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Biomimetics in Dentistry – Review

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Abstract **Review Article**

Nature is our ideal model to imitate. Biomimicry is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems Biomimetics is the field of science that uses the natural system for synthesizing materials through biomimicry. A Biomimetic material can replace, regenerate or mimic the missing tooth structure and helps to return the tooth to its full function and esthetics. This article provides a literature review of biomimetic materials and its applications in various fields mainly in restorative dentistry.

Keywords: Biomimetics, smart materials, regeneration, emdogain.

INTRODUCTION

Biomimicry describes a new science that studies nature's best ideas and imitates these designs and processes to provide innovative and sustainable solutions for industry and research development It mimics like consulting life's genius as nature to create new products, processes, and policies to create new ways of living that are well adapted to earth. It is an era that is based not on what we can extract from nature, but on what we can learn from the nature [1].

DEFINITION

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.It is also known as bionics or biognosis or bionical creativity engineering. They are derived from Greek words Bio meaning 'life' and Mimesis meaning 'imitation'.

History

During the 1950s the American biophysicist and polymath Otto Schmitt developed the concept of "biomimetics" triggered by studying the nerves in squid, attempting to engineer a device that replicated the biological system of nerve propagation. ". He continued to focus on devices that mimic natural systems and by 1957 he had perceived a converse to the standard view of biophysics at that time and he called it as biomimetics [2].

In 1960 Jack E. Steele coined a similar term, bionics. Steele defined bionics as "the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues. Schmitt used the term "biomimetic "in the title of one of his papers, and by 1974 it had found its way into Webster's Dictionary. Biomimicry was popularized by scientist and author Janine Benyus in her 1997 book Biomimicry: Innovation Inspired by Nature [2, 3].

BIOLOGICALLY INSPIRED MECHANISMS

Leonardo da Vinci's work is a fundamental example of biomimicry. He designed a "flying machine" inspired by a bird. Velcro is an invention derived from the action of the hooked seeds of the burdock plant (Fig-1) [4].

The leaves of lotus which are always clean, despite growing in muddy and stagnant water, led to the production of Lotusan, a paint for self-cleaning surfaces. Dry adhesive tape has been made using the adhesive mechanism of gecko feet in which the hair of gecko foot adheres equally well to both hydrophobic and hydrophilic surfaces. The front of the Japanese bullet train was inspired by a kingfisher's beak (Fig-2) and the bionic car was inspired by box fish [4].

Fig-1

Fig-2

Architects commonly use biology as a library of shapes. Eiffel's tower was based on the structure of trabecular struts in the head of the human femur, or the taper of a tulip stem.

BIOMIMETICS IN MEDICINE

The middle of 20th century was important in the history of biomimetic medicine due to the sophisticated inventions of the cardiac pacemaker, artificial heart valves, and knee joint replacement. The contribution of painless syringe needles is a combination of biomimetics and bioengineering to improve medical operations. A biocompatible short-lived medical bandage can be used to detect signals and help to monitor heart attacks or myocardial infarction that cannot be monitored or detected using current medical devices [5].

BIOMIMETICS IN DENTISTRY

In dental medicine the concept of Biomimetic Material is an increasingly applicable word especially in restorative dentistry. The term biomimetic suggests reproducing one or more natural phenomenon within a biological situation to produce a biocompatible material [6, 7].

Biomimetic material: It can return all prepared dental tissues to full function by a hard-tissue bond that allows functional stresses to pass through the tooth allowing the entire crown into the final functional biologic and aesthetic results. A biomimetic material should match the replaced part of the tooth by its modulus of elasticity and function [8-10].

BIOMIMETICS IN RESTORATIVE DENTISTRY

Biomimetic Remineralizers

FLUORIDES

It increases the resistance of enamel to acid attack and enhances the normal remineralization process but cannot penetrate into the subsurface body of the lesion.

CPP-ACP

Casein is the predominant phosphoprotein in bovine milk. Casein Phosphopeptide stabilize calcium phosphate in nanocomplexes in solution as amorphous calcium phosphate. It promotes remineralization throughout the body of the lesion. The CPP-ACP technology has been commercially developed and is available in sugar-free chewing gum (Recaldent^{TM}) and ToothMousse (Fig-3) [11].

Fig-3

Demineralized Dentin

Demineralized bone matrix induces chondrogenesis and osteogenesis when it comes in contact with mesenchymal cells.

Bioactive Glass

Introduced by Hench *et al*., Also known as Novamin which contains calciumaluminophosphosilicate glass. It bond chemically to bone materials and promotes osteoinduction. 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 [12].

BIOMIMETIC AMELOGENIN (Emdogain)

The enamel matrix is composed of a number of proteins, such as amelogenin, amelin, enamelin, tuft protein, and proteases. They are secreted by Hertwig's epithelial sheath. It induces dentin formation, influences cell function of pulp cell, prevent ankylosis, stimulate formation of periodontal ligament and cementum. When the pulp wound is exposed to EMD a substantial amount of reparative dentin like tissue is formed similar to wound healing

BIOMIMETIC DENTIN

Calcium hydroxide: Introduced by Hermann .Calcium hydroxide was used as the standard material for maintaining the vitality of pulp as it is capable of stimulating tertiary dentin formation. But it has some disadvantages like poordentin bonding and resorption [13].

Mineral Trioxide Aggregate was introduced by Torabinejad *et al*., in 1990.It is a mixture of Portland cement (75%), bismuth oxide (20%), and gypsum (5%). It is used to repair all dentinal defects. It is biocompatible and helps in periodontal ligament attachment, cementum growth, and dentinal bridge formation [15].

Biodentine is a quick-setting calcium silicate based dental cement. It has properties similar to that of dentin and induce mineralization in the form of osteodentine. It has less setting time than MTA [16].

Endosequence is a bioceramic material which has the ability to form hydroxyapatite and to create a bond between dentin and the filling materials [17].

Bioaggregate

It stimulates proliferation of human PDL fibroblasts and helps in periodontal regeneration [17].

SMART MATERIALS

Materials that respond to stimulus such as stress, temperature, moisture, pH and can sense and act according to changes in the environment. They can return to its original stress after the removal of stimulus. These materials are called as smart materials. Smart materials are divided in to two: active and passive.

Passive smart materials release ions by responding to external changes. e.g: GIC, Compomer

Active smart materials act when there is hazardous variation in the environment surrounding the restoration. e.g: smart gic, smart composites [18].

Glass ionomer cements: First invented by Wilson and Kent in 1929. It is a biomimetic material as it has properties similar to dentin ,its adhesion to tooth structure and the fluoride release

Smart GIC show thermal expansion or contraction in response to thermal stimuli. It is similar to the flow of fluids in the dentinal tubules and mimics the behaviour of human dentin through a type of smart behaviour. Therefore GIC is considered to be a smart material [19].

Another new approach in restorative dentistry was the introduction of an ion releasing composite material in 1998 by Ariston PHC. Also called as Smart Composites. It is a light activated nano filled restorative material. Amorphous calcium phosphate is used as filler phase in these composites and they release calcium, fluoride and hydroxyl ions when the pH drops below 5.5. These ions are deposited in the form of apatite crystals which is similar to the hydroxyapatite in teeth and bone [18, 19].

Giomer is a hybrid of glass ionomer and composite resin. It incorporates pre-reacted glass ionomer (PRG) technology which forms a stable phase of glass-ionomer suspended in a resin matrix. The presence of a pre-reacted hydrogel is responsible for the high level of fluoride release and recharge of giomers [8].

Ceromers combine the advantages of ceramics with composite resin technology. The ceramic which is the inorganic phase of the material imparts durable esthetic quality, abrasion resistance and high stability while the resin which is the organic phase determines enhanced polishability, effective bond with luting resin, low degree of brittleness and reduced susceptibility to fracture. Compomers contain fluoride compounds that are capable of releasing free fluoride under acidic conditions or in the presence of moisture [8, 9].

BIOMIMETICS IN REGENERATION

Regenerative endodontic procedures are based on tissue engineering process which includes a triad of stem cells, scaffolds and growth factors [22]. Some new biomimetic approaches in regeneration are:

Stem cell therapy: It is a simple method of injecting postnatal stem cells having regenerative potential into the disinfected root canal system. Stem cells like dental pulp stem cells derived from human dental pulp can regenerate dentin‑ pulp complex like natural human tooth [14, 20].

In pulp implantation, pulp tissue produced by tissue engineering triad can induce an organized matrix similar to pulp tissue which can lead to hard tissue formation

In Injectable scaffold delivery, hydrogel is used as a scaffold to promote pulp regeneration .It also provides a substrate for cell proliferation and differentiation to develop into an organized tissue structure. It is a non-invasive method and is easy to deliver.

Gene therapy is another procedure done with the help of viral or non-viral vectors. It delivers mineralizing genes into pulp tissue and promote tissue mineralization.

Self-assembling peptides P11-4 undergo well-characterized hierarchical self-assembly into three-dimensional fibrillar scaffolds. They are highly biocompatible with low immunogenicity. In P11-4 self-assembly, the anionic groups of the P11-4 side chains attract Ca^{++} ions, and cause precipitation of hydroxyapatite [6, 14, 21].

Biomimetic modifiers: These are proteins and factors that have the potential to alter the host tissue so as to regulate the wound healing process. These agents can act both locally as well as systemically. They help in cell migration, attachment, cell proliferation, cell differentiation and matrix synthesis.

Bone morphogenic proteins can induce new dentine formation. It increases alkaline phosphatase activity, collagen synthesis in osteoblasts.BMP-2 and BMP-7 helps in dentin formation [21].

Growth factors: Also known as morphogens. It helps in hemostasis and wound healing. Platelet derived growth factor (PDGF) plays a key role in chemotaxis of neutrophils that acts with other growth factors to produce collagen. Transforming growth factor (TGF) induces extracellular matrix deposition and collagen formation. Fibroblast growth factor (FGF) plays a role in fibroblast proliferation, angiogenesis, and matrix deposition. Vascular endothelial growth factor (VEGF) increases vascular permeability at the capillary level. Platelet rich plasma is generated by differential centrifugation and serves as reservoir of these growth factors

CONCLUSION

Biomimetics is a multidisciplinary approach that is inspired by the innovations from nature. In Biomimetic dentistry, materials can replace lost tooth structure but further research is still needed to produce materials that could regenerate enamel, dentin and even pulp. The future will be amazing.

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