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REVIEW ARTICLE

# Intelligent Periodontics: Integrating Artificial Intelligence and Nanotechnology in Next-Generation Prosthetic Dentistry

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**ABSTRACT**

This review explores how combining artificial intelligence and nanotechnology can reshape periodontics and prosthetic dentistry by enabling more precise, predictive, and personalized care. It first outlines the conceptual foundations of intelligent periodontics, emphasizing data driven decision making, the shift from conventional to digital workflows, and the integration of AI into routine diagnostic and therapeutic processes. The paper then examines current AI applications in periodontal diagnosis, disease progression prediction, and prosthodontic workflows, highlighting improvements in imaging analysis, treatment planning, and prosthesis design. In parallel, it reviews nanotechnology based strategies for periodontal regeneration, implant surface modification, antimicrobial coatings, and targeted drug delivery, focusing on their contribution to enhanced tissue integration and long term clinical performance. The convergence section discusses AI assisted design and optimization of nanomaterials, smart and responsive nano systems, and data driven development of next generation implants and prostheses. Clinical translation challenges including nanotoxicity, data privacy, algorithmic bias, regulatory gaps, cost, and training needs are critically analyzed, alongside future trends such as nanorobotics, AI enabled precision prosthodontics, and IoT based smart oral devices. Overall, the review provides a structured framework for responsibly integrating AI and nanotechnology into modern periodontal and prosthetic practice, aiming to support more effective, safe, and patient centered dental care.

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## INTRODUCTION

Periodontics and prosthetic dentistry face persistent challenges that affect diagnostic accuracy, treatment planning, and overall clinical outcomes. In periodontics, the multifactorial etiology of diseases such as periodontitis encompassing microbial, genetic, and systemic factors complicates both diagnosis and the development of effective, patient-centered treatment strategies. Similarly, prosthetic dentistry requires high precision in prosthesis design and fitting, which directly influences functional and aesthetic outcomes, yet remains difficult to consistently achieve [1, 2]. These limitations are further exacerbated by constraints in current dental materials and the need for seamless integration of advanced technologies into clinical workflows [3]. Collectively, these

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challenges highlight the necessity for innovative, interdisciplinary solutions to enhance efficiency, precision, and quality of care.

The convergence of artificial intelligence (AI) and nanotechnology presents a promising approach to overcoming these limitations. AI has demonstrated significant potential in improving diagnostic accuracy, optimizing treatment planning, and enabling predictive analytics for disease progression, particularly in periodontics through machine learning and deep learning models [4, 5]. In prosthetic dentistry, AI facilitates the design of custom-fit prostheses, enhances implant placement accuracy, and streamlines clinical workflows, thereby improving procedural precision and reducing complications [6, 7]. Concurrently, nanotechnology contributes to the advancement of dental materials by enhancing their mechanical strength, biocompatibility, and biological performance, offering improved solutions for restoration and rehabilitation [8]. The synergistic integration of these technologies has the potential to transform dental practice by enabling more precise, efficient, and personalized care.

This review aims to critically examine the transformative role of AI and nanotechnology in periodontics and prosthetic dentistry by evaluating current applications, recent advancements, and future prospects. It focuses on assessing their scientific contributions, identifying innovations in diagnostic and therapeutic processes, and analyzing their impact on clinical outcomes and patient care [1, 7]Additionally, the review addresses key barriers to widespread adoption, including high implementation costs, infrastructure requirements, limited clinical validation, and concerns related to ethics, data privacy, and professional training [6]. By synthesizing these aspects, the review aims to provide a comprehensive perspective on how these emerging technologies can be responsibly integrated into modern dental practice.

## FOUNDATIONS OF INTELLIGENT PERIODONTICS

The integration of AI and nanotechnology into periodontics is revolutionizing the field, offering new avenues for diagnostics, treatment planning, and patient care. This transformation is underpinned by a robust conceptual framework that defines intelligent periodontics, traces its evolution from traditional practices to digital and intelligent methodologies, and highlights the critical role of data-driven decision-making. These elements collectively contribute to the emergence of a more precise, efficient, and personalized approach to periodontal care.

Intelligent periodontics represents an emerging paradigm that incorporates AI and advanced digital technologies into periodontal care to improve diagnosis, treatment planning, and patient management. By leveraging techniques such as machine learning and deep learning, AI systems can process and interpret complex clinical datasets, facilitating earlier detection of periodontal diseases and enabling more personalized therapeutic approaches [9]. This concept is grounded in the integration of AI-driven tools within conventional clinical workflows to enhance diagnostic precision and treatment outcomes. At the same time, it emphasizes the importance of addressing critical considerations, including ethical implications and data privacy, to ensure responsible and effective implementation in clinical practice [9].

The shift from conventional to digital dentistry reflects the growing integration of AI-driven technologies aimed at enhancing diagnostic accuracy and treatment planning in periodontal care. AI applications, including automated disease detection, radiographic interpretation, and predictive modeling, have markedly improved the efficiency and precision of clinical decision-making [4]. Furthermore, the combination of AI with advanced digital imaging modalities such as intraoral scanning and cone-beam computed tomography enables detailed, non-invasive assessment of periodontal conditions, reducing dependence on traditional manual probing techniques [10]. This transformation supports a transition toward more proactive and individualized treatment strategies, replacing conventional reactive approaches with data-driven, preventive care models [11].

Data-driven decision-making forms the foundation of intelligent periodontics, where large and diverse datasets are leveraged to support clinical judgment and improve patient outcomes. AI systems integrate information from multiple sources, including radiographic imaging, clinical examinations, and electronic health records, to generate predictive models that assist in disease diagnosis, progression assessment, and treatment planning [12, 13]. In addition, machine learning algorithms embedded in real-time monitoring systems enable continuous tracking of periodontal

conditions, allowing for timely interventions and more personalized care strategies [11]. Despite these advancements, several challenges persist, particularly regarding data quality, standardization, and system integration, which can limit the reliability and scalability of AI applications [14]. Moreover, the increasing reliance on AI and nanotechnology introduces important ethical considerations, including data privacy, algorithmic bias, and the need for transparent decision-making processes. Addressing these concerns, alongside establishing robust data management frameworks and fostering interdisciplinary collaboration, will be essential to fully realize the potential of intelligent periodontics in modern clinical practice.

## ARTIFICIAL INTELLIGENCE IN PERIODONTICS AND PROSTHODONTICS

The integration of AI in periodontics and prosthodontics is revolutionizing these dental fields by enhancing diagnostic accuracy, treatment planning, and patient outcomes. AI technologies, particularly machine learning and deep learning, are being utilized to analyze complex datasets, improve imaging techniques, and predict disease progression. These advancements are paving the way for more personalized and efficient dental care. The following sections explore the specific applications of AI in these areas.

AI, particularly convolutional neural networks (CNNs), has demonstrated substantial potential in improving the diagnostic accuracy of periodontal diseases through image-based analysis. These models, trained on extensive datasets ranging from approximately 110 to over 7,000 intraoral images, are capable of identifying conditions such as gingivitis and dental plaque with a high degree of precision [15]. In parallel, CNN-based systems have shown performance comparable to experienced clinicians in detecting periodontal bone loss, achieving area under the curve (AUC) values exceeding 0.88 [16]. Furthermore, AI applications in panoramic radiograph analysis have enhanced diagnostic capabilities, with reported accuracy rates reaching up to 97% in tasks such as tooth segmentation [17]. Collectively, these advancements highlight the growing reliability and clinical relevance of AI-assisted diagnostic tools in periodontics.

AI applications in imaging include the use of deep learning systems for volumetric assessment in cone-beam computed tomography (CBCT), which provides higher accuracy than traditional panoramic radiographs [16]. AI-powered innovations in periodontal diagnosis have improved the detection of periodontal bone loss, with AI systems outperforming traditional diagnostic methods in terms of accuracy and sensitivity [17].

AI technologies are being used to develop predictive models for periodontal disease progression, enabling customized treatment strategies and early intervention [9]. These predictive analytics tools analyze vast clinical datasets to uncover hidden patterns and provide evidence-based clinical support, enhancing patient management and treatment outcomes [18].

In prosthodontics, AI-driven digital workflows facilitate precise intraoral data capture and the design of customized prostheses through computer-aided design and manufacturing (CAD/CAM) and 3D printing technologies [19]. AI applications include automated classification of edentulous arches and machine learning-based removable partial denture framework design, which streamline workflows and improve treatment protocols [19]. AI algorithms have demonstrated substantial capability in prosthodontics for tasks such as automated tooth shade matching and prosthesis design, with CNNs consistently outperforming traditional algorithms in image-based tasks [20].

While AI offers significant advancements in periodontics and prosthodontics, challenges remain in standardizing AI applications and ensuring their ethical use. The integration of AI into clinical practice requires continuous validation and adaptation to maintain accuracy and relevance. Moreover, AI should be viewed as an adjunct to clinical expertise, enhancing precision-based, patient-centered dental care rather than replacing human practitioners [18, 20].

## NANOTECHNOLOGY IN PERIODONTAL AND PROSTHETIC APPLICATIONS

Nanotechnology has significantly advanced periodontal and prosthetic dentistry by introducing innovative materials and techniques that enhance tissue regeneration, implant integration, and antimicrobial efficacy. This integration of nanotechnology into dental practices offers promising solutions for periodontal regeneration, implant surface modification, antimicrobial coatings, and drug delivery systems. These advancements are poised to transform traditional

dental treatments into more effective, patient-specific therapies. The following sections delve into the specific applications of nanotechnology in these areas.

Nanotechnology-based biomaterials, including nanoparticles, nanofibers, and hydrogels, have emerged as promising tools for periodontal tissue engineering and regeneration. Nanoparticles such as hydroxyapatite and titanium oxide exhibit high surface area and bioactivity, which enhance their ability to support bone formation and periodontal tissue repair [21, 22]. In parallel, nanofibers provide a three-dimensional scaffold that closely resembles the natural extracellular matrix, facilitating cell adhesion, proliferation, and differentiation. Hydrogels further complement these systems by serving as effective carriers for cells and bioactive molecules, enabling controlled and sustained release at the target site. Additionally, stimuli-responsive hydrogels can adapt to environmental changes, offering a dynamic and tunable platform for advanced periodontal therapies [23].

Nanostructured surface modifications have significantly advanced the performance and longevity of dental implants by enhancing both biological and mechanical interactions at the tissue implant interface. Coatings incorporating nanoparticles such as silver and zinc oxide exhibit strong antimicrobial properties, reducing bacterial colonization while simultaneously promoting osseointegration, thereby improving implant stability and clinical success rates [21, 24]. In addition, the development of bioactive surfaces through the incorporation of therapeutic agents further supports tissue integration and accelerates the healing process. Such approaches aim to establish a more functional and biologically compatible interface between the implant and surrounding tissues, ultimately contributing to improved long-term outcomes in implant dentistry [25].

Nanoparticle-based systems enable site-specific drug delivery, improving the efficacy of periodontal treatments. These systems can provide sustained release of antimicrobial and anti-inflammatory agents, reduce the frequency of administration and enhance patient compliance [21, 26]. Nanocarriers such as liposomes and polymeric nanoparticles allow for the controlled release of drugs, ensuring a consistent therapeutic effect over time [22].

While nanotechnology offers transformative potential in periodontal and prosthetic applications, challenges such as nanotoxicity, regulatory hurdles, and high production costs remain. The long-term biocompatibility and environmental impact of nanomaterials need further investigation to ensure safe clinical application. Additionally, interdisciplinary collaboration and rigorous clinical trials are essential to translate these innovations from the laboratory to dental practice [21, 24].

## CONVERGENCE OF AI AND NANOTECHNOLOGY

The convergence of AI and nanotechnology is revolutionizing the field of periodontics by enabling the development of intelligent prosthetic dentistry solutions. This integration facilitates the design of advanced nanomaterials, responsive systems, and personalized treatment strategies, enhancing the precision and effectiveness of dental care. The synergy between AI and nanotechnology is particularly evident in the AI-assisted design of nanomaterials, the creation of smart nanomaterials and responsive systems, the integration of these technologies in diagnostics and personalized treatment, and the data-driven optimization of biomaterials. Each of these aspects contributes to the advancement of intelligent periodontics.

AI algorithms, including machine learning (ML) and deep neural networks, are accelerating the discovery and optimization of nanomaterials by predicting properties such as conductivity, biocompatibility, and catalytic activity. Techniques like generative adversarial networks (GANs) and reinforcement learning enable the logical programming of nanostructures, significantly reducing the time required for experiments. AI-driven platforms have simplified the synthesis of carbon-based nanomaterials and metal-organic structures, making them scalable for industrial applications [27].

Smart nanomaterials are engineered to respond dynamically to environmental cues such as pH shifts, microbial activity, and enzymatic signals, offering precise, site-specific therapies for dental conditions. These materials are used in intelligent coatings for dental implants, anti-biofilm agents, and remineralizing agents for enamel repair. Innovations include nano-structured scaffolds for tissue regeneration and photodynamic nanoparticles for oral cancer therapy [28].

AI and nanotechnology integration enhances personalized medical applications, including the design of intricate nano-electronic components

and the enhancement of drug delivery systems [29]. AI-designed nanotherapeutics demonstrate advances in polymeric nanoparticles for localized delivery and nanosensors for early diagnosis of oral conditions [30]. Deep learning, a subset of AI, optimizes therapeutic strategies and enhances diagnostic accuracy, improving patient outcomes in personalized medicine [31].

AI-driven approaches rapidly identify ideal properties of nanomaterials, enhancing the interaction between drugs and nanoparticles. Predictive modeling using ML algorithms accelerates progress in nanocarriers, nanosensors, and imaging technologies, enabling early disease detection and customized therapeutic strategies [32]. Data-driven design approaches enable patient-specific implant development and predictive modeling of biological responses [33].

While the convergence of AI and nanotechnology offers transformative potential in periodontics, challenges such as data quality, multidisciplinary cooperation, and ethical considerations persist [29]. Additionally, regulatory and scalability challenges must be addressed to ensure the successful implementation of AI-generated designs in clinical settings [30]. Despite these challenges, the integration of AI and nanotechnology continues to pave the way for next-generation prosthetic dentistry solutions, promising more secure, efficient, and tailored dental care. The principal domains, clinical applications, benefits, and implementation challenges associated with the integration of AI and nanotechnology in periodontics and prosthetic dentistry are summarized in Table 1.

## APPLICATIONS IN NEXT-GENERATION PROSTHETIC DENTISTRY

The integration of AI and nanotechnology in prosthetic dentistry is paving the way for next-generation applications that promise enhanced patient outcomes and more efficient clinical workflows. These advancements are particularly evident in the development of smart implants and prostheses, the use of bioactive and self-healing materials, the incorporation of digital workflows integrating AI and nanotechnology, and the exploration of clinical case scenarios and translational examples. Each of these areas contributes to a more personalized, efficient, and sustainable approach to dental care.

AI is revolutionizing implant procedures by enhancing precision in treatment planning and execution. AI-driven tools facilitate automated implant planning, image analysis, and predictive modeling, which improve accuracy and patient outcomes [3, 34]. Smart oral devices and AI-guided planning tools are being developed to enable remote monitoring and personalized dental rehabilitation, integrating AI with IoT and 5G technologies [13]. Nano-engineered surfaces and specialized coatings on implants enhance osseointegration and confer antibacterial properties, contributing to the longevity and success of dental implants [25].

Emerging biomaterials, such as magnesium alloys and polylactic acid/β-tricalcium phosphate composites, are being explored for their bioactive and bioresorbable properties, offering regenerative potential and improved osseointegration [35]. Self-healing materials and bioactive liners are being integrated into prosthetic designs to enhance

**Table 1.** Integrated roles of AI and nanotechnology in intelligent periodontics and nextgeneration prosthetic dentistry.

| Domain / focus area | Representative applications | Main clinical benefits | Key limitations and challenges |
|---|---|---|---|
| AI in periodontics | CNN-based image analysis, CBCT interpretation, and predictive models for disease progression. | Earlier and more accurate diagnosis, data-driven treatment planning, and individualized maintenance. | Variable data quality, limited standardization, workflow integration issues, and privacy/ bias concerns. |
| AI in prosthodontics and implantology | CAD/CAM-based prosthesis design, automated arch classification, shade matching, and AI-guided implant planning. | Better prosthesis fit, more accurate implant placement, reduced chair-time, and streamlined digital workflows. | High setup costs, training needs, lack of harmonized metrics, and possible over-reliance on automated output. |
| Nanotechnology in periodontal regeneration | Nano-biomaterials and carriers (nanoparticles, nanofibers, hydrogels) for scaffolds and local drug delivery. | Enhanced tissue regeneration, controlled local release of bioactives, and defect-specific regenerative strategies. | Uncertain long-term safety, regulatory complexity, and limited large-scale clinical evidence. |
| Nanotechnology in implants and prostheses | Nano-textured surfaces, antimicrobial coatings, bioactive and self-healing or bioresorbable materials. | Improved osseointegration, reduced infection risk, increased durability, and more biologically responsive restorations. | Manufacturing and cost constraints, optimization of degradation and mechanics, and scalability to routine practice. |
| Convergence of AI and nanotechnology | AI-guided nanomaterial design, smart coatings, nanosensors, and AI-optimized nanocarriers and implants. | Faster, rational development of nano-enabled therapies and devices, highly personalized and feedback-driven care. | Dependence on rich multimodal datasets, need for close interdisciplinary work, and evolving regulatory and ethical frameworks. |

durability and patient satisfaction, addressing common issues such as wear and tear [36, 37]. The development of bioresorbable systems requires optimization of degradation kinetics and mechanical durability to ensure consistent long-term clinical success [35].

Digital workflows, including CAD/CAM systems and digital impressions, are enhancing the precision and efficiency of prosthetic fabrication. These technologies allow for better customization and fit of prostheses. AI and machine learning contribute to treatment planning and predictive analytics, improving the accuracy of implant placement and reducing deviations compared to traditional methods. The integration of AI with digital technologies facilitates minimally invasive procedures and enhances communication between clinicians and patients [38].

AI-assisted diagnostics achieve high accuracy in anatomical segmentation and predicting implant failure, which is crucial for developing personalized treatment plans [35]. Clinical case studies demonstrate the successful application of AI-driven design platforms and bioprinted regenerative bases, which improve patient outcomes by enhancing customization and hygiene [36, 37]. Translational examples highlight the potential of AI and nanotechnology to regenerate native dental structures, such as dentin and periodontal ligament, moving beyond conventional prosthetic restoration [25].

While the integration of AI and nanotechnology in prosthetic dentistry offers numerous benefits, challenges remain in terms of accessibility, clinician training, and regulatory validation. The high costs associated with these technologies and the need for specialized training can hinder widespread adoption [38, 39]. Additionally, ethical considerations regarding the use of digital data and the standardization of clinical endpoints for emerging technologies are critical for ensuring consistent long-term success [36]. Continued interdisciplinary research and clinical validation are essential to fully realize the potential of these innovations in prosthetic dentistry.

## CLINICAL TRANSLATION AND CHALLENGES

The integration of AI and nanotechnology in periodontics and prosthetic dentistry holds significant promise for advancing clinical outcomes. However, the translation of these technologies into clinical practice is fraught with challenges that need to be addressed to ensure their safe, effective, and ethical application. These challenges include biocompatibility and safety concerns, regulatory and ethical considerations, cost-effectiveness and accessibility, and barriers to clinical adoption. Each of these aspects plays a crucial role in determining the feasibility and success of these innovations in real-world settings.

Nanotechnology in dentistry, while offering advanced therapeutic options, raises concerns about nanotoxicity and long-term biocompatibility. Potential risks include oxidative stress, DNA damage, and immune modulation following nanoparticle exposure, which are not yet fully understood [21]. AI systems, although beneficial for diagnostics and treatment planning, also pose risks related to data privacy and the potential for algorithmic bias, which could affect patient outcomes [9, 40]. Comprehensive preclinical evaluations and standardized biosafety frameworks are essential to mitigate these risks and ensure patient safety [41].

The regulatory landscape for AI and nanotechnology in dentistry is still evolving, with incomplete frameworks posing significant hurdles for clinical translation [41]. Ethical concerns include data privacy, informed consent, and the potential for over-reliance on AI systems, which could undermine clinical judgment and patient autonomy [40, 42]. Transparent patient engagement and robust ethical protocols are necessary to address these issues and build trust among patients and practitioners [41].

High initial costs and technical complexity associated with AI and nanotechnology can limit their accessibility, particularly in resource-constrained settings. While these technologies promise cost savings in the long term through improved efficiency and outcomes, the upfront investment remains a barrier for widespread adoption [40]. Strategies to reduce costs and enhance accessibility include scaling production, fostering interdisciplinary collaboration, and leveraging economies of scale [21].

Limited clinical trials and evidence-based validation hinder the adoption of AI and nanotechnology in clinical practice [43]. Clinicians may be hesitant to adopt these technologies due to a lack of familiarity, training, and confidence in their efficacy and safety [41]. Addressing these barriers requires comprehensive education and

training programs, as well as pilot clinical trials to demonstrate the practical benefits and safety of these innovations [41, 43].

While the integration of AI and nanotechnology in periodontics and prosthetic dentistry presents numerous challenges, it also offers transformative potential for improving patient care. Addressing these challenges through rigorous research, ethical practices, and collaborative efforts will be crucial for realizing the full benefits of these technologies in clinical settings.

## FUTURE PERSPECTIVES AND EMERGING TRENDS

The integration of AI and nanotechnology in prosthodontics is paving the way for intelligent periodontics, offering transformative potential in next-generation prosthetic dentistry. This evolution is characterized by advancements in AI-guided precision dentistry, nanorobotics, IoT integration, and personalized prosthodontics. These emerging trends promise to enhance diagnostic accuracy, treatment efficiency, and patient outcomes, while also addressing challenges such as cost and ethical considerations. The following sections explore these future perspectives and emerging trends in detail.

AI is revolutionizing prosthodontics by enhancing diagnostic imaging, treatment planning, and patient-specific prosthesis design. AI-driven tools facilitate precise tooth preparation and restoration design, optimizing casting and manufacturing processes [3, 40]. Machine learning algorithms can analyze radiographs with higher accuracy than traditional methods, identifying dental issues at early stages, which contributes to timely interventions and improved patient outcomes [44].

Nanotechnology and nanorobotics are revolutionizing orthodontics and prosthodontics by offering advancements in treatment efficiency, patient comfort, and precision. Applications include nano-enhanced adhesives, nanocomposites, and nanorobot-assisted procedures. Nanorobots promise accelerated tooth movement, smart brackets with real-time feedback, and plaque control, although biocompatibility and ethical concerns remain [45]. The integration of robotics and AI into prosthodontics is redefining traditional workflows, moving towards digitally driven, automated precision [46].

The integration of AI, IoT, and 5G technologies in prosthodontics enhances diagnostic precision and enables remote monitoring, promoting sustainable digital workflows. Smart oral devices and AI-guided planning tools are part of this integration, aiming to improve patient care and clinic efficiency. Wearable oral devices, combined with IoT, can provide real-time data on oral health, facilitating preventive care and personalized treatment strategies [44].

AI offers opportunities to enhance diagnosis, treatment planning, and patient care, enabling personalized and preventive prosthodontics [47]. AI-driven software supports orthodontics by enabling precise treatment planning through 3D imaging technologies, ensuring personalized and effective care [44]. Personalized prosthodontics involves the use of AI to design patient-specific prostheses, improving treatment outcomes and patient satisfaction [48].

While the integration of AI and nanotechnology in prosthodontics holds great promise, it is not without challenges. High initial costs, technical complexity, data privacy concerns, and ethical issues present significant barriers to widespread adoption. Additionally, the dependence on high-quality data and the risk of over-reliance on AI systems are critical considerations [40]. Addressing these challenges through continuous education, robust data management, and ethical practices will be essential for the responsible deployment of these technologies in prosthodontics.

## CONCLUSION

The convergence of AI and nanotechnology is poised to redefine prosthetic dentistry and periodontics by enabling more precise, personalized, and predictable care. Artificial intelligence enhances diagnostic accuracy and streamlines treatment planning across prosthodontic subspecialties from fixed and removable prostheses to implant and maxillofacial rehabilitation by improving digital impression workflows, optimizing implant placement, and supporting individualized restorative strategies. In periodontics, AI-driven imaging analysis and predictive models increasingly support earlier and more reliable detection of periodontal bone loss and more accurate assessment of alveolar bone levels, achieving diagnostic performance that approaches experienced clinicians.

When paired with advances in nanotechnology, these intelligent systems can further elevate clinical

outcomes. Nanoscale modifications to biomaterials and coatings promise improved durability, tissue integration, and biocompatibility of prosthetic devices, while AI can guide the selection and design of such materials to meet individual patient needs. This synergistic approach enables patient-specific prostheses, smarter treatment workflows, and hybrid solutions that combine nanoengineered surfaces with algorithm-informed clinical decision-making.

Realizing this potential requires addressing practical and ethical barriers. Data privacy, algorithmic transparency, cost, and clinician training are key obstacles to broad clinical adoption and must be tackled through interdisciplinary collaboration, robust validation, and adherence to regulatory and reporting standards. Future research should prioritize clinically explainable AI models, integration with additive manufacturing and regenerative therapies, and prospective studies evaluating long-term outcomes in diverse patient populations.

In summary, integrating AI with nanotechnology offers a transformative pathway for next-generation prosthetic dentistry and periodontics. By combining algorithmic intelligence with nano-enabled materials and devices, the field can advance toward more accurate diagnoses, individualized treatment planning, and improved patient-centered outcomes provided ethical, technical, and educational challenges are proactively managed.

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## CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest related to the research, authorship, or publication of this manuscript. All authors have disclosed any financial or personal relationships that could potentially influence or bias the work presented.

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