Review Article

Biomaterials in Conservative Dentistry and Endodontics

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ABSTRACT

The widespread use of biomaterials in medicine and dentistry could be a relatively new phenomenon dating back to the 1950's yet, today, an estimated 20 million individuals have an implanted medical device. Despite the large impact that biomaterials have had on patients' quality of life, improvements in device performance and also the development of alternatives to reinforce available therapies are continuously being sought. Clinical demand, advances in molecular and cell biology and also the increased understanding of the role of the tissue material interface on clinical performance has led to a metamorphosis of the biomaterials' field over the past 25 years. This has resulted during a change within the nature of biomedical devices from being biologically passive to actively integrated. This article explores the event and application of biomaterials over the past 25 years, examining this clinical demand, the scientific rationale, and also the technical challenges to be overcome. As biomaterials are applied in surgery and tissue regenerative therapies, these areas are explored with specific samples of recent developments and current research activities accustomed illustrate the changing perspectives.

Keywords: Biomaterials, Dental pulp capping, Differentiation, Regenerative endodontics, Root end filling materials

INTRODUCTION

The development of latest biocompatible materials, existing material composition and progressing techniques is anticipated to broaden the range of applications of biomaterials in dentistry field in upcoming years.[1] The utilization of dental stem cells as sources of cells to facilitate repair of nondental tissues like bone and nerves has been introduced.[2,3] The transforming growth factor (TGF), activins/inhibins, and bone morphogenetic protein (BMP), regulate cell proliferation and embryonic maturity. Any impact of truly biological materials depends on a mix of both technology and price, a considerable window remains for developing far better synthetic materials.

Williams in 1987 defined biomaterial as a non-viable material used in medical device intended to interact with biological systems. When an artificial material is placed within the flesh, tissue reacts towards the implant in different kinds of ways betting on the fabric type. The mechanism of tissue interaction depends on the tissue response to the implant surface. In general, there are three terms during which a biomaterial could also be described in or classified into representing the tissues responses, bioinert, bioresorbable, and bioactive.[4-6]

METHODOLOGY

Medline, PubMed and Google Scholar database was searched for the literature under the following key terms "biomaterials", "apexogenesis", regenerative endodontics", "apexification", "pulp capping" and "root end filling". All the keywords were restricted to title or the abstract. An offline search was also made for these keywords in our institutional library to find relevant articles from journals and chapters from the reference books. The aim of this review is to identify various biomaterial used in

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operative dentistry for the conservative approach of dental treatment.

GLASS IONOMER CEMENT

The invention glass ionomer cement in 1969 (first reported by Wilson and Kent in 1971) resulted from basic studies on dental silicate cements where the phosphoric acid was replaced by organic chelating acids. These cements are also called polyalkenoates because the polymer chains in the liquid are made up of alkenoic monomers like acrylic acid, tartaric acid and maleic acid.

Reinforced Glass Ionomers

Further development lead to the introduction of resin modified glass ionomer or hybrid cements by Mathis and Ferracane in 1989. In these caments the glass ionomers were reinforced by incorporation of resins and the fundamental acid base curing reaction was supplemented by a second polymerization curing process,which initiated by light (dual cure) or both i.e. light and chemical (Tricure). HEMA (Hydroxy Ethyl Methacrylate) is the hydrophilic ionomer used in the liquid component of resin modified glass ionomer, so that the final restorations have 4.5 to 6% resin.

Continued evolution produced the "Polyacid modified composite resin" these materials were introduced in 1993 by manufacture's effort to improve and combine the best properties of glass ionomers and composite resins.The earliest term for these materials was "ISOSIT" but it was trademarked by a single manufacturer. The industry adopted the alternative arrangement of combined terms (composite and ionomers) COMPOMER.[7-9]

Glass Ionomers are rapidly setting cements with setting time in the range of 3-8 minutes. Working time should not exceed 45 sec. They have high compressive strength, which may range from 200-400 Mpa but are weak in flexure [5- 40 Mpa]. They are called bioactive materials due to their property of forming adhesive bonds with enamel and dentin, which not only plays a major role in bonding but also prevents secondary caries and the ability to release fluoride over a prolonged period of time. These materials are classified as Biocompatible, they show less exothermic reaction on setting and less shrinkage than resin. They have some disadvantages and limitations like being sensitive to addition or removal of water during initial setting, poor abrasive resistance, less tensile and flexure strengths and technique sensitive.

The co-efficient of thermal expansion of conventional glass ionomer cements is close to that of dentinal hard tissue and has been cited as a significant reason for the good marginal adaptation of glass ionomer restoration.

As root end filling material it is easy to handle and does not cause any adverse histological reaction in the periapical tissue. A GIC-based root canal sealer might exhibit long-term adhesion to dentin, which would be an obvious advantage over zinc oxide eugenol–type or epoxy resin-type sealer cements.

CALCIUM HYDROXIDE

Calcium hydroxide is a strong alkali, which can be formed by the reaction of calcium oxide. If the oxide is treated with only sufficient water to make it crumble to a fine, white, dry powder, slaked lime is produced.[10,11]

Calcium hydroxide is alkaline (pH 11), and thus kills bacteria. All the beneficial effects of calcium hydroxide are believed to be secondary to its bactericidal properties, i.e., in the absence of infection, natural healing can take place. This healing includes creation of tertiary dentine to protect the pulp in vital teeth, and to close the apices of immature non-vital teeth. All Calcium hydroxide preparations have a limited shelf life as they eventually turn into calcium oxide. The control of microorganisms by Calcium hydroxide is determined by the liberation of hydroxyl ions, which requires an ideal length of time for effective microbial destruction.

Chemical Characteristics of Calcium Hydroxide

Lime stone is a natural rock composed of calcium carbonate (CaCO3) which forms when the calcium carbonate solution existing in mountain and sea water becomes crystallized. The combustion of limestone between 900-1200o C causes the subsequent chemical process.

$CaCO3 \rightarrow CaO + CO3$

The calcium oxide formed (CaO) is called 'quicklime' and has a strong corrosive ability. When calcium oxide contacts water, the subsequent reaction occurs-

$CaO + H2O \rightarrow Ca(OH)2$

It can be used for direct pulp capping, indirect pulp capping, pulpotomy, apexification, perforation repair and regenerative endodontics (apexogenesis).

MINERAL TRIOXIDE AGGREGATE (MTA)

Mineral Trioxide Aggregate (MTA) was introduced by Mohmoud Torabinejad in 1993 and was given approval for endodontic use by the U.S. Food and Drug Administration in 1998.

Types

a. Grey MTA
b. White MTA

The tooth coloured white MTA was introduced in 2002 to eliminate the greyness of the previous MTA.The major difference between GMTA and WMTA is within the concentrations of Al_2O_3, MgO and Fe0.[12-14]

Mineral trioxide aggregate is a powder consisting of fine hydrophilic particles of dicalcium silicate, tricalcium silicate, tricalcium aluminate, tetracalcium aluminate. Bismuth oxide is added to form the powder radio-opaque. Trace amount of silica, calcium oxide, magnesium oxide, potassium sulphate and sodium sulphate.

Properties

Initial pH (when hydrated) 10.2. Set pH -12.5. Normal healing response without inflammation. Well tolerated by the tissues and biocompatible. Potential to stimulate the cementoblasts and thus the cementum production. MTA also stimulates the overgrowth of PDL fiber over its surface. MTA basically consists of calcium, silica, and bismuth oxide. After hydration MTA releases calcium hydroxide that is the reason of the high pH value of the material. It produces more dentinal bridging with superior structural integrity than Ca(OH)2 in a shorter time span with significantly lesser inflammation. It has superior ability to resist for further penetration of bacteria than calcium hydroxide. Has significant antimicrobial property on some of the facultative bacteria. MTA is highly biocompatible with pulpal tissue and it is hydrophilic as it sets in presence of moisture. Set MTA has pH of 12.5 and may induce dentinogenesis.[12,13] The presence of blood has little impact on degree of leakage of MTA. *In vitro* and *in vivo* studies confirmed MTA's excellent sealing ability and biocompatibility. According to M. Aeinehchi et al after six month follow up using MTA a 0.43 mm-thick dentine bridge and a nearly regular odontoblastic layer were noted. No inflammation, necrosis or calcifications were registered. After Six-month follow up using calcium hydroxide, calcification and necrosis were seen underneath a bridge of maximum 0.15 mm thickness.

MTA is used for Direct pulp capping and pulpotomy, apexification, apexogenesis (regenerative endodontics) repair of root perforations (surgical and non-surgical) and root-end filling. [13,14]

BIOACTIVE GLASS

Bioactive glass first introduced by Hench et al are surface active glasses that bond chemically to bone materials. Bioactive glasses (45S5) contain different ratios of Na2O (24.5%), CaO (24.5%), P2O5 (2.6%), SiO2 (45%).

When a bioactive glass is present in an aqueous solution, it reacts with it. As a result of this reaction, a change within the structure and chemical composition of bioactive glass occurs which causes its dissipation and HCAP is formed.

Indicated for post apicectomy, bone regeneration, restoration of cystic defects, implant placement procedures, treatment of perimplantitis, pulpotomy, dentine hypersensitivity caused by gingival recession etc. It also acts as a vehicle for calcium, PO4 and silica which then enhances mineral deposition in dentinal tubules. [15,16]

It enhances bone regeneration, has a local hemostatic effect, antimicrobial and easy to use. It is 100% synthetic so, no risk of disease transmition and completely absorbable leading to faster bone formation.[15-17]

ENAMEL MATRIX DERIVATIVES

Enamel matrix proteins secreted by Hertwig's epithelial sheath play an important role in

cementogenesis and in the development of the periodontal attachment apparatus. Composition: amelogenin, amelin, enamelin and tuft proteins.

The Emdogain formulation

Amelogenins are the major component of the emdogain gel formulation while the amelogenins are insoluble at physiologic pH they can be dissolved at low or high pH. An aqueous solution of propylene glycol alginate (PGA) a non-setting alginate is found to be a suitable vehicle to facilitate application of EMD, EMD is then released to aggregate and form an insoluble precipitate (or matrix) on the root surface adsorbing onto hydroxyapatite, collagen and other exposed surfaces.[18,19]

Mode of Action of EMD

The root sheath is a bi-layered structure, the inner layer of which is an extension of the ameloblastic layer in the crown. The ameloblasts incorporate and secrete the proteins of the enamel matrix during enamel formation. As the enamel matrix proteins precipitates → induce apoptosis within the cells of the basis sheaths. Enamel matrix proteins are exposed to the mesenchymal cells of the encompassing dental follicle. Mesenchymal cells are going to be drawn to the matrix surface and migrate through the fenestration into the basis sheath to colonize the root surface and starts forming collagen, cementum and PDL.

Clinical Application

a. Pulp capping agent: Factors that help in healing:

1. The inherent stability and continued presence of EMD at the applying site enables stimulation of pulpal healing and dentin formation over a period sufficient for a favourable clinical outcome.

2. it's also reported that growth of some bacteria including streptococcus mutans is inhibited by presence of EMD.

b. EMD has been shown to induce reparative dentin formation without eliciting adverse side effects like necrosis or internal resorption. Effect of emdogain on cementum and periodontal ligament of Avulsed teeth Emdogain appears to stop ankylosis completely or a minimum of delay the recurrence of ankylosis dramatically. Recent studies have found that emdogain is also extremely beneficial in teeth with extended extra oral dry time not only to make the root more immune to resorption but possibly stimulate the formation of advanced periodontal ligament from the socket. EMD may facilitate cementoblast growth onto the denuded root surface by enhancing migration and differentiation of progenitor cells thereby regenerating the attachment apparatus.[18]

c. Effect of EMD on osteoblast.[19] Concerning the formation of the alveolar bone in vitro studies have shown that EMD stimulates proliferation of early stage osteoblast and enhances their differentiation at later stages. It also been shown that EMD increases the expression of collagen I, interleukin-6, prostaglandin, synthase 2 which is related to the regeneration of alveolar bone.[20,21]

RESIN BASED COMPOSITES

Improvements and enhanced formulation of resin composites have resulted in their durability and reliability during a wide spectrum of restorative procedures.

Major emphasis for research has been within the area of reduced polymerization shrinkage and stress. As these materials have the ability to mimic the natural tooth in appearance with an acceptable level of biocompatibility with the added advantage of fluoride release comparable to glass inomers they can be termed as 'biomimetic materials'.

These include:

1. Smart composites
2. Giomers
3. Ormocers
4. Ceromers

Smart materials:

Tooth colored restorative which are cariostatic by their inherent ability to leach fluoride.

Passive smart materials: These are materials that release ions into the oral cavity continuously with or without the necessity to prevent caries .eg. Glass inomer cement.

Active smart material: These are material which can react preferably when there is a hazardous

varitation in the environment surrounding the restoration and prevent caries eg smart composite.

It is based on a new developed alkaline glass which aims at reducing demineralisation and buffering acid produced by microorganisms when the pH around the restorative material falls below 5.5,the material releases hydroxyl ,calcium and fluoride ions. They are composed of BISGMA, UDMA, TEGEDMA resin and alkaline calcium silicate glass, Ba-Al-F silicate glass, ytterbium fluoride and silicon dioxide as fillers.

Giomers:

It is a hybrid of glass ionomer and composite resin, developed by Roberts et al. 1998,they have properties of both glass ionomers (fluoride release and recharge) and resin composites (excellent esthetics, easy polishibility).they are distinguished by the fact that , while they are resin based , they contain pre reacted glass ionomers particles PRG composites,.the particles are made up of fluorosilicate glass that have been reacted with polyacrylic acid prior to being incorporated in to the resin.[22-24]

They employ of PRG technology that involoves the pre reaction of fluoroalumino silicate glass fillers with poylacrylic acid forming a stable phase of glass ionomer described as' wet siliceous hydrogel' the resulting glass ionomer is then freeze dried, milled, silane treated and ground to form the PRG fillers. These fillers are then blended in a resin matrix. The final product is composed of a stable phase of glass ionomer attached in a resin matrix, the presence of a prereacted hydrogel responsible for the high level of release of fluoride and giomers.

Composed of PRG particles, Silica particles, Hydrophilic monomers, HEMA and UDMA.

Indicated for restoration of root caries, non-carious cervical lesions and class- V cavities.

Ormocers:

It was developed by Fraunhofer Insititue for silicate research, Wurzburg in corporation with partners from the dental industry in 1998. It is composed of ormocers matrix –Ceramic polysiloxane (silicon-oxygen chain), Zirconium and glass fillers (1-1.5microm in size) & Coupling agents.

It is biocompatible, polymerization shrinkage is low, high abrasion resistance, esthetic & anticaries property.

Ceromers (Ceramic optimized polymers):

They are unique combination of the latest in ceramic filler technology and advanced polymer chemistry which provide enhanced function and esthetics. It is composed of barium glass, Spheroidal mixed oxide, Ytterbium tri-fluoride, BISGMA and Urethane dimethyacrlate.

It has a durable esthetic quality, high abrasion resistance, high stability, excellent polishibilty and fluoride release. It can be used for single unit metal free full coverage metal free implant super structure jacket crowns inlays and onlays. [25]

CERAMICS

Dental ceramics with their unmatched esthetics, excellent biocompatibility and good strength make them one in all the foremost promising materials in restorative dentistry and with the recent advances to compensate their few short comings are also called as 'biomimetic materials'

Dental ceramics are often classified based on: fusion temperatures application fabrication techniques & crystalline phases. They have three major ingredients: feldspar kaolin & quartz.[26,27]

GENETICALLY ENGINEERED MATERIALS

These materials aim in mimicking the essence of tooth substance and in regenerating the dental tissue. The epithelial signals that trigger initiation of odontogenesis also regulate a very important category of genes namely 'BRAX-1' which is also responsible for enamel growth.[28]

This gene has been isolated and developed in gel form, which is applied onto the cavitated tooth surface and helps in re-growth of enamel, filling up the decayed portion of tooth.

BIODENTINE

"Biodentine" was developed by Septodont's Research Group as a replacement of dental material which could conciliate high mechanical properties with excellent biocompatibility, also a

bioactive behavior.[29] It is composed of tri-calcium silicate, di-calcium silicate, calcium carbonate, calcium oxide, iron oxide and zirconium oxide.

Mechanism of Action

Biodentine promotes mineralization within the osteodentine by expressing markers of odontoblasts & stimulates TGF-Beta-1 secretion from pulpal cells thus promoting early mineralization. Biodentine encourages apposition of reactionary dentine by odontoblast stimulation and reparative dentin formation. It can be used for pulp capping, repair of root perforations, root-end filling, apexification and apexogenesis i.e., regenerative endodontics.

CONCLUSION

Biomaterials try to repair the damaged living tissue, using or promoting natural mechanisms of growth. This method provides remarkable possibilities well beyond the standard mode of treatments in most fields of dentistry including preventive, restorative, periodontal and cosmetic surgery. It is hoped further research will extend the potential of all such biomimetic materials.

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