodontics for regeneration, repair and reconstruction by acting directly on the vital tissue inducing its healing and repair through induction of various growth factors and different cells. This article reviews on the properties and clinical application of newer bioactive materials in endodontics and periodontics, with primary focus on the biocompatibility and tissue response to these materials.

Keywords: bioactive, dental material, MTA

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INTRODUCTION

In an attempt to restore the lost structure of the teeth or the periodontium due to damage, decay or disease, several materials were tried and tested that could mimic the function, structure, esthetics and strength of natural teeth and periodontium. Products that came into limelight were bioactive materials and biomimetics. Bioactivity or biocompatibility is the ability of the material to elicit an appropriate biological response in a living tissue.[1]

Schmitt in 1969 first mentioned about “Biomimetics”. It was defined as “the study of the formation, structure, or function of biologically produced substances and materials (as enzymes or silk) and biological mechanisms and processes (as protein synthesis or photosynthesis) especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones.”[2] Newer materials have been evaluated for its biocompatibility and its effective use in endodontics and periodontics.

Classification

Bioactive materials were classified into two major groups by Hench in 1994.[3]

Class A: Osteoproduktive Materials

Class A bioactivity occurs when a material elicits both an intracellular and an extracellular response brought by the colonization of osteogenic stem cells at its interface resulting in both osteoproduktive and osteoconductive properties. eg: 45S5 Bioglass.

Group B: Osteoconductive Materials

Osteoconductive bioactivity occurs when a material elicits only an extracellular response at its interface by providing a biocompatible interface along which bone migrates.eg: Synthetic hydroxyapatite (HA).

MATERIALS

Mineral Trioxide Aggregate (MTA)

Mineral trioxide aggregate (MTA) is a mechanical mixture of three powder ingredients: Portland cement(dicalcium silicate, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite) (75%), bismuth oxide (20%), and gypsum (5%).[4]

Introduced by Torabinajed in 1993, MTA has shown promising results as an root end filling material due to its good sealing properties, biocompatibility and potential to stimulate cementogenesis. It has been used for pulp capping, pulpotomy, apexogenesis, apical barrier formation in teeth with open apex, repair of root perforations, as a root canal filling material and for maintaining periodontal tissue vitality.[5]

MTA sets in the presence of moisture.[6] On contact with an synthetic tissue fluid it dissolves and releases cations that in further triggers the precipitation of hydroxyapatite on its surface and in the surrounding fluid resulting in a chemical between its apatitic surface and dentin, thus rightly proving its sealability, biocompatibility, and dentinogenic activity.[7]

MTA promotes dentin repair likely through release of growth factor from the dentin matrix, antibacterial effect, anti-inflammatory property, and induction of morphogene expression as well as signaling pathway associated with dental pulp cell differentiation.[8]

When MTA is implanted, a series of biochemical and biophysical reactions occurs at the MTA-dentin-tissue interface inducing a proinflammatory and pro-wound healing environment that activates cellular and tissue events in the inflammatory and biomineralization processes and culminates in the formation of an apatite-like layer that allows the integration of the biomaterial into the environment.[9]

Owing to these properties, MTA has shown promising results when used in cases of pulp capping, furcation perforation repair, resorption repair, pulpotomy root canal filling in primary dentition and for perforation repair, pulp capping, resorption repair, root end filling, apical barrier for tooth with necrotic pulps and open apex, coronal barrier for regenerative endodontics and root canal sealer in permanent dentition.[10-13]

Bioaggregate

Bioaggregate belongs to a new generation of root canal filling material that utilizes advanced science of nanotechnology to produce ceramic particles which on reaction with water produces biocompatible and aluminium-free ceramic biomaterial. The major components of bioaggregate are calcium silicate oxide and calcium silicate with significant amount of tantalum oxide instead of bismuth oxide as compared to that in MTA.[14]

Apart from its excellent root canal sealing ability, BioAggregate has also proved to be nontoxic, highly biocompatible, a potent antimicrobial agent, and has shown significant bone and periodontal regeneration, and optimizes the proliferation and mineralization ability of human dental pulp. [15-20]

Biodentine

Biodentine was developed as a dentin replacement material having similar properties of dentin which is composed of purified tri-calcium silicate powder and has a positive effect on vital pulp cells stimulating tertiary dentin formation.[21]

On application, calcium hydroxide is formed as a result of the chemical reaction which results in increase in the pH which causes irritation at the area of exposure. This resultant zone of coagulation necrosis causes division and migration of precursor cells to substrate surface; addition and cytodifferentiation into odontoblast like cells.²⁴[22]

Biodentine has proved to be an excellent pulp capping agent as proved in a research which showed complete dentinal bridge formation with layers of well arranged odontoblast and odontoblast –like cells under the osteodentin and absence of inflammatory pulpal response.[23]

Biodentine is the material of choice for the repair of root perforations and apexification owing to its appreciable properties like ease of handling, faster setting kinetics, biocompatibility, early mineralisation.[24]

Calcium enriched mixture (CEM)

CEM was introduced to dentistry in 2006 as an endodontic filling material which is primarily composed of alkaline earth metal oxides and hydroxides e.g. calcium oxide and calcium hydroxide, calcium phosphate, and calcium silicate.[25,26]

It promotes hydroxyapatite formation and the process of stem cell differentiation and induces hard tissue formation.^{29,30}[27,28] Positive results have been attained as a pulp capping agent, for furcation perforation repair and for vital pulp therapy of primary molars as well as mature/immature permanent teeth with reversible/irreversible pulpitis.[29-31]

Ceramicrete

A versatile phosphate ceramic originally used for treatment of hazardous waste, construction materials, structural materials requiring high compressive strength, and sealants and coatings was further modified for use in dentistry and medical application.

The material is nonporous and generates calcium and phosphate ions during the setting reactions ensuing its potential applications as a root-end-filling material. Another research showed that ceramicrete had radio opacity similar to root dentin with this excellent apical sealing property.[32,33]

Endosequence Root Repair Material (ERRM)/ Endosequence Root Repair Putty (ERRP)

Brasseler USA(Savannah, GA) introduced this product consisting of calcium silicates, monobasic calcium silicates and zirconium oxide with an added advantage of reduction in its particle size as compared to its other competitive products rendering it equally bioactive, biocompatible, high pH contributing to its antimicrobial activity. ERRM has shown cytotoxicity similar to MTA.[34,35]

iRoot BP, BC Sealer

Bioceramic sealers have been introduced in the market in an effort to provide efficacious obturation method with added benefits of its biocompatibility and physical properties. These materials render a gap-free interface between gutta-percha, sealer, and dentin, are highly biocompatible and are antibacterial.[36]

Ceramir C&B

Recent modification in bioactive chemically bonded cements is a calcium aluminate–glass ionomer luting cement a hybrid composition combining both calcium aluminate and glass ionomer.[37] Owing to its properties like improved flow, early adhesion to tooth structure, bioactivity-apatite formation and lack of solubility/degradation this cement has shown positive results 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.[38]

Bioactive glass

These glasses are silicate-based and can form a strong chemical bond with the tissues. Being highly biocompatible these materials can form a hydroxyapatite layer when implanted in the body. It is such a versatile material that it has been used for several procedures and has gained excellent positive results.

Extensive research has been done regarding treatment for dentinal hypersensitivity and Bioglass has substantiated enough proof to be used for the treatment of the same by mineralizing tiny holes in the dentine and reducing tooth sensitivity, augments the process of remineralisation, bioactive glass coated implants ensure improved bonding to the host bone, possesses antibacterial properties against enamel caries (*Streptococcus mutans*), root caries (*Actinomyces naeslundii*, *S. mutans*) and periodontitis (e.g. *Actinobacillus actinomycetemcomitans*), can restore osseous defects and develop a new attachment to the root surface, supports proliferation of human periodontal ligament cells.[39-41]

CONCLUSION

Positive results achieved through numerous clinical and nonclinical trials has encouraged the use of bioactive materials in endodontics, surgical as well as nonsurgical scenarios which has eventually changed the treatment plan provided to the patients with effective outcomes and extended prognosis. The preference of “saving the natural dentition” is now re-established. Further developments to meet additional restorative clinical needs are anticipated in this newly emerging category of dental materials.

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