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Review

The Digital Frontier: Personalization and Predictive Analytics in Modern Prosthodontics

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ABSTRACT

The discipline of prosthodontics is undergoing a radical transformation in 2026, shifting from a reactive "replacement" model to a proactive "predictive" framework. This evolution is driven by the integration of Artificial Intelligence (AI) and Machine Learning (ML), which synthesize multidimensional patient data including radiographic imaging, intraoral scans and systemic health markers to optimize clinical interventions. This article examines the two primary pillars of this shift: Predictive Treatment Planning and Personalized Material Selection. Predictive analytics now allow for high-accuracy forecasting of prosthetic longevity and the early identification of biological complications such as peri-implantitis and mechanical ceramic chipping. Simultaneously, AI algorithms facilitate the selection of restorative materials based on patient-specific biomechanical environments, including bone density and parafunctional load patterns. This review synthesizes current evidence to demonstrate how these technologies enhance precision, reduce human error and foster a new era of intelligent biological integration in restorative dentistry.

Keywords: Artificial Intelligence, Predictive Analytics, Prosthodontics, Machine Learning, Personalized Medicine, Dental Materials, Treatment Planning, Deep Learning, Peri-implantitis

1. Introduction

Historically, prosthodontics relied on generalized clinical protocols and "average" material recommendations. However, the high variability of the human stomatognathic system often leads to unpredictable long-term outcomes[1]. In 2026, the frontier of the specialty is defined by Precision Prosthodontics, which utilizes big data to tailor treatments to the individual[2,3]. By leveraging Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs), clinicians can now transition from static designs toward dynamic, bio-integrated rehabilitations that monitor and respond to the oral environment[4,5].

2. Predictive Treatment Planning: Forecasting Clinical Success

Predictive analytics utilizes historical data and mathematical modelling to anticipate the future behaviour of prosthetic systems[6]. This moves the clinician from a state of clinical intuition to data-driven certainty.

2.1. Longevity and failure forecasting

Machine learning models, particularly Random Forests and Gradient Boosting machines (XGBoost), are used to analyze the "lifecycle" of various restorations by processing large heterogeneous datasets[7,8].

- **Survival analysis:** By evaluating variables such as crown-to-root ratio, the material of the antagonist tooth and patient-specific habits (e.g., smoking, diabetes markers), AI can provide a percentage-based survival probability over 5, 10 and 15 years[9,10].
- **Complication mitigation:** Predictive models can identify patients at high risk for "mechanical fatigue" or "ceramic chipping." By simulating dynamic occlusal forces in a virtual environment, the AI suggests design modifications such as increasing wall thickness or adjusting cusp inclination prior to fabrication[11,12].

2.2. Biological risk assessment and early detection

CNNs are now capable of detecting subtle changes in bone density and marginal bone levels from CBCT scans with accuracies exceeding 95%[13,14]. These systems flag early signs of peri-implantitis or bone remodelling patterns that are often missed by the human eye. Recent studies have demonstrated that AI-powered risk assessment frameworks can generate individualized risk profiles for implant failure, promoting a shift from reactive to preventive implant care[15,16].

3. Personalized Material Selection: A Biomechanical Approach

The selection of restorative materials is no longer limited to a choice between "strength" and "aesthetics." AI systems now cross-reference material properties with the patient's unique "digital twin"[17, 18].

3.1. Factoring parafunctional habits and bone quality

Patients with bruxism or clenching habits impose extreme cyclical stresses on restorations. AI algorithms analyse wear facets and motion-tracking data to recommend high-toughness materials, such as monolithic zirconia ($K_{IC} > 10 \text{ MPa}\cdot\text{m}^{1/2}$), specifically tailored to resist these loads[19,20].

Conversely, in areas of low bone density (Type IV bone), AI-guided material selection may favor shock-absorbing polymers like PEKK (Polyetherketoneketone) or high-density polyethylene (HDPE) reinforced with nano-hydroxyapatite. These materials possess a lower elastic modulus, which reduces "stress shielding" and protects the bone-implant interface from mechanical overload[21-23].

3.2. Aesthetic and optical fingerprinting

AI-powered spectrophotometry allows for "Optical Fingerprinting"[24]. By analysing the translucency, fluorescence and opalescence of adjacent natural teeth, AI recommends specific ceramic ingots or milling blocks that provide a seamless match. This reduces the trial-and-error associated with traditional shade taking[25,26].

4. Intelligent Biological Integration and Regeneration

The future of prosthodontics lies in Bio-intelligent Systems. These are no longer passive tissue replacements but interactive, adaptive systems[27,28].

Smart prostheses: Emerging prostheses are embedded with biosensors capable of monitoring peri-implant tissue health oral pH and temperature in real-time[29].

Generative design: Using 3D GANs, AI can automate the design of single-tooth prostheses by learning features from the patient's remaining dentition, ensuring the morphology is perfectly biomimetic and functional[30-32].

5. Challenges and Ethical Considerations

Despite the unprecedented benefits, several hurdles remain:

- **Data privacy:** The use of large-scale EHR and biometric data requires robust cybersecurity[27].
- **Algorithm bias:** Models must be trained on diverse populations to ensure equitable outcomes[33,34].
- **Explainable AI (XAI):** Clinicians must move away from "black box" models toward systems where the rationale for a treatment prediction is transparent and verifiable[35,36].

6. Conclusion

The integration of personalization and predictive analytics represents a fundamental reimagining of prosthodontic care in 2026. By harnessing AI to forecast complications and tailor materials to the individual, the profession can significantly increase the success rates of complex rehabilitations. As these technologies mature, the standard of care will shift toward a data-driven, bio-integrated approach that prioritizes long-term biological harmony over mere mechanical replacement.

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