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Biomimetic Materials in Restorative Dentistry–A Review

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Abstract— *"Biomimetics" is the field of science that uses the natural system for synthesizing materials through biomimicry. This method can be widely used in dentistry for regeneration of dental structures and replacement of lost dental tissues. This is a review paper that states its scope, objectives of different types of biomimetic material based on composition, and its further use in dentistry.*

Keywords— *Biomimetic materials, regeneration, remineralization.*

I. 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.[(1-4)]

Objectives

The main objectives of biomimetic material is to return the tooth to its function, esthetics, and strength. In conventional approach, more tooth structures are removed; the diseased tooth structures are replaced with rigid materials. These techniques and materials have shortened the life span of restorations and weakened the tooth structures. Therefore, attempts are being made to develop materials which will regenerate dental structures and replacement of lost dental tissues by processes which mimic natural ones.

II. BIOMIMETIC MATERIALS BASED ON COMPOSITION

1) Glass Ionomer Cement (GIC) Based

Glass ionomer cement (GIC) which was invented in 1969 is composed of fluoroaluminosilicate glass powder and water soluble polymer (acids). When powder and liquid is blended, it undergoes hardening reaction that involves neutralization of the acidic group together with significant release of fluorides [(5)].

Bioactive formulation (such as 45S5, S53P4) has bioactive glass and hydroxyapatite. The mechanical properties of GIC have been improved with incorporation of metals such as stainless steel and bio inert ceramics like zirconia [(6)].

KT-308 (GC Corporation Company, Tokyo, Japan)

It is a GIC sealers, provides more resistance to coronal ingress of bacteria into the root canal system better zinc oxide-eugenol-based sealer [(7)].

ZUT (University of Toronto, Ontario, Canada)

A combination of GIC and an antimicrobial silver-containing zeolite is effective against E fecalis and hence can be more effective in treating teeth of persistent apical periodontitis [(6)].

Active Gutta-Percha (GP) (Brasseler USA, Savannah, GA, USA)

It has GIC impregnated Gutta-Percha (GP) cones that are bondable to GIC based sealer and claims to offer adhesive bonding of the active GP to intraradicular dentine [(7,8)].

III. RESIN BASED COMPOSITE

Introduced by Bowen, Resins offers wear resistance, color stability, improved physical properties and radiopacity [(9)].

Developments in Nanocomposites

Modifications	Materials Used
Reinforced Fillers	Electro spun nylon Nano fibers containing highly aligned silicate single crystals • Nano fibers and e-glass fibers with Baal SiO_2 in semi-interpenetrating polymer network (IPN) matrix • TiO_2 Nano composites modified with Allytriethoxysilane (ATES)
Caries prevention fillers	• Nano-DCPA whiskers • TTCP-whiskers • CaF_2 nanoparticles with reinforcing whisker fillers • Polymer-kaolinite Nano composite
Resins	• Epoxy-polyol matrix • Epoxy functionalized cyclic siloxane • Bioactive poly i.e. methyl methacrylate/SiO_2-CaO Nano composite • Epoxy resin ERL-4221 (3,4-Epoxycyclohexylmethyl-(3,4-epoxy) cyclohexane carboxylate) • Silsesquioxane (SSQ)
Nanoparticles surface modification with different silanes	• 3-methacryloxypropyltrimethoxysilane (MPTS) • n-octyltrimethoxysilane (OTMS) • Dual salinization with MPTS and OTMS • Equal masses of MPTS and MPTS • γ glycidoxypropyl trimethoxysilane (GPS) • Allytriethoxysilane (ATES)

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MTYA1-Ca

Atsuko Niinuma developed resinous direct pulp capping agent containing calcium hydroxide. The powder composed of 89.0% microfiller, 10.0% calcium hydroxide and 1.0% benzoyl peroxide and was mixed with liquid (67.5% triethyleneglycol dimethacrylate, 30.0% glyceryl methacrylate, 1.0% o-methacryloyl tyrosine amide, 1.0% dimethylaminoethylmethacrylate and 0.5% camphorquinone).

MTYA1-Ca developed dentine bridge formation without formation of a necrotic layer, revealed to have good physical properties, and was not inferior to Dycal, histopathologically. Therefore, it is suggested that the biomimetic material, MTYA1-Ca promises to be a good direct pulp capping material [10].

Theracal

TheraCal LC is a light cured, resin modified calcium silicate filled liner designed for use in direct and indirect pulp capping, as a protective base/liner under composites, amalgams, cements, and other base materials. TheraCal LC performs as an insulator/barrier and protectant of the dental pulpal complex.

The proprietary formulation of TheraCal LC consists of tricalcium silicate particles in a hydrophilic monomer that provides significant calcium release making it a uniquely stable and durable material as a liner or base. Calcium release stimulates hydroxyapatite and secondary dentin bridge formation. TheraCal LC may be placed directly on pulpal exposures after hemostasis is obtained. It is indicated for any pulpal exposures, including carious exposures, mechanical exposures or exposures due to trauma.

Gandolfi et al., compared chemico physical properties of TheraCal, ProRoot MTA and Dycal and concluded that TheraCal displayed higher calcium releasing ability and lower solubility than either ProRoot MTA or Dycal. The capability of TheraCal to be cured to a depth of 1.7 mm may avoid the risk of untimely dissolution[11]

IV. Calcium Silicate Based Material

Mineral Trioxide Aggregate (MTA)

MTA which was developed by Mahmoud Torabinejad at Loma Linda University, consists of 50-75 % (wt.) calcium oxide and 15-25 % silicon dioxide. It has high pH (12.5), causes regeneration of the periodontal ligament (PDL), dentinal bridge formation, biomineralisation and stimulation of cell differentiation and has antimicrobial activity. However, difficulty in manipulation and longer setting time are its limitations.[12,13]

Biodentine

Introduced in 2011 is composed of tricalcium silicate, calcium carbonate and zirconium oxide and a water based liquid containing calcium chloride as the setting accelerator [12,14]. When biodentine comes in contact with dentine it results into the formation of the tag-like structures next to an interfacial layer and is called ''Mineral Infiltration Zone,'' which may contribute to adhesive properties[15]. It has improved physical properties, reduced setting time (12 min) and induces odontoblast-like cell differentiation and mineralization [12].

V. Calcium Phosphate Based Cement

Bioaggregate

Introduced in 2006, is delivered as powder form of nanoparticles containing calcium phosphate monobasic, tricalcium silicate, dicalcium silicate, amorphous silicon dioxide, tantalum pentoxide (radio pacifier) while it's liquid form contains deionized water. It is aluminum free formulation, thus it stimulates proliferation of human PDL fibroblasts and aids in periodontal regeneration [16-20].

CEM (Calcium Enriched Mixture)

Introduced by Asgary. It is also known as CEM. It is composed of calcium phosphate, calcium oxide, calcium carbonate, calcium silicate, calcium sulfate, and calcium chloride. This cement releases both calcium and phosphorus ions leading to hydroxyapatite production might promote differentiation of stem cells and cementogenesis [21].

Hydroxyapatite

It is the most thermo dynamically stable of the synthetic calcium phosphate ceramics. It has good biocompatibility with neutral pH -7.0. It can be used as scaffolding for the newly formed mineralized tissue [22].

VI. Calcuim Aluminate Based Cements

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 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 leading to the formation of katoite and gibbsite [23]

Endobinder

It is composed of Al_2O_3 (≥68.5%), CaO (≤31.0%), SiO_2 (0.3-0.8%), MgO (0.4-0.5%), and Fe_2O_3 (<0.3%). The cement is produced by the process of calcining Al_2O_3 and $CaCO_3$ at temperatures between 1315ºC and 1425ºC to achieve a uniform composition. The product resulted of this process is cooled and then triturated until an adequate particle size is obtained. The final product is a result of the following chemical reaction: $CaCO_3+Al_2O_3=Ca(AlO_2)_2+CO_2$ [24, 25].

EndoBinder has good cell response, allowing greater development of cells at an advanced state of osteoblastic differentiation than the one obtained with MTA [26, 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. 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]

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VII. Ceramic Based Material

Bioactive Glass (BAG)

Calcium sodium phosphosilicate is used in cariology, restorative dentistry and periodontology, air polishing procedures, desensitizing toothpastes, and as a bonding and bone regeneration material [(29-31)]. Mohn et al mixed BAG particles with 50% bismuth oxide and used it as root canal filling material. BAG has directly and indirectly pH related antibacterial effect [(32)].

HX-BGC

It is novel BAG-ceramic available in powder form and containing SiO2-P2O5-CaO-Na2O-SrO. It was used to reduce dentine permeability and works by the property of occluding dentinal tubule [(33)]

VIII. Conclusion

Biomimetic in dentistry is a very useful concept and further comprehension of technological advances and composition of biomimetic materials conviction about improved restorative materials. Regeneration of the lost dental tissue rather than mild replacement with dental materials ensures better prognosis, excellent biocompatibility, and high success rate. The scope of biomimetic dentistry is enormous in the near future. Biomimetic dentistry would successfully replace lost dentin, enamel, cementum, and pulp and open a new era of dentistry.

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