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Review Article

Biomaterials in prosthodontics: current trends and future directions

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ABSTRACT

Modern prosthodontic treatment is heavily dependent on biomaterials since their properties directly influence the function, esthetics, longevity, and biocompatibility of the dental prostheses. Development in material sciences led to production of high-performance ceramics, advanced polymers, titanium alloyed materials, bioactive biomaterials, and nanomaterials, all contributing to positive clinical results in prosthodontics. This review aims at giving an overview of the currently used biomaterials in prosthodontics and emerging technologies which may shape the future of prosthodontic practice. The literature search was carried out in PubMed, Scopus, Google Scholar, and ScienceDirect. All articles published between January 2015 and May 2026 in the mentioned databases were considered for the review. Foundational publications in the field were selected depending on the need for understanding the concept. Peer-reviewed original research, systematic, and narrative reviews, as well as clinical studies about prosthodontic biomaterials, were chosen for consideration. Recent progress in CAD/CAM, additive manufacturing, 3D printing, nanotechnology, and development of bioactive biomaterials expanded the boundaries of prosthodontic rehabilitation. Biomaterials with mechanical, biological, and esthetic advantages include, but are not limited to, zirconia, polyether ether ketone (PEEK), titanium and titanium alloys, bioactive glass, and calcium phosphate-based biomaterials.

Keywords: Prosthodontics, Biomaterials, Dental implants, CAD/CAM, Nanotechnology, Bioactive materials

INTRODUCTION

Biomaterials are naturally occurring or artificially engineered materials meant for use in interaction with living tissues and organisms. They are widely used in prosthodontics in complete dentures, removable partial dentures, fixed dental prosthesis, implant supported restorations, and maxillofacial prostheses. The continuous exposure of the oral cavity to saliva, temperature changes, masticatory forces, microbial action, and chemicals makes it necessary for the prosthodontic biomaterials to have suitable mechanical, chemical, biological, and aesthetic characteristics to ensure successful use.[1]

The developments in prosthodontic biomaterials have had a tremendous impact on modern dentistry. Old materials such as gold alloys and porcelain laid the groundwork for restorative dentistry. On the other hand, developments in metallurgy, polymer science, and ceramics have resulted in materials such as acrylic resin, cobalt-chromium alloys, high strength ceramics, and titanium based materials for implants. Modern materials for restoration such as zirconia and lithium disilicate ceramics have much better aesthetics and performance compared to old generation dental materials.[2,3]

The advent of digital technologies has revolutionized modern prosthodontic practice. Technologies such as computer-aided design and computer-aided manufacturing (CAD/CAM) technology allow precise restoration manufacturing with better efficiency and consistency. At the same time, additive manufacturing and 3D printing technologies have enabled the manufacture of customized prostheses of complex geometry that cannot be easily manufactured using traditional manufacturing techniques.[4-6]

Nanotechnology has emerged as a promising field of study for dental biomaterials. Introducing nanoscale fillers and surface treatments will change the mechanical, optical, surface, and antimicrobial properties of materials; however, the clinical significance of many of these laboratory results should be further verified. Stimuli responsive smart biomaterials reacting to changes in pH, temperature, moisture, or mechanical loads are also considered as promising candidates for new-generation materials.[7,8]

Despite remarkable advances made in the area, there still remain issues relating to the degradation of materials, their colonization by microbes, biocompatibility, aesthetic limitations, and availability from an economic point of view. More studies are needed in order to design biomaterials which are resistant, biologically active, affordable, and suitable for patients.

This review aims at presenting an overview of the biomaterials used in prosthodontics currently, summarizing recent developments and applications, discussing the existing limitations, and suggesting possible future developments that can impact the future generations of prosthodontics.

METHODS

This review intends to analyze the present situation, application in clinics, and future possibilities of biomaterials used in prosthodontics. Literature search was performed using online databases such as PubMed, Scopus, Google Scholar, and ScienceDirect, focusing on articles dated between January 2015 and May 2026. Older landmark papers were included as required for providing the background for established biomaterials and concepts.

Keyword and MeSH term combination such as: "prosthodontic biomaterials," "dental materials," "zirconia," "lithium disilicate," "polyether ether ketone (PEEK)," "implant biomaterials," "CAD/CAM dentistry," "3D printing," "additive manufacturing," "bioactive materials," "nanotechnology in dentistry," "tissue engineering," and "regenerative prosthodontics" were used as the search strategy.

Inclusion criteria involved peer-reviewed original papers, systematic reviews, narrative reviews, clinical trials, and relevant in vitro studies that have been published in English. Papers that do not apply to prosthodontics, conference papers, editorials, duplications, and non-English articles were excluded from this review.

The selected literature was screened based on title and abstract relevance, while full-text screening was applied where necessary. Selected papers were grouped into various thematic groups such as: removable prosthodontic biomaterials, implant biomaterials, nanotechnology-based biomaterials, bioactive materials, digital manufacturing biomaterials, and novel prosthodontic regenerative biomaterials.

BIOMATERIALS IN REMOVABLE PROSTHODONTICS

Polymethyl methacrylate

Polymethyl methacrylate (PMMA) is still widely used as a denture base material for the fabrication of removable prosthesis since its first use in the 1930s. The reasons for its popularity are esthetic properties, convenient processibility, low price, light weight and adequate biocompatibility.[1]

Processing of PMMA may include heat-polymerization, self-polymerization, microwave-polymerization, and injection molding. Among all of them, heat-cured PMMA usually has better mechanical properties and lesser residual monomer amount in comparison with self-cured materials, which gives an opportunity to increase its clinical effectiveness.[1]

However, there are some disadvantages of PMMA which should be considered. It has low impact strength and poor resistance to fractures, which makes dentures fragile and prone to breakage when biting or moving. Also, the residual monomer in some cases may cause mucosal irritation or hypersensitivity reaction.[1]

Water sorption and rough surface favor bacterial colonization and the formation of biofilms that includes *Candida albicans* and may lead to the appearance of denture stomatitis. To improve the mechanical properties and anti-microbial effects, reinforced acrylic resin and nanoparticle containing denture base materials were developed.[1,7] Thus, the advantages of low price and convenient processing explain the relevance of PMMA despite the development of new denture base materials.

Reinforced acrylic resins

To overcome the limitations of conventional PMMA, various reinforcement strategies have been developed.

Fiber-reinforced composites

As a solution to the inherent shortcomings of PMMA, there are various methods used to reinforce this dental prosthesis material in order to improve its physical properties and increase its clinical performance. In this regard, fiber-reinforced composite resins have gained much popularity because of their ability to provide increased flexural strength, impact resistance, and fatigue resistance while having minimal impact on the total weight of the prosthesis.[1]

Various types of fibers have been used in acrylic resins, such as glass fibers, polyethylene fibers, aramid fibers, and carbon fibers. Glass fiber reinforcement is the most commonly used one due to good aesthetics, biocompatibility, and strong adherence to the resin. The studies conducted show that glass fiber-reinforced acrylic resins have increased fracture resistance compared to the conventional PMMA dentures.[1] As far as the clinical aspect is concerned, reinforcement may be considered useful if the benefits from increased fracture resistance are sufficient to justify the extra effort required.

Nanoparticle reinforcement

Nanotechnology has made the inclusion of nanoparticles in denture base resins possible for the purpose of improving their mechanical, physical, and biological characteristics. The small size of nanoparticles, with a high surface area to volume ratio, allows them to interact effectively with the matrix and thereby improves their performance.[7]

Several types of nanoparticles such as zirconia, titanium dioxide, silica, hydroxyapatite, and silver nanoparticles have been included in PMMA denture base resins. It has been seen that zirconia nanoparticles improve the flexural strength, fracture toughness, and wear resistance, while titanium dioxide nanoparticles improve the surface hardness and antimicrobial property of the resins.[7] Though these results are very promising, the advantages found in the lab do not necessarily make clinical sense.

Denture framework materials

Cobalt-chromium alloys

Cobalt-chromium (Co-Cr) alloys are considered a gold standard for the material of choice in making removable partial denture frameworks because of their outstanding mechanical characteristics and resistant to corrosion along with good clinical performance. One of the main characteristics of cobalt-chromium alloys is the high modulus of elasticity that helps to create thin frameworks that at the same time are strong enough in comparison with many other alloys.[1] This feature not only increases comfort but maintains good rigidity of the frameworks during function. However, there are certain disadvantages in manufacturing cobalt-chromium frameworks, which is a highly technique-sensitive procedure, as well as difficulties with casting and adjustment or repair processes. Besides, the metallic coloration can be aesthetically unacceptable for some patients because of visible clasps during talking or smiling.[1]

The recent development of new methods such as CAD/CAM milling and additive manufacturing in dentistry made it possible to manufacture Co-Cr frameworks with increased precision and consistency. As a result, there is a possibility to decrease manufacturing errors and improve the quality and fit of the dentures.[4] Thus, Co-Cr is a reference material for removable partial denture frameworks while digital manufacturing improves its manufacturing process.

Titanium and titanium alloys

Titanium and its alloys are increasingly used as biomaterials in removable prosthodontics because of their excellent biocompatibility, corrosion resistance, and favorable mechanical properties. Compared with conventional cobalt–chromium alloys, titanium is considerably lighter, allowing the fabrication of frameworks that are easier and more comfortable for patients to wear while still providing adequate strength and rigidity.[10,11] A major advantage of titanium is the formation of a stable oxide layer on its surface. This passive layer protects the metal from corrosion and contributes to its good biological compatibility, making titanium useful in both removable prosthodontics and implant dentistry.[11] Its high strength-to-weight ratio and low density also allow lightweight frameworks to be produced, which may be particularly beneficial for patients who require comfortable prostheses for prolonged periods.[10,11] However, the conventional casting of titanium presents certain technical challenges. Its high melting temperature and strong affinity for oxygen at elevated temperatures make the casting process more demanding and require careful control of the manufacturing environment. These factors can increase both the complexity and cost of fabrication.[11] The development of CAD/CAM technology and additive manufacturing has helped overcome some of these limitations. Digital techniques allow more precise and predictable fabrication of titanium frameworks while reducing several of the difficulties associated with conventional casting. As a result, the clinical use of titanium in removable prosthodontics has continued to expand, and further advances in digital and additive manufacturing may make titanium frameworks even more accessible and practical in the future.[4,11]

Flexible denture materials

Flexible denture materials have become increasingly popular as esthetic and comfortable alternatives to conventional removable partial dentures. Most of these prostheses are made from thermoplastic polyamide (nylon)-based resins, which offer greater flexibility and resistance to fracture than conventional acrylic resin materials.[1] A major advantage of flexible dentures is their ability to engage soft-tissue undercuts with minimal or no tooth preparation. Their flexibility allows them to adapt closely to the oral tissues, which can improve comfort during function. The absence of visible metal clasps also provides a more natural appearance, making these prostheses particularly appealing to patients with high esthetic expectations.[1] Flexible denture materials also have good resistance to fracture and are less likely to break when accidentally dropped. Their lightweight nature, combined with the absence of metal components, can further improve patient comfort and acceptance.[1] However, flexible dentures are not without limitations. Procedures such as relining, rebasing, and repair can be more difficult than with conventional acrylic dentures. In addition, concerns regarding long-term color stability, surface polishability, dimensional stability, and the provision of adequate support and indirect retention should be considered during treatment planning.[1]

Therefore, although flexible denture materials offer clear esthetic and comfort advantages, their benefits should be weighed against their limited adjustability and the challenges associated with achieving predictable support and retention in certain clinical situations.

Polyether ether ketone in removable prosthodontics

Polyether ether ketone (PEEK) is a high-performance thermoplastic polymer that has attracted considerable interest as a biomaterial in modern prosthodontics. Its favorable mechanical properties, chemical stability, low density, and excellent biocompatibility have made it a potential alternative to conventional metallic framework materials.[10,12]

One of the important advantages of PEEK is its elastic modulus, which is closer to that of cortical bone than that of traditional metallic alloys. This property may allow a more favorable distribution of stresses and reduce stress concentration on the supporting oral tissues, potentially improving patient comfort and overall biomechanical performance.[10,12]

PEEK frameworks are lightweight, metal-free, and resistant to corrosion, making them particularly useful for patients with metal hypersensitivity or those who prefer metal-free prosthetic solutions. The material also demonstrates favorable biocompatibility and may be associated with reduced plaque accumulation, contributing to good tissue response and patient acceptance.[10,12]

PEEK has been investigated for use in removable and fixed prostheses, as well as implant components, because of its favorable strength-to-weight ratio, chemical stability, and potential to provide a more bone-like elastic response than conventional metallic frameworks. CAD/CAM processing can further improve the consistency and accuracy of fabrication, although long-term clinical evidence for its use in removable prosthodontics is still more limited than that available for established metal frameworks.[10]

Despite these advantages, PEEK has some limitations. Its grayish-white appearance may require veneering in highly esthetic areas, while achieving a reliable bond between PEEK and veneering materials remains a clinical challenge. In addition, long-term clinical evidence is still limited compared with conventional framework materials such as cobalt-chromium alloys.[13]

Therefore, PEEK may currently be considered a promising alternative for selected patients rather than a universal replacement for conventional Co-Cr frameworks, until stronger long-term clinical evidence becomes available.

Soft liners and resilient materials

Soft liners are resilient materials used to improve the adaptation of dentures to the supporting oral tissues by providing a cushioning layer between the denture base and the mucosa. They can be particularly useful for patients with severely resorbed ridges, thin or sensitive mucosa, chronic denture-related soreness, or implant-supported overdentures.[1]

Soft liners are broadly classified into acrylic-based and silicone-based materials. Acrylic-based soft liners generally provide good adhesion to denture base resins and are relatively easy to process. However, their resiliency may gradually decrease during clinical use because of the leaching of plasticizers.[1]

Silicone-based soft liners generally offer better long-term elasticity, chemical stability, and resistance to hardening. They are therefore often preferred for long-term applications because they can maintain their cushioning effect for longer periods. However, silicone liners may have weaker adhesion to denture bases and can be more susceptible to microbial colonization and discoloration over time.[1]

Despite their clinical benefits, soft liners have certain limitations, including surface deterioration, color changes, microbial biofilm accumulation, and the need for periodic replacement. Current research is therefore focused on incorporating antimicrobial agents and nanotechnology-based modifications to improve their durability, hygiene, and long-term clinical performance.[7]

Maxillofacial prosthetic materials

Maxillofacial prostheses are used to restore defects caused by trauma, congenital anomalies, or surgical treatment of malignancies. Silicone elastomers are commonly used for these prostheses because of their flexibility, biocompatibility, and ability to provide a natural-looking appearance.[1]

An ideal maxillofacial prosthetic material should have good color stability, tear resistance, flexibility, and biocompatibility, while also being able to withstand environmental changes and degradation during clinical use.[1]

Despite advances in material science, maintaining long-term color stability and elasticity remains a major challenge in maxillofacial prosthetics.[1]

Future trends in removable prosthodontic biomaterials

The future of removable prosthodontics is increasingly moving toward digital workflows, personalized treatment, and the development of more advanced biomaterials. Additive manufacturing techniques now allow the production of denture bases and frameworks with greater accuracy, reduced material waste, and improved manufacturing efficiency.[4,6,14]

Researchers are also exploring smart biomaterials that can release antimicrobial agents, respond to changes in their surrounding environment, and potentially support tissue regeneration. The combination of nanotechnology, bioactive materials, and tissue engineering may further improve the longevity, biological performance, and comfort of removable prostheses.[5,7,8,15]

Artificial intelligence is increasingly being explored for applications such as image analysis, treatment planning, digital prosthesis design, material selection, and prediction of clinical outcomes. Although its potential in biomaterial development and prosthodontic treatment is promising, its clinical application still depends on the quality of available data, proper validation, explainability, and appropriate clinical oversight.[4,11] Overall, the future is likely to involve a combination of digital and conventional workflows, with clinical adoption guided by scientific evidence, material reliability, and the individual needs of each patient.

IMPLANT BIOMATERIALS

Titanium and titanium alloys

Titanium is widely regarded as the gold standard material for dental implants because of its excellent biocompatibility and favorable mechanical properties. Commercially pure titanium and titanium alloys, particularly Ti-6Al-4V, are extensively used in implant fabrication because of their reliable clinical performance.[3,11,16] The excellent performance of titanium is largely attributed to the spontaneous formation of a stable titanium oxide layer on its surface. This protective oxide film provides high resistance to corrosion and supports favorable interactions between the implant surface and surrounding biological tissues.[11,16]

Advantages of titanium implants

Titanium offers excellent biocompatibility, high corrosion resistance, good mechanical strength, and predictable osseointegration. It has also demonstrated reliable long-term clinical performance.[3,11,16] Titanium implants have shown high long-term survival rates, making them one of the most predictable treatment options in implant dentistry.[3,16,17] However, some limitations should be considered. The grayish metallic color of titanium may affect esthetics in patients with thin gingival biotypes, particularly in the anterior region. Although uncommon, hypersensitivity reactions to titanium have also been reported.[3,11]

Zirconia implants

Zirconia implants have emerged as a promising alternative to titanium, particularly with the growing interest in metal-free dentistry. Their tooth-colored appearance and favorable optical properties can provide improved esthetic outcomes, especially in the anterior region.[3,9,18] Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is the most commonly used zirconia material for dental implants because of its high fracture toughness, flexural strength, and excellent biocompatibility.[3,9]

Advantages of zirconia implants

The tooth-colored appearance, excellent biocompatibility, and relatively low plaque accumulation associated with zirconia make it an attractive option for selected patients. It also provides a metal-free alternative for implant-supported restorations.[3,9,18] Current systematic reviews suggest that zirconia implants can provide favorable clinical outcomes and short-term survival rates comparable to titanium in selected situations. However, the available evidence is still more limited, with shorter follow-up periods compared with titanium implants. Mechanical complications and long-term clinical performance therefore remain important areas for further investigation.[9] Overall, current evidence supports titanium as the more established implant material, while zirconia can be considered a useful alternative in appropriately selected cases, particularly when esthetic concerns are a priority.

Surface modifications for enhanced osseointegration

The characteristics of an implant surface play an important role in determining the rate and quality of osseointegration. Surface modifications are therefore used to improve cell adhesion, proliferation, and new bone formation around the implant surface.[12,16,19]

Mechanical surface treatments

Mechanical surface treatments increase surface roughness and surface area, which can improve bone-to-implant contact and contribute to primary implant stability. Common techniques include sandblasting, grit blasting, machining, and laser texturing.[12,19] Roughened implant surfaces have generally shown improved osseointegration and faster bone healing compared with smooth implant surfaces.[16,19]

Chemical surface treatments

Chemical surface modifications alter the surface chemistry of implants to promote biological interactions and improve osteoblast attachment. Common techniques include acid etching, alkali treatment, and anodization.[11,19] Acid-etched implant surfaces can increase surface energy, which may enhance cell adhesion and support early healing responses.[11,19]

Bioactive coatings

Bioactive coatings represent an important development in implant biomaterials because they are designed to interact actively with the surrounding tissues, promoting bone formation and improving implant integration.[15,16]

Hydroxyapatite coatings

Hydroxyapatite closely resembles the mineral component of natural bone and can promote direct bonding with osseous tissue. Hydroxyapatite-coated implants have been associated with faster osseointegration and increased bone-to-implant contact. However, coating delamination and long-term stability remain potential concerns.[15,16]

Calcium phosphate coatings

Calcium phosphate coatings have good osteoconductive properties and can support new bone formation around implant surfaces. Their biodegradability also allows the coating to be gradually replaced by natural bone during the healing process.[15,16]

Bioactive glass

Bioactive glass has the unique ability to form a biologically active apatite layer when exposed to physiological fluids. This property can enhance tissue integration and support regenerative processes at the implant–tissue interface.[1,15]

Nanotechnology in implant biomaterials

Nanotechnology has introduced new possibilities in implant surface engineering by allowing surface modifications at the nanoscale that more closely resemble the architecture of natural bone. These modifications can influence cellular behavior and promote improved osseointegration.[7,11,19] Nanostructured implant surfaces have been shown to improve protein adsorption, osteoblast adhesion, cellular proliferation, and bone mineralization, thereby enhancing the biological performance of dental implants.[7,19]

The incorporation of nanoparticles such as titanium dioxide, silver, and zinc oxide may also provide antimicrobial effects by reducing bacterial colonization and potentially lowering the risk of peri-implant diseases.[7,8,11]

Although these findings are promising, further long-term clinical studies are needed to establish the safety, durability, and clinical effectiveness of nanotechnology-based implant surfaces.[7,11,19] The clinical value of these nanoscale modifications will ultimately depend on whether the biological improvements observed in experimental studies translate into sustained reductions in complications and better patient outcomes.

Antimicrobial implant surfaces

Peri-implantitis remains one of the important complications associated with dental implants. The formation of microbial biofilms can trigger inflammation, progressive bone loss, and, in advanced cases, implant failure.[11,17]

To address this problem, researchers have explored antimicrobial implant surfaces incorporating silver nanoparticles, antibiotic or antimicrobial coatings, antimicrobial peptides, and photodynamic approaches.[7,8,11]

These approaches are primarily aimed at reducing bacterial adhesion and colonization while maintaining compatibility with surrounding tissues and supporting successful osseointegration.[8,11]

Biomaterials for soft tissue integration

The long-term success of implant therapy depends not only on successful osseointegration but also on the formation of a healthy peri-implant soft tissue seal. A stable soft tissue barrier helps protect the underlying bone and implant surface from microbial invasion and plays an important role in maintaining implant health and longevity.[3,11,16]

Materials such as zirconia and surface-modified titanium have demonstrated favorable interactions with gingival fibroblasts and epithelial cells, which may promote better soft tissue attachment and biological integration around implants.[3,11]

Emerging surface modification techniques are being developed to improve soft tissue integration by altering implant surface topography and chemistry at the microscopic and nanoscopic levels. These approaches may help improve peri-implant tissue stability and contribute to better long-term clinical outcomes.[8,11,19]

Future perspectives in implant biomaterials

Current research is exploring a range of advanced approaches, including self-healing surfaces, drug-delivery coatings, growth-factor-releasing biomaterials, stem-cell-based regenerative strategies, and smart implants with biosensing capabilities.[4,5,8,10]

These next-generation biomaterials aim to do more than simply replace missing structures; they are being developed to actively support tissue regeneration, control infection, and potentially prevent disease. Although these approaches are promising, their transition from experimental concepts to routine clinical application will require reliable manufacturing processes, long-term safety data, and strong clinical evidence demonstrating meaningful improvements in patient outcomes.

Challenges and limitations

Despite the considerable advances in prosthodontic biomaterials, several limitations still influence their clinical performance and long-term use. No single biomaterial can therefore be considered universally superior. Material selection should instead be based on the specific prosthetic indication, biological environment, functional demands, maintenance requirements, patient expectations, and the available clinical evidence.

Material degradation

Mechanical fatigue, wear, corrosion, and hydrolytic degradation can gradually affect the performance and longevity of prosthodontic restorations. The oral cavity is a particularly challenging environment, with materials being continuously exposed to changes in temperature, repeated masticatory forces, chemical substances, and microbial activity. Over time, the combined effect of these factors can alter material properties and ultimately contribute to clinical failure.[1,15]

Biofilm formation

Microbial biofilm formation remains an important concern with both removable prostheses and dental implants. Accumulation of biofilm can contribute to conditions such as denture stomatitis, peri-implant mucositis, and peri-implantitis, potentially compromising the biological health of the surrounding tissues and the long-term success of prosthodontic treatment.[7,11,17]

Biocompatibility concerns

Although most contemporary prosthodontic biomaterials have good biocompatibility, adverse tissue responses and hypersensitivity reactions can still occur in susceptible individuals. This highlights the importance of thorough biological evaluation and adequate long-term clinical assessment, particularly when introducing newer materials into routine practice.[3,11,16]

Esthetic limitations

Despite major improvements in restorative materials, achieving a truly natural appearance remains challenging, particularly with some high-strength materials. Materials that provide excellent mechanical performance may not always reproduce the translucency, color, and light transmission characteristics of natural teeth. Finding the right balance between strength and esthetics therefore remains an important consideration in prosthodontic treatment.[3,18]

Economic considerations

The use of advanced biomaterials and digital manufacturing technologies, including CAD/CAM systems and additive manufacturing, can increase treatment and laboratory costs.

This may limit their accessibility in resource-constrained clinical settings and highlights the importance of considering cost-effectiveness alongside material performance when selecting newer technologies.[4,6,17]

FUTURE DIRECTIONS

Tissue engineering

Tissue engineering combines scaffolds, stem cells, and growth factors with the aim of regenerating damaged oral tissues. In the future, prosthodontic treatment may increasingly incorporate biological regeneration rather than relying entirely on artificial replacement. Such an approach could potentially provide more natural and long-lasting functional and esthetic outcomes.[4,8,10]

3D bioprinting

Three-dimensional bioprinting is an emerging technology that aims to fabricate living tissues and complex biological structures using bioactive materials and cells. Its potential application in craniofacial reconstruction and regenerative prosthodontics is particularly promising, as it may eventually allow the development of patient-specific biological substitutes that more closely match individual anatomical requirements.[4,20]

Artificial intelligence in biomaterial design

Artificial intelligence and machine learning can process large datasets to assist in biomaterial selection, prediction of clinical performance, prosthesis design, and treatment planning. AI-assisted approaches may accelerate biomaterial development and improve the predictability of prosthodontic rehabilitation.

However, their clinical value will ultimately depend on the quality of the data used, appropriate validation, and meaningful integration with clinical decision-making.[20,21]

Self-healing materials

Self-healing biomaterials are designed to repair microcracks or early structural damage, with the potential to improve the durability of prosthetic restorations and reduce the progression of material failure. Although these materials are still largely at the experimental stage, their ability to respond to damage rather than simply resist it represents an interesting direction for future prosthodontic applications.[5,8,22]

Personalized prosthodontics

Advances in digital dentistry, genomic medicine, artificial intelligence, and additive manufacturing may facilitate the development of patient-specific prostheses that are better adapted to individual anatomical and biological characteristics. The convergence of biomaterials science, regenerative medicine, and digital technologies is likely to further reshape prosthodontic rehabilitation.[4,5,8,20]

The major challenge, however, is not simply demonstrating that these technologies are technically possible, but ensuring that they can be translated into safe, reproducible, clinically useful, and accessible treatment options.

CONCLUSION

Biomaterials form the foundation of contemporary prosthodontic practice. Advances in polymers, ceramics, metals, composites, additive manufacturing, and bioactive systems have considerably broadened the range of materials available for removable, fixed, implant-supported, and maxillofacial rehabilitation. The integration of CAD/CAM technology, additive manufacturing, nanotechnology, and bioactive approaches has further expanded the possibilities of prosthodontic treatment. Modern biomaterials are increasingly designed not only to restore function and esthetics but also to influence surface interactions, tissue integration, infection control, and regenerative processes.

As biomaterial science continues to develop, prosthodontics is gradually moving beyond a purely replacement-based approach toward more regenerative and personalized forms of patient care. Continued collaboration between clinicians, researchers, material scientists, and biomedical engineers will be essential to translate promising laboratory developments into predictable and clinically meaningful therapies. Ultimately, the most appropriate bio-material is not necessarily the newest or strongest option, but the one that provides the best evidence-supported balance of mechanical performance, biological compatibility, esthetics, longevity, maintenance, cost, and the individual needs of the patient.

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