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Review Article

Nature's Blueprint: Biomimetic Materials Leading The Future Of Dental Care

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ABSTRACT:

Biomimetics is an interdisciplinary approach that involves studying natural systems to design and create innovative solutions. In context to dentistry, biomimetics mainly focuses on creating materials and techniques that can mimic the natural properties of tooth& oral tissues, improving the aesthetic outcomes in both restorative & regenerative dentistry. In restorative dentistry, biomimetics has taken a new turn with several innovative advancements like advanced biomimetic materials, minimally invasive techniques, bioactive materials&self-healing materials. This reflects increased use of biomimeticapproaches in modern restorative dentistry to improve the treatment efficacy & sustainability of outcomes.In regenerative dentistry,these approaches foster the natural repair and regeneration of pulp, bone and periodontal structures involving procedures like stem cell therapy, pulp implantation&root canal revascularization. This review will discuss the utilisation of biomimetic materials in restorative & regenerative dentistry comparing the applications & outcomes in restorative & regenerative contexts.

Keywords: Biomimetics, restorative dentistry, regenerative dentistry, bioactive materials, pulp implantation, root canal revascularization.

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INTRODUCTION

Biomimetics is a greek word where "bio" refers to life and "mimesis"refersto copy or imitate.[1]Biomimetics involves the study of the structure, function & formation of a biologically product that is formed through various biological processes.Employing biomimetics in dentistry will mainly focuses on mimicking the natural properties of the tooth structure to replace the lost dental tissues(enamel,dentin, bone, cementum etc.)and restore the tooth with full function improving its strength and aesthetics. This biomimetictechnique forms a material through natural processes whichis referred to as biomimetic material.[2]

Biomimetic materials can be customised according to the specific oral tissues, as they have excellent repair and regeneration capabilities.[3]A variety of natural and synthetic polymers, as well as hydroxyapatite and ceramics (inorganic materials) can be used to fabricate biomimetic materials. Apart from its primary objective, biomimicry has a secondary objective: todevelop restorative materials withpropertiessimilar to tooth. Biomimicry is more like biological dentistryin thatboth approachesavoid using toxic and non-biocompatible materials.

Back in 1950, an American biophysicist &Polymath Otto Schmitt discovered about biomimetics.[4] During his postdoctoral research Schmitt continued to work on the devices that used to mimic the natural systems.Jack E.Steele in 1960 similarly coined a term as "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"[5] In 1997, the scientist & the author Janine Benyuspopularised the word biomimicry inherebook *Biomimicry: Innovation Inspired by Nature*. Benyus clearly stated that sustainability is an important objective of biomimicry.

This review will delve into the principles & applications of biomimetic approaches within both

restorative & regenerative context. It will also highlight the recent developments of novel biomaterials & techniques that aim to restore and regenerate dental tissues with greater precision & efficacy.

OBJECTIVES

The main purposeof using biomimetic materials in dentistry is to restore the lost function of the tooth & improve its aesthetics along with strength.Traditionalapproaches involvesunnecessary loss of tooth structure,where the diseased part of the tooth is replaced with a hard material. These methods and ideascan affect the life of the tooth structure and reducethe results ofrestoration.Employing biomimetics in dentistry will mimic the natural properties providing a similar effect on restoredtooth structure and surrounding tissues with enhanced biocompatibility& fewer failures.

BIOACTIVE MATERIALS

Bioactive materials are potentially capable to affect and produce a response from a living tissue. This property is referred to as bioinductive property. Anideal biomaterial should provide bacteriostatic or bactericidal effect, should promote the formation of reparative dentin as well as maintain the vitality of healthy pulp.[6]

a) Synthetic Polymers

Polymersare macromolecules (large molecule) which are formed by combining multiple units of monomer (small molecules). These monomers are chemically bonded to each other through a procedure called as polymerization.[7]Polymers can be of two types; natural polymers and synthetic polymers. Synthetic polymers are organic, man-made polymers whichcan beproduced artificially in the laboratories.[8]The resulting properties of the polymers depends on the type & nature of monomer used like Methacrylates, Polyethylene glycol(PEG), Polylactic Acid(PLA), Polycaprolactone (PCL), Polyvinyl Chloride (PVC), Polyurethane etc. Synthetic polymers are known for theirdurability, versatility &biocompatibilitybecause theyhave the ability to be engineered with different chemical and physical properties to achieve the goals of biomimetic dentistry.[9]Synthetic polymers can be used as restorative materials, sealants, tissue engineering scaffolds, root canal sealers, bioactive cements, etc.in biomimetic dentistry.[10]Synthetic polymers alone are not bioactive because they do not interact with the biological tissue, so to make them bioactive they need to be developed artificially by adding bioactive molecules, controlled degradation so that they can release beneficial ions like calcium or phosphate, or modifying their surfaces for cellular interactions. It can be a strong candidate for biomimetic applications.

b) Ceramics

Ceramics are inorganic, non- metallic materials known for their brittleness. The low tensile strength and high compressive strength is responsible for this brittlenesswhich makes ceramics more prone to fracture.[11]Ceramics are widely known for its ability to mimic the natural toothstructure.[12]

Biomimeticceramicscan be really promising as they can be more effective& long lasting.They should not be confused with conventional ceramics. Biomimetic ceramics are engineered in such a way, so that they can interact with the biological tissues to promote growth and regeneration, unlike conventional ceramics. Specific characteristics like biocompatibility, porous structure, chemical composition, osteoconductivity&bioactivity makes it more ideal to be used in dental applications. It shares similar properties with bone& teeth making it more ideal to be used for bone repair and regeneration. Some examples of biomimetic ceramics are hydroxyapatite, bioactive glass, zirconia& calcium phosphate ceramics.Biomimetic ceramics can be used in various applications like dental implants, bone grafts, orthopaedic implants & tissue engineering.[13]

BIOMIMETIC RESTORATIVE DENTISTRY

The main aim of using biomimetics in restorative dentistry is to replace & restore the lost hard tissue through a restorative material that will promote the strengthand imitate the biomechanics of the tooth.[14]So, that tooth function as a single entity. In conventional approach, the decayed portion of the tooth is removed and replaced with a hard restorative material. This procedure shortens the life span of the restoration and weakens the tooth. On contrary side, biomimetic approach involves the concept of no dentistry or less dentistry.[1] Biomimetic restorative material definitely aims to restore the decayed portion of the tooth but alsoretains the inherent properties of the tooth.

BIOMIMETIC RESTORATIVE MATERIALS

a) Glass Ionomer Cement

Glass ionomer cements are direct aesthetic restorative material which chemically bond to the tooth structure. They are biocompatible, fluoride releasing, coefficient of thermal expansion is similar to tooth structure and thus reducing the risk for microleakage, low solubility&good compressive strength making it favourable to be used as biomimetic material. It's fluoride releasing property makes it anti-cariogenic.[15]

b) Composite Resin

Composite resin is widely used as biomimetic material in dentistry, it has the ability to replicate the properties of the tooth. It bonds strongly to the enamel & dentin. Due to its mechanical & aesthetic properties it is preferred in many restorative & cosmetic procedures.It exhibits properties like shade matching, good compressive strength, elastic modulus similar to dentin, bonds well to the tooth, good wear resistance , marginal integrity, biocompatibility, increased durability& longevity. One of the major limitation of composite resin is polymerization shrinkage. Despite

its limitation, it still remains a favourable choice among dentists.[16]

BIOMIMETIC REGENERATIVE DENTISTRY

Regenerative endodontic procedures (REPs) are biological procedures that involve replacement of damaged structures like dentin, root structures &pulp-dentin complex.[17] This procedure is mainly carried out in cases like necrotic pulp or immature permanent tooth where conventional root canal procedures are not effective.[18]This procedure is based on the concept of tissue engineering& involves induction of bleeding which results in the formation of blood clot that acts as scaffold. The outcome of REPs depend on absence of inflammation, proper healing of bony lesion, increased root lengthening, increased canal wall thickening& positive response to vitality test.[19]Using biomimetic materials in regenerative dentistry will improve healing , promote faster tissue regeneration, reduce the need of invasive treatments&will provide better aesthetic outcomes.

Biomimetic Materials

The biomimetic materials that can be used in regenerative dentistry are as follows –

a) **Bioactive Materials** –Materials like bioactive glass, bioceramics& calcium silicates as mentioned above have strong potential for remineralization& tissue regeneration.
b) **Hydrogels & Scaffolds** –Hydrogel is hydrophilic polymer (water attracting). They have the ability to retain high amount of water which makes them flexible& durable. High flexibility, biocompatibility &porous structures makes it possible for the hydrogel to act as scaffold. Scaffold acts as 3D structure that can mimicthe extracellular matrix (found in natural tissues), & provide support structure for the growth & regeneration of the damaged tissue. In order to fasten the process of healing, growth factors (GF) can also be infused into the scaffold.
c) **Calcium Phosphate Based Compounds** –Bone &tooth both have higher calcium content (inorganic content). These compounds can be used to stimulate the bone & tooth, which in return will result in formation of enamel & dentin.[20]

Stem Cell Therapy

Stem cell therapy plays animportant role part inbiomimetic regenerative dentistry by harnessing body's own tissue that has the ability to regenerateitself. This approachmainly focuses on regenerating dental tissues like pulp, dentin& even periodontal structures. Stem cells are undifferentiated cells which can be both pluripotent or multipotent in nature. Multipotent cells can differentiateinto limited types of cells like adultstem cells (present in various types of tissues like bone marrow& dental pulp)whereas pluripotent cells have the ability to differentiate into any type of body cells like embryonic stem cells(ESCs) or induced pluripotent stem cells (iPSCs). In regenerativeendodontics, the stem cells(SCs) are isolated from dental pulp (DPSCs), apical papilla (SCAP), periodontal ligament (PDLSCs)&dental follicle (DFSCs).[21]

These cells have the ability to regenerate the dentin-pulp complex exactly like the natural ones.For dental pulp regeneration, SCT offers a promising alternative treatment to conventional RCT with minimal invasiveness.The simplest way to administer is to directly infuse the stem cellsinside the disinfected root canal this will help to preserve the vitality of the tooth& promote pulp regeneration.

Stem cell therapy & regenerative dentistry both serves the role of biomimicry.[22]

CONCLUSION

The integration of biomimetic principles is revolutionising dentistry and offers promising advances that improve patient outcomes and provide sustainable healing.Despite progress, there are still challenges such as the need for further research, optimisation of equipment and resolution of treatment limitations.Continuous research and development in the field of biomimetic dentistry is necessary to unlock further potential and improve the field, forming the basis for effective and efficient treatment.

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