International Journal of Applied Dental Sciences 2020; 6(1): 31-34

ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2020; 6(1): 31-34

www.oraljournal.com
Received: 26-11-2019
Accepted: 28-12-2019

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Biomimetic materials: A realm in the field of restorative dentistry and endodontics: A review

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Abstract
Traditional approaches to treat damaged and decayed teeth require more aggressive preparation to place a "strong", stiff restoration. The emphasis is on the strength of the restoration, but no attention is placed into the function and biomechanics of the restored tooth. By ignoring this critical aspect, it is no surprise that complications such as tooth fracture occur more frequently and future treatment becomes more aggressive and invasive. So begins the restorative dental cycle in which the teeth are ultimately lost from successive treatments. With Biomimetic dentistry, only the damage and decay is removed from the teeth, and the final restoration is bonded to the remaining healthy natural tooth structure.

Keywords: Biomimetics, biomimetic materials, glass ionomer cement, bioceramics, MTA, emdogain

Introduction
The process of taking inspiration from nature for manmade design has been described as "biomimicry or biomimetics". Biomimicry (from bios, meaning life, and mimesis, meaning to imitate) involves studying nature's most successful developments and then imitating these designs to create new materials [1]. Wright brothers pointed to soaring birds as their inspiration for the first aircraft steering mechanisms [2]. Biomimetic design is a design that, fully or partially, imitates or evokes some biological phenomenon [3]. During the past few decades, a number of men made materials and devices partially mimicking the natural ones have been introduced for implantation into humans. The first artificial heart valve was implanted by Hufnagel in 1952, and the first artificial hip replacement was performed by Charney in 1954 [4]. The main disadvantage with traditional biomaterials used in the medical, biotechnological, and pharmaceutical field is that they lack the ability to integrate with biological systems through a cellular pathway. This may lead to failure of the material. Hence the current focus is on developing a biomaterial which suitably performs the functions of the biological molecule that needs to be replaced [5, 6]. In dentistry there is no one biomaterial that has the same, mechanical, physical and optical properties as tooth structure (i.e., dentin, enamel, and cementum) and possesses the physiological characteristics of intact teeth in function [7, 8]. By using biomimetic therapeutic approaches, dental professionals can improve and become closer to natural biological structures and their function. There are two major perspectives to which the term "biomimetic" is applied; a purist perspective that focuses on recreating biological tissues and a descriptive perspective that focuses on using materials that result in a mimicked biological effect [9]. Although different, both share a common goal of mimicking biology in restoration. A biomimetic material should match the part of the tooth that it's replacing in several ways, including the modulus of elasticity and function of the respective areas (e.g., pulp, dentin, enamel, dentinoenamel junction) [10].

Biomimetic dentistry
Bio-mimetic Dentistry is the art and science of restoring damaged teeth with restorations that mimic natural teeth in appearance, function, and strength [11]. It is conservative- by only replacing what is damaged, and strong- by replicating nature's original design [11]. The two foundational principles of this approach are: Treat Teeth Early and Use Proper Techniques. Treating weakened teeth earlier, allows us to preserve the healthy enamel, thus providing a better foundation for the Biomimetic bonding. Early intervention is key to less-invasive treatment! [9]. Proper Biomimetic bonding techniques save your tooth by, Removing old

bacteria and infection, Sealing out new infection & bacteria, Eliminating sensitivity, Restoring natural strength and function.

Biomimetics in restorative dentistry

The goal of Biomimetics in Restorative Dentistry is to return all of the prepared dental tissues to full function by the creation of a hard tissue bond that allows functional stresses to pass through the tooth, drawing the entire crown into the final functional biologic and esthetic results [9, 10]. One more important aspect of biomimetic dentistry needs to be addressed as; less dentistry is the best dentistry; or even say no dentistry is the best dentistry. Bonded porcelain restorations are recommended to treat the most perilous situation (non vital or fractured teeth) thus avoiding the use of intraradicular parts or full coverage crowns [9].

Biomimetic materials in restorative dentistry

A bio-mimetic material should match the part of the tooth that it's replacing in several ways, including the modulus of elasticity and function of the respective areas (e.g. pulp, dentin, enamel, dentino-enamel junction) [9]. Calcium hydroxide, Glass ionomer cements, Nanocomposite, Mineral Trioxide Aggregate, Biodentine, Bioaggregate, Bioactive glass, Calcium enriched mixture, Casein phosphopeptide amorphous calcium phosphate[CPP-ACP], Octacalcium phosphate, Calcium phosphate material, Platlet rich fibrin, Emdogain. Generex, Capasio, Quickset

Glass Ionomer cement [6, 9, 10]: Its a Bio-mimetic material, Bonds chemically to tooth structure. It releases fluorides and decrease secondary caries. It has coefficient of thermal expansion near to natural tooth

Self-healing composites [12-14]: Self healing composite contain resin filled microcapsules. If a crack occurs in the epoxy composite material, the microcapsules rupture near the crack and release the resin. The resin fills the crack and reacts with a Grubbs catalyst dispersed in the epoxy composite, resulting in a polymerization of the resin and crack repair.

Calcium Hydroxide [6]: Introduced to dentistry by Hermann. It has a pH of approximately 12.5. It has antibacterial properties and the ability to induce tertiary dentin formation.

MTA [6, 15, 16]: It is a calcium silicate based hydrophilic material developed by Torabinejad. It has ph value range 10-12.5 and forms calcium hydroxide and hydroxy-apetite like crystals on setting in presence of phosphate containing solution. It causes periodontal ligament attachment, cementum growth, and dentinal bridge formation. It show good adhesion to dentin. It has low solubility than calcium hydroxide and no tunnel defects are seen when used in vital pulp therapy.

TheraCal [6, 15]: It is a light cured resin material having calcium silicate filler particles. As compared to Pro Root MTA and Dycal, it has low solubility and high calcium release.

Nano-WMTA [15]: Introduced by Saghiri *et al*. It has small particle size than MTA and has zeolite and strontium, di sodium hydrogen phosphate in its composition. It shows less solubility in acidic ph and high push out bond strength as compared to WMTA

Ceramicrete: It is a new generation calcium based material, which has hydroxyl-apatite in powder and cerium oxide radioopaque fillers. It is biocompatible and radio-opaque and release calcium and phosphate ions during setting. Its sealing ability is higher compared to a Super EBA and Pro-Root MTA when used as root end filling material. Immersion of the set ceramicrete material in a Phosphate containing fluid (PCF), lead to formation of Di-calcium phosphate dihydrate (DPCD) or hydroxyl-apatite on the surface. Ceramicrete shows bioactivity. Setting time-150 min. It has immediate ph 2.2 which increases with time

Generex A [15, 16]: It is a calcium silicate based material, used for root end filling. It has good handling properties compared to WMTA in acidic form it has superior washout resistance than WMTA.

Generex B [15, 16]: It is new calcium silicate based material used as root canal sealer. It has flow of 29mm, that allows it enter into complex root canal system. Working time-65 min. It has film thickness of 32 micron.

Capasio: It is a new calcium silicate based material composed of bismuth oxide, dental glass, polyvinyl acetate, calcium- alumino silicate. It is used for root end filling in endodontics and penetrate dental tubule. It forms calcium hydroxide and hydroxyapatite on seting. It may be used as a permanent dentine substitute as its mechanical properties are similar to dentin. When used as base, composite placement should be delayed for more than 2 weeks to allow complete maturation of material.

Doxadent [6, 15]: It is calcium- aluminate based cement which react with water containing lithium salts to forms katoite and gibbsite. It is inorganic and nonmetallic in nature. It is available as powder liquid component. Has alkaline ph. It is a hard material with low wear resistance. It is as strong as GIC but less than composite.

Ceramir [6, 28]: It is also a calcium aluminate based material, used for permanent cementation of FPD, gold inlay, only, all zirconia, all alumina crown. It forms hydroxyapatite when comes in contact with inorganic phosphate of saliva and shows good gingival response when used as luting agent

Hydroxyapatite [15]: It is non restorable calcium phosphate material. It is osteoconductive in nature and has composition similar to bone. It bond to bone. As, it has low mechanical properties so not used in load bearing area. It is used in bone grafting, as a filler in composite resins. Hydroxyapatite has been for endodontic treatment including pulp capping, repair of perforation, apical barrier formation, and repair of periapical defects. Jean *et al*. suggested that the degree of mineralization of reparative dentin formation obtained with tricalcium-phosphate hydroxyapatite was quicker and thicker when compared with that produced by calcium hydroxide.

Calcium phosphate cement [6, 15]: It is moldable viscous, self setting material discovered by Brown and Chowin in 1980. It forms hydroxyapetite on setting and has alkaline ph. It has setting time of 20 min. It has compressive strength comparable to trabecular bone [11-12MPa] It is inexpensive and has good handling properties.

ACP Technology [Enamelon, Enamel Care] [15]: The ACP technology was developed by Dr. Ming S. Tung in1999. It is a two-phase delivery system consisting of calcium sulfate and di-potassium phosphate. When two salts are mixd, ACP forms which dissolve in saliva and help in remineralisation of tooth. Eg. Enamelon, Enamel Care toothpaste.

Tricalcium phosphate [15]: Tri-calcium phosphate materials act as osteo-conductive materials, permits growth of bone on their surface or into pores, It is biocompatible material and useful for inducing hard tissue formation, It has been used as capping agent, cleft-palate, apical barrier, apexification, vertical bone defect, and implants coating. It also has been used as tooth remineralising agent. It has poor mechanical properties and shows fast and uncontrollable rate of resorption.

Bioactive glass [17, 18]: It was first developed by Hench in 1969.these glasses are able to bind with bone and tissue and induce osteogenesis. These have different families and different composition. These can be used as bone graft and in management of dentin hypersensitivity and implant coating. Eg45S5

Emdogain [15, 17]: It is enamel matrix derivative containing product. Enamel matrix derivative protein are secreted by Hertwig epithelial root Sheth and induces the periodontal tissue formation. Emdogain mimic these processes of tooth development. Emdogain also contain non collagen proteins like Ameloblastin, tuftelin, enamelin and growth factor, bone morphogenic protein. It is used in replantation cases to decrease external root resorption, It has been used for pulpotomy, vital pulp therapy as it induces reparative dentin formation.

Platlet rich fibrin membrane [15, 19-21]: It is flexible, elastic membrane first developed by Choukaron *et al.* in France. It contain Platelets, growth factors and fibrin which enhances the wound healing.

Biomimetic principles applied to cosmetic dentistry [9]

Biomimetic dentistry is based on the philosophy that the intact tooth in its ideal hues and shades and, more importantly, its Intracoronal anatomy, mechanics and location in the arch, is the guide to reconstruction and the determinant of success [9]. This approach is conservative and biologically sound and in sharp contrast to the porcelain-fused-to-metal technique in which the metal casting with its high elastic modulus makes the underlying dentin hypofunctional [9].

Biomimetics in endodontics

Minimally invasive Biomimetic Endodontics which new technology, is photon-induced Photo acoustic streaming (PIPS) [9]. Reciprocating handpieces and sonic devices were introduced with the idea of saving precious tooth structure, but further studies are needed [9].

Materials in endodontics [9]

MTA Fillapex (angelus solutions odonatological, Londrina, PR, Brazil) is a calcium silicate-based bio ceramic sealer, created with an attempt to incorporate physical and chemical properties of a resin-based root canal sealer and the biological properties of MTA

MTA plus (Avalon biomed Inc., Bradenton, FL, USA) is a fine powder root canal sealer with composition similar to Pro Root [9].

MTA Endosequence Root Repair Material (ERRM) putty, ERRM paste RRM putty fast set (FS) and iroot FS Endosequence root repair material (ERRM) (Brasseler USA, Savannah, GA) delivered as a premixed mouldable putty (iRoot BP Plus) or as a preloaded paste in a syringe with delivery tips for intracanal placement. It contains calcium phosphate monobasic, calcium silicates, zirconium oxide and tantalum oxide. Inside dentinal tubules, ERRM forms tag-like structures [9, 15]. The RRMs allows gingival fibroblasts to grow on their surface. RRMs are premixed, single component materials which is ready to use from the syringe or a tiny screw-cap box and does not requires mixing, thus differentiating it from MTA, bio aggregate and bio dentin. RRM putty fast set (FS) has the initial setting time of 20 min. iRoot FS (Brasseler USA, Savannah, GA) is iRoot series material with improved handling properties and shorter setting time [9, 15].

Bioceramic Sealers

Endosequence BC sealer (Brasseler USA, Savannah, GA) or iRoot SP root canal sealer (Innovative Bioceramix Inc., Vancouver, BC, Canada) is premixed bioceramic endodontic sealer containing tricalcium silicate, zirconium oxide, dicalcium silicate, calcium phosphate monobasic, colloidal silica, calcium silicates and calcium hydroxide. The iRoot SP possesses high pH, hydrophilicity, and active calcium hydroxide release.

Other bioceramic sealers: bio root rcs (septodont), gutta flow bio seal [9, 15].

Bioceramic Gutta-Percha

These are Gutta-Percha cones impregnated and coated with bioceramic nanoparticles and are verified with laser for tip and taper accuracy. Such cones with BC sealers allows "three-dimensional" bonded obturation [9, 15].

Conclusion

Biomimetics is the study of the formation, structure, or function of biologically produced substances and materials and biological mechanisms and processes especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones. And material fabricated by biomimetic technique based on natural process found in biological system is called a biomimetic material. The practice of dentistry has grown by leap and bounds in the past few decades. Replacement of diseased or lost tooth structure with biocompatible restorative materials is currently the order of today. But each of these procedures does have their own limitations and drawbacks. Regeneration of the lost tooth structure rather than replacement during treatment will ensure better prognosis and higher rate of success. Hence the future in dentistry would involve the use of such biomimetic materials which could successfully replace lost dentine, cementum and even the pulp tissue. Efforts are on through tissue engineering to create a biological tooth substitute that could completely replace the lost tooth structure. Biomimetic materials and methods will revolutionize the future of dentistry with the synergistic confluence of advances in signalling pathways underlying morphogenesis and lineage of stem/progenitor cells.

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