Artificial Intelligence in Reconstructive Implant Dentistry—Current Perspectives

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In recent years, artificial intelligence (AI) has emerged as a transformative force in reconstructive implant dentistry. The integration of AI technologies into various aspects of dental practice, including digital data acquisition, treatment planning, and prognosis evaluation, offers unprecedented opportunities to enhance precision, efficiency, and clinical outcomes. Indeed, AI applications in implant dentistry span a broad spectrum of functionalities, from enhancing digital data acquisition and integration to providing sophisticated tools for treatment planning and prognosis evaluation. These technologies have the potential to streamline workflows, reduce human error, and improve the accuracy of clinical decisions, ultimately leading to better patient care. Therefore, this commentary synthesizes findings from recent studies by three well-regarded consultant prosthodontics and implantology professors affiliated to different Emirati academic institutions, trained in Switzerland, Canada, Germany, and the United Kingdom, to provide an overview of cutting-edge AI applications in reconstructive implant dentistry. Key areas of focus include digital data acquisition technologies, bone quality assessment, automated tissue segmentation, implant fixture identification and classification, and predictive analytics for implant planning and prognosis.

In terms of digital data acquisition and integration, AI-enhanced digital data acquisition technologies, including facial scanners (FSs), intraoral scanners (IOSs), and cone beam computed tomography (CBCT) devices, facilitate accurate data collection and integration. Revilla-León et al. [1] emphasize the role of AI in the automatic alignment, noise reduction, and segmentation of anatomical structures. These advancements streamline the creation of comprehensive virtual patient models, enhancing treatment planning accuracy. Indeed, AI-driven automated tissue segmentation significantly accelerates treatment planning. Liu et al. [2] introduced a fully automated system for segmenting oral surgery-related tissues from CBCT images, achieving a high accuracy in identifying alveolar bone, teeth, and maxillary sinus. These advancements reduce the manual segmentation effort and enhance surgical precision. For instance, Hartoonian et al. [3] reviewed AI applications in dentomaxillofacial imaging, showing the potential to improve diagnostic accuracy and treatment planning. Elgarba et al. [4] validated a cloud-based convolutional neural network for the automated segmentation of dental implants, demonstrating high performance and efficiency. A systematic review by the Afrashtehfar group demonstrated that coDiagnostiX® Digital Implant Treatment Planning Software (Dental Wings GmbH in Düsseldorf, Germany) outperforms other systems in implant treatment planning [5]. These advancements facilitate accurate and efficient clinical workflows, improving overall care quality [6–12].
Accurate bone quality assessment is crucial for successful dental implants. Lee et al. [13] demonstrated that deep learning (DL) models effectively evaluate bone quality from panoramic radiographs, correlating significantly with CBCT measurements and implant surgeons' tactile assessments. This AI application enhances objectivity and precision in bone quality evaluation, which is essential for implant stability and osseointegration. Furthermore, AI algorithms enhance implant planning by detecting edentulous areas and evaluating bone dimensions. Alqutaibi et al. [14] reported the high accuracy of AI-based diagnostic tools in implant planning, while Wu et al. [15] demonstrated the potential of AI in predicting implant prognosis. These predictive analytics tools help identify potential complications, optimizing treatment outcomes.

AI models demonstrate high accuracy in identifying and classifying dental implant fixtures from radiographs. Ibraheem [16] showed the utility of AI in implant identification, which is crucial for the continuity of care when previous records are unavailable. This capability improves clinical efficiency and reduces identification errors. Moreover, Lubbad et al. [17] compared deep learning models for classifying dental implants, and found that ConvNeXt models achieve the highest classification accuracy. Similarly, Mangano et al. [18] explored AI and augmented reality (AR) for guided implant surgery, demonstrating effective 3D planning and execution. Sakai et al. [19] developed an AI model to support implant drilling protocol decisions, showing significant accuracy in predicting appropriate protocols from CBCT images. These models increase precision in implant placement and the predictability of surgical outcomes.

The significant improvement in accuracy and efficiency AI provides is common across these studies, whether in data acquisition, segmentation, or implant identification. However, differences arise in the specific methodologies and AI models employed, such as the use of deep learning architectures like ConvNeXt [17] versus traditional machine learning algorithms [16]. Additionally, the extent of automation varies, with some studies achieving fully automated workflows [2,4], while others still require significant manual input [14,19]. Critically, while AI shows promise, challenges remain. For instance, the generalizability of AI models across diverse patient populations and varying clinical conditions needs further exploration. Studies like those by Wu et al. [15] and Alqutaibi et al. [14] conclude that there is a need for high-quality datasets and rigorous validation to increase reliability and reduce biases. Moreover, ethical considerations, including data privacy and the potential for algorithmic biases [20,21], must be addressed to fully integrate AI into clinical practice.

In conclusion, the integration of AI into reconstructive implant dentistry represents a significant advancement in the field. AI technologies offer enhanced diagnostic capabilities, streamlined workflows, and improved clinical outcomes. However, challenges such as the need for high-quality datasets, the rigorous validation of AI models, and addressing potential biases in AI algorithms remain. Future research should focus on refining these technologies, expanding their clinical applications, and ensuring their reliability and generalizability in diverse patient populations. This can lead to superior patient care and treatment success. As AI technologies continue to evolve, they hold the promise of transforming dental practice, making implant procedures more predictable and successful.

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