Recent Advancements in Prosthodontics: A Review

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Abstract— **Background: The field of prosthodontics has undergone a substantial evolution, driven by advancements in digital workflows, biomaterials, implant technology, regenerative methods, and artificial intelligence.**
Objective: This review seeks to illuminate the latest developments in prosthodontics and assess their practical implications for clinical care.
Methods: A comprehensive narrative review was performed, searching PubMed, Scopus, and Web of Science databases for studies published between 2005 and 2025, with a focus on digital dentistry, dental implants, regenerative prosthodontics, artificial intelligence, and esthetic materials.
Results: The review identified five key areas of innovation: (1) Digital workflows (CAD/CAM, 3D printing) improved accuracy and reduced treatment times; (2) Implant-supported prosthodontics benefitted from enhanced osseointegration surfaces and guided surgery; (3) Regenerative prosthodontics explored stem cells, scaffolds, and bioprinting; (4) Artificial intelligence applications facilitated personalized treatment planning and predictive analysis; and (5) Advances in esthetic materials (zirconia, hybrid ceramics) improved functionality and appearance.
Conclusion: Prosthodontics is transitioning from conventional, mechanically driven rehabilitation toward biologically integrated and digitally enhanced care. Future directions will emphasize AI-driven personalization, regenerative solutions, and patient-centered outcomes.

Index Terms—**Prosthodontics, Digital Dentistry, CAD/CAM, 3D Printing, Dental Implants, Regenerative Prosthodontics, Artificial Intelligence, Zirconia**I.

I INTRODUCTION

Prosthodontics, focused on restoring and replacing missing teeth, has evolved significantly in the 21st century. Traditionally reliant on manual techniques, the field has transformed with digital technologies, advanced biomaterials, and regenerative innovations. To meet growing demands for comfort, aesthetics, and efficiency, prosthodontics now incorporates computer-aided design, implant advancements, tissue engineering, AI, and cutting-edge materials. This review explores these developments and their impact on clinical practice.

II. DIGITAL DENTISTRY: CAD/CAM AND 3D PRINTING

The introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) has revolutionized prosthetic workflows. Digital impressions enhance accuracy, minimize errors, and improve patient comfort. CAD/CAM restorations demonstrate superior marginal adaptation compared with conventional techniques [1].
The CAD/CAM technology has transformed implant-supported prosthodontics by reducing technique-sensitive errors. Digital impressions provide precise three-dimensional models, eliminate distortions from traditional materials, and enhances patient comfort while allowing seamless data storage and transfer between clinicians and laboratories. Restorations fabricated through CAD/CAM exhibit superior marginal precision, which reduces biomechanical stress, screw loosening, and peri-implant complications. Moreover, this technology enables the predictable use of high-strength ceramics such as zirconia and lithium disilicate, combining esthetics with durability. By minimizing adjustments and shortening treatment time, CAD/CAM ultimately improves efficiency and patient satisfaction.
3D printing expands possibilities, enabling fabrication of complete dentures, temporary restorations, and surgical guides. The ability to provide same-day prostheses reduces treatment time and patient satisfaction [2].
The three-dimensional printing, or additive manufacturing, has introduced new dimensions to implant-supported prosthodontics. Unlike conventional methods, 3D printing builds structures

layer by layer, allows precise fabrication of a variety of restorations and adjuncts, including complete dentures, provisional crowns and bridges, custom impression trays, and surgical guides. One of its most significant advantages is the capability to produce prostheses immediately, which shortens treatment timelines and allows patients to regain function and esthetics almost immediately after implant placement. This does not only improve convenience and satisfaction but also increases clinical efficiency. However, additive manufacturing ensures reproducibility and design standardization, while the continuous development of printable biocompatible resins and ceramics has expanded its use in durable, esthetic, and cost-effective implant restorations. Collectively,3D printing enhances both the clinical workflow and the overall patient experience, positioning it as a pivotal advancement in modern prosthodontics

Implant-Supported Prosthodontics:
Implantology has become integral to prosthodontic rehabilitation
Nanostructured and bioactive implant surfaces enhance osseointegration [3]-
Advancements in implant engineering have introduced nanostructured and bioactive modifications that significantly accelerate osseointegration. By nanoscale topographies, these increase protein adsorption and enhance osteoblast attachment, leading to faster and stronger bone–implant integration. However, bioactive coatings such as hydroxyapatite, calcium phosphate, and bioactive glass stimulate bone cell activity and improve healing in sites with reduced bone quality. Together, these innovations shorten recovery time, improve implant stability, and enhance the long-term success of implant-supported prostheses

Computer-guided implant surgery, ensuring minimally invasive and accurate placement [4]-
Computer-guided implant surgery combines CBCT imaging and digital impressions to enable precise virtual planning and the fabrication of surgical guides. This approach ensures accurate implant placement, as a result reduced surgical trauma, faster healing, improved safety, and greater predictability in implant-supported outcomes.

Immediate loading protocols, supported by improved primary stability and regenerative techniques, allowing rapid functional rehabilitation [5]-
Immediate loading protocols enable rapid functional rehabilitation by placing prostheses soon after implant insertion. This shortens treatment time, restores esthetics quickly, and enhances patient satisfaction without compromising long-term outcomes.These contribute to long-term success rates above 95%.

III. REGENERATIVE PROSTHODONTICS AND TISSUE ENGINEERING

Beyond replacement, prosthodontics is moving toward biological restoration. Recent advances include:
Stem cell research for bone and periodontal regeneration [6]-Stem cell therapies offers innovative solutions for regenerating bone and periodontal tissues critical for prosthodontic rehabilitation. Mesenchymal stem cells (MSCs) promote osteogenesis, enhancing alveolar bone volume for dental implants and ridge preservation. Periodontal ligament stem cells (PDLSCs) regenerate cementum, periodontal ligament, and alveolar bone, improving abutment stability and long-term success of fixed and removable prostheses

Growth factor therapies to accelerate tissue repair-
Growth factor therapies, including BMPs, PDGF, VEGF, and TGF-β, offer a biologically driven approach to accelerate bone and soft tissue regeneration, which is critical for prosthodontic rehabilitation. These therapies enhance alveolar bone formation for ridge augmentation, sinus lifts, and implant site preparation, while also promoting soft tissue healing, periodontal ligament repair, and optimal mucosal contours. Clinically, growth factors improve tissue repair predictability, increase implant success rates in compromised patients, and enhance prosthesis fit, esthetics, and patient comfort. When combined with stem cell or scaffold-based regenerative approaches, growth factor therapies provide a synergistic, minimally invasive strategy to optimize prosthodontic outcomes.

Biomimetic scaffolds and 3D bioprinting for alveolar ridge augmentation and periodontal reconstruction [7].
Biomimetic scaffolds and 3D bioprinting offer precise, patient-specific solutions for alveolar ridge

augmentation and periodontal reconstruction, enhancing prosthodontic outcomes. These scaffolds mimic the extracellular matrix, supporting cell adhesion, proliferation, and differentiation, and can be combined with stem cells or growth factors to accelerate bone and soft tissue regeneration. Clinically, they enable customized grafts for complex defects, improve implant positioning, enhance abutment stability, and allow minimally invasive procedures with predictable healing. The integration of 3D bioprinting into prosthodontics promises more functional, esthetic, and long-term stable rehabilitation, even in medically compromised patients.

Although still largely experimental, regenerative prosthodontics has the potential to transform future treatment protocols.

IV. ARTIFICIAL INTELLIGENCE IN PROSTHODONTICS

AI integration has improved diagnostics, planning, and outcome prediction. Key applications include:

AI-driven prosthesis design using intraoral scans and CBCT [8]-

AI-driven prosthesis design using intraoral scans and CBCT enables precise, patient-specific prosthetic rehabilitation in prosthodontics. By analyzing anatomical structures, occlusion, and bone quality, AI can generate optimal designs for fixed restorations, implant abutments, and removable dentures, ensuring accurate fit, proper occlusion, and improved esthetics. This technology streamlines workflows by automating margin detection, occlusal analysis, and prosthesis contouring, reducing chairside adjustments and treatment time. Integration with CAD/CAM and 3D printing allows fully digital, personalized prostheses, enhancing predictability, function, and long-term prosthodontic outcomes.

Smile design software that simulates post-treatment esthetics to aid patient communication-

Smile design software enables prosthodontists to digitally simulate post-treatment esthetics using intraoral scans, facial photographs, and digital models. It assists in planning tooth shape, size, gingival contours, and smile symmetry, improving esthetic predictability and treatment outcomes. The software enhances patient communication and consent by allowing visual previews, increases satisfaction, and streamlines workflows through integration with CAD/CAM systems. Additionally, it supports interdisciplinary collaboration and guides provisional and final restorations, making complex prosthodontic treatment more precise and patient-centered.

Predictive analytics for implant success, occlusal forces, and prosthesis longevity [9]-

By analyzing patient-specific factors such as bone quality, occlusion, systemic health, and prosthetic design, clinicians can optimize implant placement, tailor prosthesis design, and anticipate long-term outcomes. This data-driven approach enhances treatment predictability, minimizes complications, informs maintenance schedules, and improves patient education and satisfaction, enabling more personalized and durable prosthodontic rehabilitation.

AI holds promise in standardizing care, reducing subjectivity, and enabling personalized treatment strategies.

V. ADVANCES IN ESTHETIC MATERIALS

Material science innovations have enhanced both esthetics and mechanical performance. Notable advances include:

High-translucency zirconia and lithium disilicate ceramics that closely mimic natural dentition [10]-

They are suitable for anterior and posterior crowns, bridges, veneers, and implant-supported restorations, providing natural translucency, color gradients, and fracture resistance. Their biocompatibility and compatibility with CAD/CAM workflows enable precise, minimally invasive restorations that preserve tooth structure, enhance tissue response, and ensure long-term functional and esthetic success.

Hybrid ceramics and nanocomposites offering superior strength, esthetics, and biocompatibility-

Hybrid ceramics and nanocomposites combine the strength of ceramics with the resilience and polishability of composites, offering superior esthetics, durability, and biocompatibility in prosthodontics. They are ideal for crowns, inlays, onlays, veneers, and implant-supported restorations, providing natural translucency, fracture resistance, and tissue-friendly surfaces. Adhesive bonding allows conservative tooth preparation, while their

repairability and compatibility with CAD/CAM workflows enhance long-term functional and esthetic outcomes
Recent developments in ceramics and hybrid materials have improved both durability and esthetics. High-translucency zirconia, lithium disilicate, and hybrid ceramics closely mimic natural tooth structures while offering enhanced strength and biocompatibility [10].

Digital shade-matching systems that minimize human error in color selection [11]-
Digital shade-matching systems provide accurate, objective, and reproducible tooth color selection, minimizing human error in prosthodontics [11]. They capture precise hue, chroma, and translucency data for crowns, veneers, bridges, and implant-supported restorations, improving esthetic outcomes and patient satisfaction. Integration with CAD/CAM workflows ensures seamless fabrication of restorations, reduces chairside adjustments and remakes, and facilitates patient communication and informed decision-making These materials provide durable, lifelike restorations tailored to patient needs.
Digital shade-matching systems further refine esthetic outcomes by reducing subjective human error [11]. These materials ensure long-lasting restorations that fulfill functional and cosmetic demands.

VI. CONCLUSION

Prosthodontics has entered a new era of digital and biologically driven care. CAD/CAM and 3D printing technologies have streamlined workflows, while implant surface innovations and guided surgery have enhanced predictability. Regenerative approaches and AI integration represent emerging frontiers with significant clinical promise. Material advancements further strengthen the specialty's capacity to meet patient demands for esthetic, functional, and durable restorations.
Future directions in prosthodontics will likely emphasize biologically integrated, digitally enhanced, and patient-centered care.

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