Editorial

Biomimetic Dentistry: Restoring Teeth, the Nature's Way

The term "Biomimetics" is derived from the Latin words "bios" which means life and "mimesis" which means to copy or mimic. The phrase "biomimetic" was coined by biophysicist and biomedical engineer Otto Schmitt in the 1950s.[1] Biomimetic dentistry refers to the science and art of restoring compromised teeth with materials and techniques that replicate natural dental tissues such as enamel, dentin, and cementum in terms of morphology, function, and biomechanical integrity. This approach represents a paradigm shift from conventional restorative practices toward biologically inspired strategies that aim to preserve tooth structure when optimizing esthetics and function.[2]

Biomimetic restorations are guided by six core principles: preservation of tooth structure, immediate dentin sealing, use of dentin substitutes, adhesive bonding with stress control, anatomic and functional integration, and bioactivity with remineralization. To achieve these goals, protocols are categorized into stress-reducing and bond-maximizing techniques, ensuring optimal biomechanical performance and longevity.[3]

Biomimetic materials are broadly classified based on their interaction with biological tissues as follows:[4]

- Bioinert materials: These materials replicate mechanical properties of tissues without active biological interaction, for example, stainless steel, cobalt–chrome alloys, titanium, zirconia, alumina, silicone rubber, and acrylic resins
- Bioactive materials: These materials exhibit chemical interactions with dental tissues, promoting remineralization and healing. The key applications of these bioactive materials include dentin remineralization, either by conventional crystallite growth or by the more advanced bottom-up biomimetic approach that mimics natural dentin formation, for example, bioactive glasses, MTA, Biodentine, Bioaggregate, casein phosphopeptide–amorphous calcium phosphate hydroxyapatite, and calcium silicate-based cements. These also include noncollagenous analogs of dentin matrix proteins that regulate mineralization by stabilizing calcium–phosphate precursors and guiding hydroxyapatite formation, for example, polydopamine, polyelectrolytes (PVPA/PAA), PAMAM dendrimer poly(amidoamine), and sodium trimetaphosphate
- Biodegradable materials: These materials support regenerative healing and eventually resorb after serving their purpose, for example, polymers, collagen scaffolds, and hydrogels.

APPLICATION OF BIOMIMETIC CONCEPTS IN RESTORATIVE DENTISTRY

In restorative dentistry, biomimetic concepts are aimed at mimicking the attributes of the natural tooth in terms of mechanical properties, esthetics, and biocompatibility.[5]

1. Mechanical properties of restorative materials: Advanced resin-based composites and glass ionomer cements remain the mainstay for direct restorations. Modern formulations are designed to match the elastic modulus and surface hardness of enamel and dentin, ensuring optimal stress distribution, for example, smart dentin replacement and nanohybrid composites
2. Esthetic perspectives of restorative materials: Recent innovations, such as OMNICHROMA™ (Tokuyama) and yttria-stabilized tetragonal zirconia polycrystal ceramics, have revolutionized the domain of esthetic restorative materials. These materials exhibit superior optical properties including intrinsic color modulation, goniochromism, translucency, opalescence, and fluorescence. As a result, they achieve a harmonious and natural integration with the tooth structure
3. Biocompatibility of restorative materials: Advancements in material science have led to the development of bioactive materials that are highly biocompatible and promote remineralization of enamel and dentin by releasing therapeutic ions such as fluoride, calcium, and phosphate, thereby ensuring both biological safety and functional repair. Recent advancements in biomimetic dentistry have been further driven by innovations, with the inclusion of antimicrobial composites, smart composites, self-healing composites, self-adhesive systems, titanium oxide nanoparticle-based composites, and nanohydroxyapatite scaffold-based composites, all of which enhance tissue integration and regenerative potential.

BIOMIMETIC STRATEGIES IN ENDODONTICS

Modern endodontics applies biomimetic principles to achieve effective disinfection without compromising cell viability, thereby supporting tissue healing and regeneration. Biomimetic endodontics recommends the use of low-concentration sodium hypochlorite (≤1.5%), as these agents effectively disinfect the confines of the root

canals and maintain the regenerative potential of stem cells when minimizing cytotoxic effects.[6]

- In regenerative dentistry, traditional high-concentration antibiotic pastes, though effective against resistant bacteria, have the potential to damage periapical tissues and may adversely affect the stem cells from the apical papilla, thereby necessitating the introduction of newer approaches. One such innovation is the development of biointeractive and controlled-release antimicrobial systems (e.g., chitosan-based delivery systems and calcium hydroxide in slow-release carriers), which provide sustained and targeted drug delivery, reduce toxicity, and create a biologically favorable environment for stem cell survival and regeneration.

Biomimetic strategies in regenerative dentistry focus on restoring the vitality of the tooth. The most advanced approaches include postnatal stem cell therapy, pulp and scaffold implantation, platelet-rich plasma, nitric oxide delivery systems, 3D bioprinting, and gene therapy. These innovations promote angiogenesis, neurogenesis, and dentinogenesis, thereby achieving true biological restoration.[7]

Despite significant progress, key challenges persist, including achieving of mechanical durability under functional loads, minimizing immunogenic reactions, and implementing these technologies in clinical practice. Future research focuses on multifunctional smart biomaterials with combined antimicrobial, anti-inflammatory, and remineralizing properties, along with robust clinical validation for widespread adoption. These developments promise biologically integrated, durable, and patient-specific solutions, marking biomimetic dentistry as a transformative approach in modern dental care.[8]

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Date of submission: 07.09.2025
Date of acceptance: 07.09.2025
Published: 04.10.2025

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Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/JCDE.JCDE_740_25

How to cite this article: Singh S, Saha SG. Biomimetic dentistry: Restoring teeth, the nature's way. J Conserv Dent Endod 2025;28:955-6.