International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Biomaterials in Prosthodontics

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Abstract

The importance of biomaterials in prosthodontics is examined in this review article, which highlights how they affect dental treatment outcomes that are both aesthetically pleasing and functional. It includes developments in photopolymerizable materials, bioactive coatings, hybrid composites, bacterial-resistant biomaterials, theranostic biomaterials, and metallic biomaterials such as cobalt-chromium and titanium alloys. It also covers comparative research, the integration of nanotechnology, and the function of biomaterials in tissue engineering. The review aims to provide dental professionals with the knowledge they need to improve patient care and practice by highlighting recent breakthroughs, clinical applications, and future directions.

KEYWORDS: Metallic biomaterials, Bioactive coatings, Hybrid composites, Photopolymerizable materials, Bacterial resistance, Tissue engineering, Theranostic biomaterials, Comparative studies.

Introduction

The repair and restoration of missing dental components in prosthodontics depend heavily on biomaterials, which have a substantial impact on the functional and aesthetic results of dental care. The creation of sophisticated biomaterials has grown in significance as the discipline of prosthodontics has developed, giving physicians a wide range of alternatives that are specifically suited to each patient's needs. For these materials to survive the particular difficulties presented by the oral environment, they must possess qualities like biocompatibility, mechanical strength, and longevity.

Metals and ceramics were among the conventional materials used in prosthodontic treatments in the past. On the other hand, new developments have brought about creative choices including enhanced composite resins, yttria-stabilized zirconia, and titanium alloys. These contemporary biomaterials provide restorations that look natural and increase patient satisfaction by meeting both practical and aesthetic needs. Through the use of nanoparticles and hybrid systems, the integration of nanotechnology has notably improved the mechanical qualities and biological compatibility of these materials, further enhancing their performance.[1][2]

The necessity for evidence-based practices and the wide range of alternatives available to doctors make the selection of appropriate biomaterials crucial. To help practitioners make decisions that maximize patient outcomes, comparative studies evaluating the cost-effectiveness and clinical usefulness of these materials are crucial. In order to give readers a thorough understanding of the state of biomaterials in prosthodontics today, this review article will examine recent developments, clinical uses, and potential future paths in this rapidly evolving subject. With the goal of providing dental professionals with the knowledge they need to advance their practice and provide better care for patients, we will synthesize the body of research and highlight significant advancements.[1][2][3]

Metallic biomaterials

Metallic biomaterials play a vital role in prosthodontics, particularly in dental implants. The most commonly used metals for implants are:

Titanium(Ti) and Ti Alloys

The most popular materials for dental implants are titanium and its alloys, including Ti-6Al-4V, because of its superior mechanical qualities, resistance to corrosion, and high biocompatibility.[4][6][7]Due to its non-ferromagnetic nature, low density, and high strength-to-weight ratio, titanium is a good material to employ in magnetic resonance imaging (MRI) operations.[6]

Cobalt-chromium(CoCr) Alloys

Because of its great strength and wear resistance, cobalt-chromium alloys are used for implant frameworks, crowns, and bridges[1][4]. On the other hand, their osseointegration is poorer than that of titanium alloys.[6]

Stainless steel(SS)

Implants made of stainless steel, such 316L, are simple to make and reasonably priced.[5]But their elastic modulus is larger than that of human bone, which may cause bone resorption and stress shielding.[5][6]

Other Metals

Zirconium, palladium, tantalum, platinum, gold, and other metals are also utilized in dental implants.[4][7]Because these materials are more expensive or have lower strength than titanium and its alloys, they are often less prevalent.

The patient's oral health, the implant's placement, and the particular needs of the prosthetic device all play a role in the selection of the right metallic biomaterial for dental implants.[4][6].Since titanium and its alloys have demonstrated long-term success rates in clinical applications and great biocompatibility, they continue to be the material of choice.[6][7].

Bioactive Coating For Dental Implants

Research on bioactive coatings for dental implants is crucial since it aims to prolong the life of the implants, improve their integration with surrounding tissues, and lessen problems such peri-implantitis. These coatings, which include bioactive glasses, antimicrobial peptides, and biomimetic materials, can be divided into groups according to their makeup and use.

Types of bioactive coatings

1. ***Bioactive glass coatings***

It is well known that bioactive glasses can form a link with bone and encourage osteogenesis. They improve integration with host tissues by promoting the development of an apatite layer on the implant surface. Metallic implants are made more biocompatible and corrosion-resistant by applying bioactive glass using a variety of coating techniques, including thermal spraying and sol-gel procedures. [11][12]

2. ***Antimicrobial peptide coatings***

Natural antimicrobial peptides (AMPs) are used in these coatings to prevent the growth of biofilms and bacterial adherence on implant surfaces. Implant failure can be avoided by immobilizing AMPs on titanium implants, which has demonstrated potential in reducing peri-implantitis, a frequent inflammatory illness. Studies reveal that these peptides are capable of efficiently battling both Gram-positive and Gram-negative bacteria, consequently improving the durability and efficacy of dental implants.[8][9]

3. Biomimetic coatings

Biomolecules that resemble the extracellular matrix found in nature are used in biomimetic coatings to aid with osseointegration and tissue regeneration. Growth factors, extracellular matrix components, and hydroxyapatite layers are a few examples of these coatings that are intended to improve the surrounding tissues' biological response.[10][9]

Benefits of bioactive coatings

- Enhanced Osseointegration: Bioactive coatings boost the integration process by strengthening the link between the implant and the bone.
- Antibacterial Properties: Antimicrobial coatings assist lower the risk of infection and inflammation, two major factors contributing to implant failure.
- Controlled Release of Bioactive compounds: Certain coatings have a built-in mechanism that releases therapeutic compounds gradually to aid in integration and healing.[10]
- Customization: Based on the unique requirements of each patient, customized coatings can be created to increase the implant's overall efficacy.[10]

Hybrid biomaterial composite in prosthodontics:

Prosthodontics is using hybrid biomaterial composites more frequently because of their superior mechanical qualities and biomechanical compatibility. One such composite is the hybrid material made of polyetherketoneketone (PEKK) and hydroxyapatite (HA), which is intended for use in orthopedic applications such as dental implants. This composite shows good homogeneity of HA dispersion in the PEKK matrix without phase separation, and it boasts a high HA loading of 50 wt%, which is comparable to that of normal human bone[13]. This composite has stronger mechanical characteristics than natural bone, with a yield strength greater than that of human bone and good ductility[13]. This hybrid material may be used as the foundation for many oral implantology applications in dentistry[13]. Additional biomaterials utilized in prosthodontics include acrylic polymers with improved mechanical properties, zirconium-reinforced lithium silicate, yttria-stabilized zirconia (YTZP), and titanium (Ti) and Ti alloys[14]. Furthermore, the potential of biopolymer hybrid particles in dentistry is being investigated, especially with regard to applications like medication delivery systems, bone healing, and periodontal regeneration surgery[15].

Photopolymeraizable biomaterial in prosthodontics:

Applications for dental tissue engineering and prosthodontics are using photopolymerizable biomaterials more frequently[16][17][18].the capacity to create scaffolds in place via a minimally invasive technique, such injection.qualities of hydrogel that can resemble the physical traits of soft tissues.high biocompatibility and permeability, which qualify them for cell encapsulation[16] Synthetic polymers like polyethylene glycol (PEG) and natural polymers like collagen and hyaluronic acid are examples of photopolymerizable biomaterials that are frequently employed in prosthodontics[16]. To regulate the features of degradation, these can be altered by adding particular functional groups[17].Injectable scaffolds for dental tissue engineering, as well as the delivery of cells, growth factors, medications, and other compounds, have all been accomplished through the use of photopolymerizable biomaterials[17][18].They can be created into intricate structures using 3D printing and offer a favorable three-dimensional environment for tissue regeneration[16][18].

Bacterial resistence biomaterials:

In order to actively prevent microbial development, smart biomaterials can detect and react to environmental cues such as pH, enzymes, light, magnetism, and vibrations[19].In orthopaedic and dental biomaterials, nanoparticles have demonstrated potential in surmounting bacterial resistance. According to studies, adding nanoparticles to orthopedic and dental implants can strengthen their antibacterial capabilities and lower the chance of infections linked to the implants[20].[21] In particular, compared to metal and polymer surfaces, ceramic biomaterials such as zirconia-toughened alumina (BIOLOX® delta) and alumina (BIOLOX® forte) have shown noticeably less bacterial adherence and biofilm formation. These ceramic materials' smoother surfaces and enhanced wettability make it more difficult for bacteria to stick to them and form biofilms. [21] Furthermore, localized antimicrobial administration can be achieved with nanoparticle coatings on orthopedic and dental implants without running the risk of systemic antibiotic exposure and resistance.Silver, copper, zinc oxide, and other material-based nanoparticles have demonstrated potent antibacterial action against common implant-associated organisms such as Escherichia coli and Staphylococcus [20].

Biomaterial for tissue engineering and prosthodontics:

The most often used biomaterials for creating scaffolds in tooth regeneration are polymers. Good porosity, surface area, mechanical strength, and other qualities necessary for tissue regeneration can be achieved by customizing these [22]. Hyaluronate, chitosan, collagen, fibrin, alginate, and silk are examples of common natural biomaterials. Polyethylene glycol, poly-e-caprolactone, polyglycolic acid, and bioceramics such as hydroxyapatite, tricalcium phosphate, and bioactive glasses are examples of synthetic biomaterials.Advanced tissue engineering for dental applications also makes use of bioactive materials such as mineral trioxide aggregate and biodentine[23].3D printing is a new technology that makes it possible to create intricate tissue constructs for prosthodontic applications, medical devices, and scaffolds customized for individual patients.In order to facilitate interactions between cells and scaffolds, mimic the natural extracellular environment, and promote effective tissue regeneration, biomaterials must be carefully chosen and engineered [22][23][24].

Theranostic biomaterials:

Theranostic biomaterials are intended to be used for both diagnostic and therapeutic purposes. The noninvasive monitoring of therapy efficacy and illness development is made possible by this integration for practitioners. In tissue engineering, where customized solutions are critical, the development of these materials is essential to meeting the difficulties of precision medicine.[25][27]

Modular Design: Theranostic biomaterials can be tailored to a patient's individual requirements through modular design. This adaptability makes it possible to combine different medicinal agents with diagnostic methods, improving the biomaterials' overall functionality.[25][26]

Applications in Prosthodontics: Prosthetic device and dental implant integration can be improved in prosthodontics by using theranostic biomaterials. By incorporating diagnostic features, these materials can provide input on the healing process and the integration of implants with surrounding tissues. Both patient care and the management of problems may benefit from this. [25][26]

The application of nanoparticles in bone restoration has recently enabled customized drug administration and allowed for the imaging and monitoring of the healing process[26].The future of theranostic biomaterials is bright, however there are still many challenges to be addressed:

- ***Clinical Translation*:** In order to evaluate the safety and efficacy of these materials in clinical settings, additional study is required as many of them are still in the research stage. Studies with a longer time span are necessary to assess their performance over time. [25][27]
- ***Complexity of Design*:** Including several functions into a single biomaterial may make the design and production processes more difficult. For an implementation to be successful, functionality and simplicity must be balanced. [26][27]
- ***Regulatory Obstacles*:** Due to theranostic systems' novelty, regulatory approval may be difficult to obtain, requiring extensive testing to guarantee efficacy and safety before to clinical usage.[26][27]

Comparative studies of biomaterials in prosthodontics

The effectiveness of many biomaterials used in prosthodontics has been compared in a number of studies: Biomaterials: Alloplastic vs Xenogeneic In major bone defects in rats, a study examined the efficacy of a new alloplastic biomaterial called Blue-Bone®, a xenogeneic biomaterial called Bio-Oss®, and a combination of both biomaterials with autogenous bone[29]. The outcomes revealed:

- To achieve greater results, Bio-Oss® needed to be combined with autogenous bone.
- Blue-Bone® did not require mixing with autogenous bone in order to generate a more cellular and vascularized bone matrix.

Ceramic and Titanium Implants

For dental implants, titanium (Ti) and yttria-stabilized zirconia (YTZP) are two popular biomaterials. The use of reinforcements like glass fibers and nanoparticles to improve their mechanical properties has been the subject of recent study.[29]

Denture base materials

PMMA, or polymethyl methacrylate, is a common material for denture bases. Fillers, hybrid systems, or their combination as reinforcement can improve its mechanical qualities. [28] But the majority of research is still conducted in vitro, and additional in vivo investigations are required. Although these studies shed light on how different biomaterials function in comparison, additional investigation is required to evaluate the clinical efficacy and financial viability of these materials in prosthodontic therapies. In comparison clinical trials, variables such as long-term results, patient satisfaction, and financial concerns should be assessed.[28][29].

Conclusion

To sum up, biomaterials have revolutionized prosthodontics by greatly enhancing both the functional and cosmetic results. Improved biocompatibility, durability, and natural tissue mimicking are provided by advanced materials such as titanium alloys, bioactive coatings, hybrid composites, and photopolymerizable materials. Tissue engineering and bacterial-resistant biomaterials are two advances that help with infection management and regenerative medicine. Empirical research informs practical clinical judgments. Ongoing research guarantees that these developments result in better, patient-specific care. Dental professionals can enhance treatments and improve patient happiness and oral health by keeping up with these advances.

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