



Biomaterials in Dentistry: A Comprehensive Review

Arun Vashisht ^{*1}, Surabhi Jayeshbhai Prajapati ², Navreet Kaur³

1. BDS, MDS, PG Prosthodontics, Director, GimmeSmile PPLC, Texas, North America.
2. BDS, Dharmsinh Desai University, Naidad, India.
3. BDS, Genesis Institute of Dental Sciences and Research, Ferozepur, Punjab, India.

***Correspondence to:** Arun Vashisht, BDS, MDS, PG Prosthodontics, Director, GimmeSmile PPLC, Texas, North America.

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Abstract:

The use of the broadest range of materials—from polymers, metals, ceramics, inorganic salts, to composite materials—may be specific to dentistry. The main focus of materials used in dentistry up to this point has been on the aesthetics of restorative materials and their capacity to function in the demanding oral environment without experiencing changes in dimension and stability. Due to enamel and dentine's limited capacity for remodeling, this concept has found relatively limited application despite advancements in tissue engineering and regeneration in the field of regenerative medicine; however, research on biomimetic approaches for dentine modification represents a significant step forward. Biomaterials have revolutionized the field of dentistry by offering solutions for various dental applications. This abstract provides an overview of biomaterials in dentistry, their uses, benefits, and future implications. The discussion covers the types of biomaterials commonly used in dentistry, including metals, ceramics, polymers, and composites. Furthermore, it highlights their roles in dental restoration, prosthetics, implantology, and tissue engineering. The abstract also emphasizes the importance of biocompatibility and the interactions of biomaterials with the oral environment. In addition, current challenges and future prospects for biomaterials in dentistry are discussed to illustrate the potential for further advancements in this field.

Keywords: Biomaterials, Dentistry, Oral Health, Biocompatibility, Applications, Future Prospects.

Introduction

Biomaterials play a pivotal role in the advancement of dentistry, offering a diverse range of materials and technologies to address various clinical needs, from dental restorations to tissue engineering. These materials have significantly impacted the practice of dentistry by providing solutions that are functionally and biologically compatible with the oral environment, leading to improved patient outcomes and quality of care. Biomaterials and technologies are not only replacing missing or damaged tissues but also promoting tissue regeneration.¹⁻³ There are many areas of research where biomaterials

and dental stem cells were used. They offer potential for tissue regeneration in dentin, periodontal ligament, dental pulp, and even enamel. Also, the use of dental stem cells as sources of cells to facilitate repair of nondental tissues such as bone and nerves has been introduced. In this issue, some research related to MTA or Biodentine were accepted which have capability to stimulate tertiary dentin formation. However, as the cellular mechanisms behind successful tertiary dentin formation are largely unknown, few materials have been rationally designed to induce regeneration of root-like structures.³⁻⁶ In this introduction, we delve into the evolution of biomaterials in dentistry, the types of biomaterials commonly used, their applications, importance of biocompatibility, and current challenges and future prospects in the field.

The Evolution of Biomaterials in Dentistry:

The history of biomaterials in dentistry dates back to the use of metals and minerals for dental prosthetic restorations, such as gold and silver fillings, which were common practice in the ancient world. Over time, technological advancements and scientific discoveries have led to the development of more sophisticated biomaterials tailored for specific dental applications. The introduction of ceramics, polymers, and composites has expanded the possibilities for dental restorations, prosthetics, and implantology, enabling more aesthetically pleasing and durable solutions for patients. This evolution has paralleled the growth of dental material science, which has become a distinct discipline within dentistry.^{1,3,7}

Types of Biomaterials in Dentistry:

Dental biomaterials can be broadly categorized into metals, ceramics, polymers, and composites, each with unique properties that make them suitable for different clinical applications. Metals such as titanium and its alloys are commonly used in dental implants due to their excellent mechanical properties and biocompatibility. Ceramics, including alumina and zirconia, are widely utilized in dental crowns, bridges, and other restorations for their natural tooth-like aesthetics and biocompatibility. Polymers, such as resin-based composites, are popular for direct restorations and aesthetic enhancements due to their ability to bond to tooth structure and mimic natural tooth colors. Composites, which combine two or more materials, offer a versatile approach for dental materials that can be tailored for specific applications, such as fiber-reinforced composites for implant frameworks and rebar-based composites for bone tissue engineering.^{2,7,8}

Biomaterial:

Biomaterials used in dentistry encompass a wide range of materials, including metals, ceramics, polymers, and composites. These materials are chosen for their biocompatibility, mechanical properties, and durability. Biocompatibility is crucial to ensure that the biomaterials used in the oral cavity do not elicit adverse reactions or immune responses. Furthermore, the mechanical properties of biomaterials must mimic the natural tissues they are replacing or repairing to ensure proper function and longevity.

Properties of Biomaterials:

The properties of biomaterials in dentistry are essential considerations in their selection for specific applications. These properties include biocompatibility, mechanical strength, hardness, durability, corrosion resistance, esthetics, and ease of manipulation. Biocompatibility ensures that the material does not cause harm to the surrounding tissues, while mechanical properties are vital for withstanding the forces encountered in the oral cavity. The esthetic properties of biomaterials are particularly important in restorative dentistry, where natural-looking materials are desired for dental prostheses and restorations.^{1,9,10}

Application of Biomaterials in Dentistry:^{1,5,6,10-15}

1. **Dental Implants:** Appropriate selection of the implant biomaterial is a key factor for long term success of implants. The biologic environment does not accept completely any material so to optimize biologic performance, implants should be selected to reduce the negative biologic response while maintaining adequate function. Every clinician should always gain a thorough knowledge about the different biomaterials used for the dental implants. Biomaterials are widely used in the fabrication of dental implants. Materials such as titanium and its alloys are favored for their excellent biocompatibility, corrosion resistance, and osseointegration properties, allowing them to integrate with the surrounding bone tissue effectively.

2. **Restorative Dentistry:** Biomimetic has emerged as a multi-disciplinary science in several biomedical subjects in recent decades, including biomaterials and dentistry. In restorative dentistry, biomimetic approaches have been applied for a range of applications, such as restoring tooth defects using bioinspired peptides to achieve remineralization, bioactive and biomimetic biomaterials, and tissue engineering for regeneration. Advancements in the modern adhesive restorative materials, understanding of biomaterial–tissue interaction at the nano and microscale further enhanced the

restorative materials' properties (such as color, morphology, and strength) to mimic natural teeth. In addition, the tissue-engineering approaches resulted in regeneration of lost or damaged dental tissues mimicking their natural counterpart.

3. Orthodontic Braces: Nickel-titanium alloys are commonly used as biomaterials in orthodontics due to their unique properties of shape memory and superelasticity. These materials allow for the fabrication of orthodontic wires that can apply gentle and continuous forces to move teeth into the desired position effectively.

4. Tissue Engineering: Biomaterials are utilized in tissue engineering to develop scaffolds and constructs for periodontal and bone tissue regeneration. These scaffolds provide a framework for the growth of new tissue and promote the restoration of damaged or diseased oral tissues.

5. Endodontic Materials: Biomaterials are employed in endodontics for root canal treatments. Gutta-percha, a biocompatible and inert biomaterial, is commonly used for filling and sealing the root canals after the removal of infected or damaged dental pulp, aiding in the long-term success of endodontic procedures.

6. Biomaterial Coatings: Biomaterial coatings are used to enhance the biocompatibility and performance of dental implants and prostheses. These coatings can improve the integration of implants with the surrounding tissues, reduce the risk of bacterial infections, and promote better long-term stability and success of the implant.

7. Remineralization Agents: Biomaterials are utilized in the development of remineralization agents to restore and strengthen tooth structure. These agents can help in the reversal of early stages of tooth decay by depositing essential minerals, such as calcium and phosphate, onto the tooth surface, effectively remineralizing and strengthening the enamel.

8. Maxillofacial Prosthetics: Biomaterials are used in the fabrication of maxillofacial prosthetics such as dentures, bridges, and facial prostheses. These materials are selected for their biocompatibility, durability, and ability to mimic natural tissues, enabling the creation of functional and esthetic prosthetic replacements for missing or damaged oral and facial structures.

9. Drug Delivery Systems: Biomaterials are leveraged in the development of dental drug delivery systems, enabling targeted and controlled release of medications for the treatment of oral infections, periodontal diseases, and other oral health conditions. These systems offer the advantage of localized treatment, reducing systemic side effects and improving the efficiency of therapy.

10. Dental Bone Grafting: Biomaterials play a critical role in dental bone grafting procedures, where they are used to augment and regenerate bone tissue in preparation for dental implant placement. Synthetic biomaterials or natural bone graft substitutes can be utilized to support new bone formation and enhance the success of implant procedures in areas with insufficient natural bone volume.

11. Temporomandibular Joint (TMJ) Implants: Biomaterials are utilized in the fabrication of implants for temporomandibular joint disorders. These implants can aid in restoring proper jaw function and alleviating pain associated with TMJ disorders, allowing patients to regain normal jaw movement and function.

12. Salivary Gland Prostheses: Biomaterials play a role in the development of salivary gland prostheses for patients who have undergone surgical removal of salivary glands due to conditions such as tumors or blockages. These prostheses can help in restoring saliva production and maintaining oral health by simulating the function of natural salivary glands.

13. Temporary Prosthetic Materials: Biomaterials are used in the fabrication of temporary prosthetic materials such as temporary crowns and bridges. These materials provide interim solutions while permanent prostheses are being fabricated, allowing patients to maintain proper oral function, aesthetics, and comfort during the treatment process.

14. Dental Adhesive Systems: Biomaterials are integral to the development of dental adhesive systems used for bonding various restorative materials, such as composite resins and ceramic restorations, to the natural tooth structure. These adhesive systems provide strong and durable bonds, leading to long-lasting restorations.

15. Cleft Palate Repair: Biomaterials are employed in the repair and reconstruction of cleft lip and palate defects. Tissue-engineered scaffolds and implants made from biocompatible materials can assist

in the restoration of normal oral and facial structures in patients with congenital or acquired cleft conditions.

These additional applications further demonstrate the versatility and significance of biomaterials in addressing a wide spectrum of dental conditions, from structural and functional restoration to the enhancement of treatment outcomes and patient quality of life.

Advantages of Biomaterials in Dentistry:^{12,13,16-18}

1. **Biocompatibility:** Biomaterials used in dentistry are designed to be well-tolerated by the human body, reducing the risk of adverse reactions or tissue rejection. This biocompatibility contributes to the overall safety and success of dental treatments.
2. **Versatility:** Biomaterials offer a diverse range of properties and applications, allowing for their use in various dental procedures, including restorations, implants, orthodontics, tissue engineering, and drug delivery systems.
3. **Aesthetic Appeal:** Certain biomaterials, such as tooth-colored composites and ceramics, provide aesthetic benefits by closely mimicking the natural appearance of teeth, enhancing the overall cosmetic outcome of dental restorations.
4. **Durability:** Many biomaterials used in dentistry are engineered to withstand the harsh oral environment, providing durable solutions for restorations, implants, and prosthetics that can endure the forces of chewing and oral hygiene practices.
5. **Osseointegration:** Biomaterials utilized in dental implants, such as titanium and its alloys, possess the ability to integrate with the surrounding bone tissue, promoting stability and long-term success of implant restorations.

Disadvantages of Biomaterials in Dentistry:^{12,13,16-18}

1. **Cost:** Some advanced biomaterials used in dentistry may be associated with higher production and manufacturing costs, which can contribute to increased treatment expenses for patients.
2. **Allergic Reactions:** In some cases, patients may exhibit allergic responses to certain biomaterial components, emphasizing the importance of thorough assessment of patient medical history and material compatibility testing.
3. **Longevity:** While biomaterials are designed for durability, certain factors, such as wear and tear or degradation over time, may impact their long-term performance, potentially requiring replacement or maintenance.

4. **Complex Manufacturing:** The production and fabrication of certain biomaterials may involve intricate processes and quality control measures, necessitating advanced manufacturing expertise and facilities.

5. **Regulatory Compliance:** Adhering to stringent regulatory standards and requirements for biomaterials used in dentistry adds complexities to their development, validation, and commercialization, which can impact accessibility and availability.

These advantages and disadvantages underscore the multifaceted nature of biomaterials in dentistry, highlighting their significant contributions to patient care alongside the considerations and challenges associated with their implementation and usage.

Future Prospects:

The future of biomaterials in dentistry holds great promise, with ongoing research and development focused on enhancing material properties, promoting tissue regeneration, and advancing treatment modalities. Nanotechnology, bioactive materials, and tissue engineering approaches are likely to drive the next generation of dental biomaterials, offering improved biointegration, longevity, and patient comfort. Furthermore, the integration of digital technologies, such as 3D printing and computer-aided design, will continue to revolutionize the fabrication and customization of dental biomaterials, paving the way for personalized treatment solutions.

Conclusion

Biomaterials engineered to interact with biological system for either therapeutic (treat, augment, repair or replace a tissue function of the body) or a diagnostic purpose have undergone biological evolution over a period of time. This can be attributed to the advent of new innovative technology combined with human curiosity for search of new materials that mimic biological tissues in terms of physical and chemical properties for orchestration of wound healing and tissue regeneration. In conclusion, biomaterials have revolutionized the field of dentistry, offering versatile solutions for a wide range of clinical applications. From dental implants to restorations and tissue engineering, the use of biomaterials has significantly improved patient care and treatment outcomes. While biomaterials present advantages such as biocompatibility and enhanced functionality, it is crucial to address their limitations and challenges, including cost and longevity concerns. The future of biomaterials in dentistry is bright, with continued advancements shaping the landscape of oral healthcare, emphasizing the need for ongoing research and innovation in this dynamic field.

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