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An Updated Review On Biomimetics

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ABSTRACT :

Biomimetics—the study of mimicking natural processes and structures—has completely transformed contemporary dentistry. The intricate structure and operation of dentin-pulp tissues in endodontics provide particular difficulties for restoration and regeneration. Biomimetics attempts to repair the structure and function of injured tooth tissues by utilizing the designs seen in nature.

This article examines how biomimetic concepts can be incorporated into endodontics, with an emphasis on cutting-edge methods such as growth factor application, stem cell therapy, and nanotechnology, all of which are covered in relation to biomimetic endodontic treatments. Biomimetic techniques, which bridge the gap between synthetic interventions and biological harmony, promise improved healing, lifespan, and biocompatibility in root canal treatments by mimicking the accuracy of nature. The potential of biomimetics to revolutionize endodontics and open the door to minimally invasive, biologically integrated dental treatment is highlighted in this research.

Keywords: Biomimetics

1. Introduction :

The study of biological materials' composition, development, and use, as well as biological processes themselves, is known as biomimetics. It also includes the construction of artificial mechanisms that replicate biological processes to make similar objects and organic ones. A material made with biomimetic technology that resembles a natural method is known as a biomimetic substance.(1)
"Bio" means "life," and "mimesis" is the Greek word for imitation. The field of study known as "biomimetics" aims to use biomimicry in system design and material creation. The primary intent of biomimetic dentistry is to use materials to replace missing dental tissues in order to fully restore function and bear with all functional strains and the preservation of aesthetic outcome.

2. OBJECTIVES :

Restoring the tooth's strength, function, and appearance are the primary goals of biomimetic dentistry. The traditional method involves extracting more tooth structure and replacing the unhealthy tooth structure with inflexible materials. The lifespan of restorations has been limited by these methods and materials, and reduced the strength of the tooth structures. Consequently, efforts are being made to create materials that can restore destroyed dental tissue and regenerate dental structures tissues using procedures that resemble natural ones.

3. BIOMIMETIC APPROACHES FOR DENTAL RESTORATIVE BIOMATERIALS:

In essence, it seeks to repair the damaged tooth structure in a far more conservative manner than standard tooth preparation, which entails more involved and intrusive procedures to promote resistance and retention. To put it briefly, the conventional restorative approaches prioritized the material's demand. [(2)] The development of restorative materials that can replicate teeth, elements including colours, tints, intracoronal structure, dynamics, and placement of The biomimetic principles should be respected when choosing teeth for the arch.

4. BIOMIMETICS IN RESTORATIVE DENTISTRY:

4.1 Enamel Biomimetics:

The outermost hard tissue that covers the tooth structure's crown is called enamel. Because of its high inorganic content (96%) and three-dimensional arrangement of interlaced hydroxyapatite crystals, it is regarded as the toughest substance in the body,
with exceptional structural and aesthetic qualities.

Nonetheless, ongoing and intricate modifications taking place within the oral microenvironment can occasionally cause enamel demineralization, which starts production of caries. Enamel regeneration is still a difficult procedure, and it gets significantly more complicated when used in a clinical setting. Thus, it's critical to consider other approaches to enamel restoration and create biomaterials that closely resemble the natural enamel in terms of both structure and biology. Pandya along with others. four distinct routes for enamel tissue engineering and regeneration were described by:

- Physiochemical synthesis
- The growth of enamel crystals guided by a protein matrix.
- enamel surface remineralisation
- cell-based regeneration

4.2 Biomimetic Aspects of Dentin and Dentin-Pulp-Complex Regeneration:

Dentin, a very complex tissue, makes up the majority of the tooth's structure: The mineral content of the dentin is responsible for 70% of its structure, with the remaining 30% coming from water and organic matter.Compared to enamel, dentin is more likely to demineralize more quickly due to its lower mineral content. Because of its intricate structure, it remineralizes more slowly, which accelerates the spread of caries into dentin and ultimately leads to pulp tissue infection and periapical disorders.

To build dentinal tubules and promote remineralization, it is imperative to design intelligent and efficient biomaterials to replace lost tissue mineral and organic content. This process can be triggered by a variety of substances and bioactive analogs such as resin-based adhesives and bioactive glass for dentin remineralisation.

5. BIOMIMETIC RESTORATIVE MATERIALS :

Perhaps the most significant synthetic biomaterials used in clinical settings today are dental materials. The most often used medical devices for repairing human tissue are aesthetic direct restoratives, which successfully take the place of enamel and dentine to shield the pulp (reducing discomfort) and restore vital processes associated with eating, speaking, and looking.
These include materials like GLASS IONOMER CEMENT (GIC), Dental composite resin,ceramics, mineral trioxide aggregate, Biodentine,Bio-Aggregate, Antibacterial Dental Composites and Bonding Agents(Cention-N, Zirconomers,Ormocers)

6. BIOMIMETIC ENDODONTICS :

Biomaterials (irrigation agents, intra-canal medications, and cements) and tissue regeneration (dentin and pulp regeneration, revascularization) are just two examples of the many biomimetic applications in endodontics.(3-5)

6.1) Endodontic Irrigants:

It has long been known that bacteria are the main causative agents of pulp and periapical lesions.(52–54)For root canal therapy to be successful, pulpal tissue and dentin must be thoroughly debrided using chemomechanical techniques. detritus, and infective bacteria.

The use of irrigations can enhance mechanical debridement by eliminating debris and dissolving tissue as well as keeping the root canal system clean. Specifically, chemical debridement is required for teeth that have intricate internal structures, such fins, or other abnormalities that instrumentation might overlook.These include irrigants like sodium hypochlorite,chlorhexidine and EDTA.

6.2) Intra-canal Medicaments:

After cleaning and irrigating the root canals, intra-canal medicaments (ICM) are injected to eradicate any remaining germs.Furthermore, between-appointment medications stop bacteria from growing back in the vacant pulp area.Intracanal medicine has been recommended for many years in infected root canals.

The objectives of using an intracanal medication, one can: After canal instrumentation, eradicate any leftover bacteria and diminish periapical tissue and pulp residual inflammation, neutralize tissue fragments and render canal contents inert,serve as a stopper to prevent leaks from the temporary filling and lastly assist in drying out recurrently damp canals.(6-9)

6.3) Biomimetic Endodontic Cements:

a) Calcium Hydroxide:

Calcium hydroxide, or Ca(OH)2, is a white, odorless, alkaline (pH ~12.5) substance that is widely utilized in endodontic applications, including pulp-capping and apexification treatments. First, bactericidal action, followed by bacteriostatic action. Encourages restoration and recovery. Fibroblasts are stimulated by high ph. Put an end to internal resorption.

On the other hand, prolonged application of Ca(OH)2 during apexification may cause resorptive activity (66) and possibly fracture of the root, weakening the root dentin.

Calcium hydroxide has a few drawbacks, including: Does not only promote dentinogenesis; it also promotes reparative dentin exclusively. connected to the resorption of primary teeth. May disintegrate with cavosurface disintegration after a year.

Applications of Calcium Hydroxide in Endodontics:

- Root Canal Sealer
- In Weeping Canal
- Perforation Management
- Role in Root Resorption

B) TRIPLE ANTIBIOTIC PASTE:

Three antimicrobial drugs, bacteriostatic (minocycline) and bactericidal (metronidazole, ciprofloxacin), make up TAP, an ICM. With the help of these antibacterial medicine microorganisms in the root canals are completely eradicated. TAP, at a dosage of 1 mg/mL (1:1:1), is frequently used in clinical settings for regenerative operations and has demonstrated encouraging results in the removal of 99.99% of root canal bacteria as well as the stimulation of revascularization in immature permanent teeth.

Applications of TAP:

The applications of TAP in endodontics can be considered as follows:

1. In the regeneration and revascularization protocol of the pulp
2. As an intracanal medicament for the treatment of:

- Periapical lesions
- External inflammatory root resorption
- Root fracture
- Primary teeth

3. 3. As an intracanal agent to control flare-ups
4. 4. As a medicated sealer (to prevent possible re-infection)
5. 5. As an additive to gutta-percha points in root canal obturation (known as medicated gutta-percha points)
6. 6. As an intracanal medicament loaded on a scaffold.

Disadvantages of Triple Antibiotic Paste:

1. TAP and decreased strength of radicular dentine
2. Discoloration of the tooth structure
3. Removal of the paste from the canal.

7. BIOCERAMICS:

Among the newly developed materials in endodontics that have altered the field's landscape are bio-ceramics.Biocompatible ceramic materials or metal oxides with improved sealing capabilities are known as bio-ceramics. Antifungal and antibacterial properties that are used in dentistry and medicine.These consist of calcium silicates, hydroxyapatite and resorbable calcium phosphates, radiotherapy glasses, bioactive glass, glass ceramics, and alumina and zirconia.

7.1 Bioceramics are categorized as follows:

- **Bioinert:** (alumina, zirconia) non-interactive with biological systems
- **Bioactive:** strong tissues (bioactive glasses, bioactive glass ceramics, hydroxyapatite, calcium silicates) that can undergo interfacial interactions with surrounding tissue
- **Biodegradable** substances are soluble or resorbable and can eventually be replaced by or integrated into tissue (bioactive glasses, tricalcium phosphate).

7.2 Advantages of Bioceramics:

- Its resemblance to biological hydroxyapatite.
- They possess intrinsic osteoinductive capacity, which enables them to absorb substances that promote bone repair in the vicinity of the process.
- Serve as a resorbable lattice scaffold for regeneration, providing a framework that gradually dissolves when the body regenerates tissue.
- Capacity to create a chemical link with the tooth structure, develop an excellent hermetic seal, and have good radiopacity.

Bioceramics used in endodontics:

- Calcium silicate based Cements-Portland Cement
- Mineral trioxide aggregate (MTA) Biodentine (Septodont, France) Sealers
- MTA Fillapex (Angelus, Brazil)BioRoot RCS (Septodont, France)

Calcium phosphates/ tricalcium phosphate/ hydroxyapatite based:

- Mixture of calcium silicates and calcium phosphates - iRoot BP, iRoot BP Plus,iRoot FS (Innovative Bioceramix Inc., Vancouver, Canada)
- EndoSequence BC Sealer (Brasseler, Savannah, GA, USA)/ Total Fill
- Bioaggregate (Innovative Bioceramix Inc., Vancouver, Canada)
- Tech Biosealer

8. BIOMIMETIC TISSUE-ENGINEERING ASPECT :

Through tissue reconstruction or the development of an inherent biological system, biomimetic tissue-engineering techniques seek to replicate the intrinsic biological environment in an effort to repair and enhance diseased or damaged tissues. The goals of the multidisciplinary field of biomimetic tissue engineering can be met by combining expertise in biology, chemistry, engineering, genetics, and physics. In many dental specialties, tissue engineering is a more recent and promising treatment strategy that aims to regenerate and repair damaged dental tissues while also restoring their function. The regenerative ideas of today can change the dental health benefit. Regenerative endodontics is based on the idea of replacing unhealthy, damaged, or non-vital pulp tissue with a functional, healthy pulp-dentin complex. Particularly in endodontics and pediatric dentistry, regenerative endodontics may be the preferred course of treatment for individuals with nonvital teeth that have an open apex. In a nonvital tooth, full root formation is susceptible, which weakens the tooth and allows the tooth to sustain typical chewing stresses, which leads to a high incidence of root fractures. The goal of biomimetics in regenerative endodontics is to enhance the thickness of the root dentinal wall while achieving full root growth.

The triad of tissue engineering is as follows:

- **Stem Cells:** These are the undifferentiated, clonogenic cells with the ability to differentiate into many lineages and self-renew. Two distinct cell types can be differentiated from stem cells: One stem cell daughter and one parent cell.
- **Scaffolds:** Biomaterials known as scaffolds are those that support and carry particular cell types during the process of tissue regeneration. A scaffold that promotes cell proliferation, differentiation, and organization in the intended location is optimal**.**
- **Growth Factors:** Growth factors are polypeptides or proteins that attach to particular receptors on target cells' surfaces (such as BMP receptors) and cause a variety of cellular processes, including migration, proliferation, differentiation, and all dental pulp cells, including stem and progenitor cells, undergo apoptosis.

9. FUTURE TRENDS IN BIOMIMETICS:

9.1 BIOMIMETIC STRATEGY FOR ENAMEL REMINERALISATION:

Tooth enamel is an extremely special tissue-specific biomaterial with remarkable mechanical and structural qualities in addition to its aesthetic appeal. Enamel's distinct physico-chemical characteristics result from its high presence in hydroxyapatite, the interlaced alignment of perpendicular prisms in a picket fence that resembles three-dimensional order, and the parallel arrangement of individual elongated apatite crystals into enamel prisms. When combined, these properties provide a biomaterial with exceptional physical resilience and hardness. Éclat de verre, or biomaterials similar to enamel, have enormous potential as structural elements for upcoming biomedical and applications in engineering, such as:

9.2 BIOCHEMICAL ENAMEL ENGINEERING:

It's common to hear that tissue engineering can be used to replicate developmental biology for regenerative purposes. To mimic the production of natural tooth enamel for tissue engineering applications, an amelogenin-rich protein matrix and adding calcium phosphate ions to enhance it. After the initial apatite crystal formation, this cocktail would be processed enzymatically with enamel matrix proteases like kallikrein 4 (KLK4) and matrix metalloprotease 20 (MMP20), which would likely cause the initial c-axis crystal to elongate and then lateral crystals to grow in the a- and b-axis directions.

- CERCON: One brand of zirconia used in dentistry is called Cercon. This particular kind of ceramic material is utilized to make dental restorations like implants, bridges, and crowns. Strong and aesthetically pleasing, the Cercon material is utilized to make ultra-thin but durable posterior restorations. The strength to sustain the thin posterior is provided by a monolithic block of solid yttria-stabilized zirconia that is used in its milling bridges with single components to long spans. Full Contour Cercon With 26% greater translucency than regular zirconia and a vitality that resembles real teeth, zirconia is devoid of metal.
- The EQUIA system: It is a glass ionomer-based restorative technology that has been applied to long-term restorations in biomimetic dentistry. It has proven to be a dependable substance for small Class I and permanent Class I applications.In Class I cavities, the technology has also been proven to have superior clinical performance in comparison to a micro-hybrid composite.
- Nano-Endodontic sealers:In root canal therapy, zinc oxide nanoparticles have been employed as sealants. These sealers consist of zinc oxide powder that reacts with a liquid, usually ethanol. In endodontics, chitosan nanoparticles have also been utilized to enhance the removal of biofilm bacteria from the root canal system. The purpose of these nanoparticles is to seal the canal space during root canal therapy and to enhance root canal disinfection.
- yttria-stabilized zirconia (YSZ): This ceramic substance finds application in multiple domains, such as restorative dentistry. Zirconia stabilized with yttria is known as YSZ, and it has increased wear and fracture resistance.
- Zirconia-containing glass-ionomer cement (GIC): It's a variety of GIC with zirconia added as an additive. By lessening the opaqueness of the regular GIC or modified material, zirconia can improve the aesthetic qualities as well as the mechanical ones of GIC.

CONCLUSION:

It is clear that years of intensive study have produced incredibly inventive, cutting-edge biomaterials and methods for mimicking and replacing the natural structures found in the craniofacial region. However, in the role of a biomimetic. Taking into account, materials that are physiologically similar or organically generated have been shown to produce better clinical results, increasing the likelihood of patient use and clinical translation. This is explained by the diversity of biological systems, which are made up of concurrent physiological, physiochemical, mechanical, and metabolic activities. Therefore, to further the current research in dentofacial regeneration, an interdisciplinary strategy incorporating medicine, bioengineering, biotechnology, and computational sciences is required. Several types of in vitro and Research on animal models indicates that innovative therapeutics are being developed towards groundbreaking clinical interventions. We draw the conclusion that while dentistry has made significant progress toward regenerative medicine, there are still a plethora of opportunities to pursue while looking for ideas from other areas of biomedical research.

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