Digital Dentistry in Periodontics for Implant Therapy: A Contemporary Review

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Abstract- Digital technologies are changing how implants are cared for in people who have had periodontitis in the past. They provide accurate diagnoses, controlled surgical execution, prosthetic refinement, and proactive maintenance. This review summarizes the latest research on intraoral scanning (IOS), cone beam computed tomography (CBCT), static guides, dynamic navigation, photogrammetry, CAD/CAM provisionalization, occlusal analytics, finite element analysis (FEA), AI-driven disease detection, tele dentistry, and economic factors. We stress useful protocols for reduced arches and complicated anatomies, talk about accuracy and soft-tissue stability levers, and explain how to govern ethical AI and data ecosystems that can work together. Artifacts and inconsistent reporting still make it hard to generalize, but strict workflows and validation can make digital periodontics a reliable, patient-centred way to get long-lasting implant results.

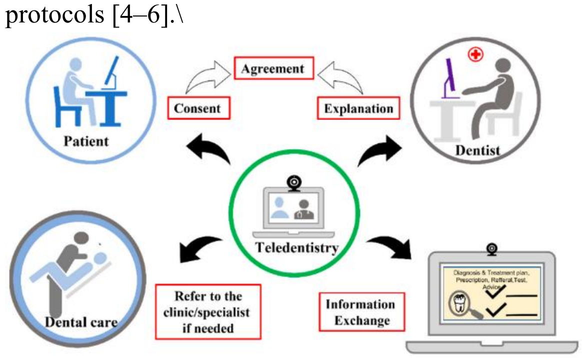
Keywords- Digital dentistry; periodontitis; implant therapy; intraoral scanning; guided surgery; AI in periodontics; occlusal analytics

I.INTRODUCTION

Patients with periodontitis face an elevated risk of peri-implant complications, necessitating enhanced precision at all phases of care—planning, placement, restoration, and maintenance [1–3]. Digital dentistry offers a cohesive framework that enhances accuracy and accountability by integrating 3D imaging with surface scans, directing drills in real time, standardizing prosthetic contours, measuring occlusal risk, and revealing early indicators of disease.

II.TELE DENTISTRY MAINTENANCE FOR HIGH-RISK COHORTS

"Remote care pathways that incorporate structured triage systems, secure digital platforms for photo and video submissions, intelligent symptom assessment tools, and recall protocols tailored to individual risk profiles help in periodontal treatment. These approaches not only enhance accessibility and reduce the incidence of missed clinical visits, also help earlier recognition and more rapid intervention for acute symptoms such as gingival bleeding and swelling. For patients predisposed to periodontitis, such digitally enabled workflows support proactive disease management, improve clinical outcomes, and contribute to the overall efficiency and responsiveness of oral healthcare systems." [4,5]. Mobile adherence tools can reinforce hygiene and capture early changes, alerting clinicians between chairside visits [6]. Onboarding aids in Set hygiene goals, app usage guidance, and escalation thresholds [4,5], Risk alignment helps to tie visit frequency to clinical findings [7–9,4], Key performance indicators track adherence, urgent visits, and satisfaction to optimize protocols [4–6].\



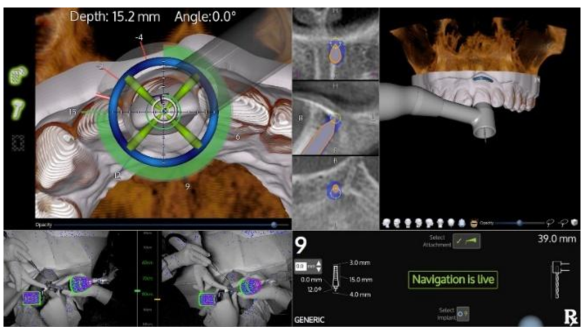
III.GUIDED SURGERY: STATIC TEMPLATES AND DYNAMIC NAVIGATION

Static Guided

Static Guided Implant Surgery involves preplanned implant placement using CAD/CAM-generated 3D printed surgical guides. It has limited intraoperative flexibility and depends a lot on the guide fitting correctly and the tissue being stable. It works best for simple cases with predictable anatomy.

Dynamic Navigation

Dynamic Navigation Implant Surgery assists in placing in an implant by using computer-guided tracking. It requires high operator skill, both to set it up at the chairside and to calibrate it correctly during the procedure. It works best on complex anatomy and reduced ridges, and it gives you more accuracy and flexibility. The technique works better with constant visual feedback.



Accuracy, Complications, and Workflow Control

Static surgical guides work well when the anatomy is very similar to what was planned before the surgery. But if the tissue is compressed or the guide doesn't fit right, the accuracy could be affected [10,11]. Dynamic navigation systems, on the other hand, give real-time feedback on angulation and depth. This lowers the risk of incidents like cortical perforations and makes implant placement safer. Meta-analyses indicate that dynamic navigation attains comparable or enhanced accuracy in complex anatomical scenarios, with results significantly affected by operator expertise and compliance with calibration protocols [11–13]. To maintain precision, daily calibration routines are essential for verifying tracking integrity and handpiece accuracy, as well as monitoring for drift [11,12]. Intraoperative validation through guide pins or anatomical checkpoints in high-risk areas enhances procedural accuracy [10–12]. Additionally, the establishment of safety zones in relation to adjacent structures, supplemented by alert systems, introduces an extra level of intraoperative control and risk reduction [11,12].

IV.PROSTHETIC OPTIMIZATION AND PERI-IMPLANT SOFT TISSUE STABILITY

CAD/CAM Provisionals and Emergence Profile Control

Digitally generated provisional restorations allow for precise control of pressure and emergence contours, which help soft tissue mature and lead to better papilla fill and wider keratinized tissue [14,15]. Regular intraoral scanning, usually every 2 to 4 weeks, lets doctors check how soft tissue is changing and make any necessary changes, such as customizing healing abutments to minimize differences in outcomes [14]. Foundational anatomical relationships, including the distance from the contact point to the bone crest and mucosal height, are vital parameters in the design of interproximal contours that facilitate papilla formation around implants [16,17]. To enhance this workflow, clinicians ought to execute phenotype mapping during placement to record soft tissue thickness and biotype [14,16,17], implement a serial scanning protocol to modify contours while preserving vascular perfusion [14], and integrate design heuristics such as convex–concave transitions and gentle pressure zones, especially in instances involving thin biotypes [15–17].

Diagnostic Digitization and Data Fusion

In implant planning, intraoral scanning (IOS) captures soft tissue and tooth surfaces, while cone-beam computed tomography (CBCT) defines the bony structures and adjacent anatomical features critical for surgical accuracy. Comparative studies of IOS systems have assessed accuracy and precision in both partially and fully edentulous cases [20]; To improve digital integration, it is important to have strong registration of CBCT and IOS using landmark-rich zones and pre-planning error assessment [4,5], to reduce artifacts by optimizing CBCT settings and using metal reduction protocols when grafts or restorations are present [4,5], and to use photogrammetry more often when passive fit is important [18,19]. A periodontal–implant digital twin is a dynamic model of a patient that uses CBCT, IOS, occlusal dynamics, microbiome profiles, and behavioural data to simulate tissue remodelling and help with personalized maintenance plans [31,33]. Interoperability standards like DICOM for imaging and HL7 FHIR for clinical data are needed for scalable deployment of these kinds of models. Privacy-preserving analytics and secure, role-based access control are also needed [33,34]. Standardization across platforms enables the acquisition of research-grade data [34].

Digital Periodontal Profiling and Systemic Modifiers

Electronic periodontal charts make it possible to consistently stage, grade, and monitor changes in inflammation and attachment over time [24–26]. incorporating systemic data (like blood glucose levels, smoking, and medications) into digital records helps with planning and maintenance that takes risk into consideration. Calibration among clinicians improves reliability for long-term decision-making.

V.OCCLUSAL ANALYTICS AND BIOMECHANICAL LOAD MANAGEMENT

Measuring Occlusion Digitally

Digital occlusal systems measure the sequence of contact and the distribution of force, revealing parafunctional risk zones and helping with tailored modifications or protective appliances [27]. Combining occlusal data with IOS/CBCT helps shape the morphology of crowns and the way they contact each other, especially when the ridges are smaller.

Finite Element Analysis (FEA) for Stress-informed Decisions

Finite element analysis (FEA) converts occlusal forces and anatomical geometry into detailed stress distribution maps around dental implants. This helps clinicians choose the best parameters for factors like implant angulation, platform diameter, thread design, splinting strategy, cantilever length, and framework material selection to minimize peak stress concentrations and the risk of micro strain [28,29]. Post-adjustment iterative scanning is very important for checking occlusal balance and linking biomechanical improvements to early signs of implant stability on X-rays [27–29]. To improve clinical outcomes, strategies encompass the elimination of premature contacts in regions with thin cortical bone or grafted tissue to alleviate stress concentrations [28,29], the adjustment of design variables, such as increasing platform diameter or altering angulation, and the selection of more rigid framework materials for longer spans [28,29]. Re-scanning after occlusal refinements guarantees ongoing load distribution and upholds long-term biomechanical integrity [27–29].

T-Scan

The T-Scan system is a digital occlusal analysis tool that provides real-time insights into bite force distribution, contact timing, and occlusal balance. Unlike traditional methods such as articulating paper, T-Scan quantifies occlusal forces and sequences, enabling precise adjustments in implantology, prosthodontics, and TMD management. It is especially valuable in cases involving limited proprioception, such as osseo-integrated implants, where accurate load distribution is critical. Clinicians can identify premature contacts, high-force zones, and asymmetries, improve prosthetic longevity and reduce complications. T-Scan supports splint design, full-mouth rehabilitation, and patient education through visual feedback. Its integration into digital workflows enhances clinical decision-making and outcome predictability. Studies have shown that T-Scan improves execution by converting qualitative indicators into actionable data, making it a powerful tool for modern dental practices focused on precision and patient-centred care. Regular use can support iterative refinements and long-term biomechanical stability in complex restorative cases. [27]

AI for Early Disease Signals

Machine learning algorithms applied on panoramic, periapical, and CBCT images have shown to be better at finding patterns of periodontal bone loss and early peri-implant disease than traditional methods, especially when used with clinical indices like bleeding on probing and pocket depth measurements [30–32]. For these models to work, they need to be properly calibrated, include transparent reporting of sensitivity and specificity metrics, and be constantly monitored by clinicians to make sure they are safe and reliable. To make sure that performance is fair, governance frameworks should include systematic bias monitoring across variables like soft tissue biotype, arch location, imaging modality, and patient demographics [30–32]. Also, for reproducibility and compliance with regulations, it is important to support version control through regular retraining and thorough documentation of model updates and validation procedures [31]. To build trust in clinical settings and encourage their use, models must also give outputs that can be explained, with feature-level explanations that make decision-making clearer and help clinicians make informed choices [31].

VI.CHALLENGES AND FUTURE DIRECTIONS

Digitally Guided Regeneration

Virtual defect mapping, customized grafts/membranes, and guided sinus protocols show potential for reproducible augmentation; however, they necessitate clinical validation, assurance of sterility, and standardization of outcomes prior to widespread implementation [37,38]. Early feasibility with 3D-printed membranes is promising but requires larger trials [39].

Ethical AI and Oversight

To protect patients and allow for early detection and maintenance planning, transparent, fair AI must remain under the control of clinicians. This means that there must be audit trails, checks on subgroup performance, and clear rules for overriding decisions [30–32]. Institutional oversight should control the updates to models and the ways they can be integrated [31,33].

VII.CONCLUSION

Digitally enabled periodontics can enhance implant therapy by making it more accurate, consistent, and preventive for patients with a high risk of periodontitis. To get the most benefit, you need a validated CBCT–IOS fusion, the right choice of surgical guidance, controlled soft-tissue conditioning, measured occlusal control, early risk detection through AI, and ethical data systems that can work together. With careful calibration and constant training, clinical teams can provide long-lasting, individualized results while keeping costs under control.

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