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Review Article

Digital impressions in implant dentistry: Revolutionizing accuracy, comfort, and efficiency

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Abstract

Digital impression technology has revolutionized implant dentistry by improving the planning, placement, and restoration of implants. Traditional conventional impression techniques were often inaccurate and uncomfortable. Intraoral scanners now provide precise 3D models for accurate surgical guides and prosthetic designs, integrating with CAD/CAM software for efficient workflows. The benefits include enhanced precision, reduced chair time, and improved patient comfort. Real-time feedback and seamless CAD/CAM integration minimize errors. Clinically, digital impressions support pre-surgical planning, custom guides, and follow-up care, improving implant success rates, especially with CBCT integration. Challenges include high costs, clinician training, and limitations in scanning certain areas. Environmental factors like moisture and large file management also pose difficulties. However, advancements in implant planning software and CAD/CAM technologies continue to improve efficiency. Future innovations in AI, machine learning, and cloud systems will further enhance diagnostic accuracy and accessibility, transforming implant dentistry and patient care.

Keywords: Digital Impression, Implants, Impression Techniques, Models

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1. Introduction

Implant dentistry offers solutions for missing teeth, providing functional, aesthetic, and durable outcomes. Success depends on precise planning, placement, and restoration, making accurate impressions essential for creating surgical guides, custom abutments, and prostheses. Traditional methods, involving silicone or alginate materials, often led to inaccuracies, discomfort, and inefficiencies. These limitations prompted the development of digital impression technologies, now the gold standard in implant dentistry.

1.1. History of digital impression technology

Digital impression technology began in the early 1990s with scanning devices aimed at dental impressions. Early systems like CEREC (1985) were bulky and inaccurate. Advancements in the 2000s, including Lava C.O.S. and iTero, improved precision and user-friendliness. Integration with implant planning and surgical guides, along with the advent of Cone Beam CT (CBCT), further refined digital workflows. Today, intraoral scanners are compact, fast, and highly accurate, seamlessly working with CAD/CAM and implant planning software for precise implant placement.[1]

1.2. Fundamentals of digital impressions in implant dentistry

Digital impressions in implant dentistry use advanced scanning technology to capture highly accurate 3D images of a patient's oral structures, eliminating the need for traditional

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impression materials. Intraoral scanners (IOS) capture detailed digital models of the teeth, gums, and oral cavity, which are then used for treatment planning, prosthesis design, and implant placement. This method provides superior accuracy, enabling precise implant planning and customization of restorations, reducing errors and improving fit. It also supports the creation of surgical guides for optimal implant placement. Digital impressions are faster, more comfortable, and less invasive than traditional methods, improving patient comfort and reducing the need for retakes. Additionally, they enhance communication among dental professionals and streamline the process, ensuring better collaboration and outcomes. Overall, digital impressions offer a more efficient, precise, and patient-friendly alternative to conventional techniques in implant dentistry.[1] Common scanning technologies include optical scanning (iTero, Trios), light reflectance (Planmeca Emerald), and laser triangulation (3Shape TRIOS, Carestream CS 3600). Many scanners combine these methods for improved precision and real-time feedback.[2]

1.3. Types of digital impression systems[13]

1.3.1. Digital impression systems vary by hardware, software, and clinical application.

1. Intraoral Scanners: Handheld devices used for capturing digital impressions, such as iTero, Trios, and Planmeca Emerald. These scanners offer fast, accurate results with real-time feedback.
2. Chairside and Laboratory-Based Systems: Chairside systems, like CEREC, are portable for in-office use, while laboratory systems (e.g., 3Shape D800) handle complex restorations.
3. Software Solutions: CAD software (e.g., Exocad, 3Shape Dental System) designs restorations, while CAM software (e.g., Dental Wings CAM) facilitates manufacturing. Digital implant planning software (e.g., coDiagnostiX, BlueSkyPlan) aids in virtual implant placement.

1.3.2. Advantages of digital impressions in implant dentistry[14]

1. Accuracy and Precision: Digital impressions provide superior accuracy, essential for precise implant placement, custom restoration design, and surgical guides.[3,4]
2. Time Efficiency: Faster scanning reduces chair time, enhances workflow, and allows for direct file transfers to labs, speeding up the overall process.
3. Patient Comfort: No messy materials or bulky trays, making the procedure more comfortable, especially for patients with sensitive gag reflexes.
4. Reduction in Errors: Real-time feedback allows for instant corrections, reducing distortion, voids, and errors.
5. Integration with Digital Workflow: Direct connection to CAD/CAM systems streamlines design and manufacturing, reducing adjustments.
6. Enhanced Communication: Instant sharing of digital files improves collaboration between clinicians and labs, ensuring better outcomes.

1.3.3. Clinical applications of digital impressions in implant dentistry[15]

1. Pre-Surgical Planning: Digital impressions create accurate 3D models that integrate with implant planning software and CBCT for precise placement and virtual simulations of implant surgeries.
2. Surgical Guides: Custom surgical guides, created using CAD/CAM, ensure accurate implant placement and reduce complications.
3. Implant Prosthetics: Digital impressions aid in designing custom restorations, such as crowns and bridges, and allow for rapid fabrication of temporary prosthetics.
4. Follow-Up and Long-Term Monitoring: Digital impressions track changes in oral anatomy, helping detect complications like bone loss early and facilitating prosthetic adjustments.

1.3.4. Challenges and limitations of digital impressions in implant dentistry

1. Cost Considerations: Intraoral scanners have a high upfront costwith ongoing maintenance and training expenses.
2. Learning Curve: Clinicians must learn new scanning techniques and integrate digital impressions into existing workflows, which may disrupt efficiency initially.
3. Material and Technique Limitations: Issues with scanning deep bites, soft tissue, or reflective prosthetic materials may require supplementary methods or traditional impressions.
4. Data Quality and Management: Poor scanning technique or environmental factors can lead to incomplete scans and data loss, requiring rescans and causing treatment delays.
5. Intraoral Scanning Limitations: Moisture, difficult-to-reach areas, and patient movement can affect scan accuracy, requiring extra time or specialized techniques.2-5

1.3.5. Digital impressions and implant planning software

Digital impressions, when integrated with implant planning software, improve the precision of implant placement. Popular systems like coDiagnostiX and BlueSkyPlan combine digital impressions with CBCT data, creating accurate 3D models and virtual treatment planning. Benefits include improved visualization, accurate placement, and minimized complications. Integration with CBCT provides detailed views of bone and soft tissue, enhancing implant

planning and ensuring safe placement by identifying critical structures like nerves and sinuses.[5,6]

1.3.6. Digital impressions and CAD/CAM technology in implant dentistry

1. Integration with CAD Software: Digital impressions facilitate the design of precise custom restorations, including abutments and prostheses. CAD software allows real-time design modifications for optimal results.
2. CAM (Computer-Aided Manufacturing): After design, CAM systems use milling or 3D printing to fabricate restorations, offering customization and high precision.
3. Benefits of CAD/CAM Workflow: Faster turnaround times, improved fit, fewer adjustments, enhanced aesthetics, and cost savings result from digital impression integration with CAD/CAM.[1,6,8]

1.3.7. Future directions in digital impressions for implant dentistry

Advancements in technology are continuously transforming implant dentistry. Key trends shaping the future include:

1. Advances in Scanner Technology: Future scanners will capture finer details, offer faster scans, and provide real-time feedback for improved accuracy.
2. Artificial Intelligence and Machine Learning: AI will automate error correction, predict treatment outcomes, and enhance diagnostic capabilities.
3. Wearable and Mobile Devices: Handheld scanners and smartphone integrations will make digital impressions more accessible in various settings.
4. Interoperability: Unified systems will streamline workflows, allowing seamless data transfer between devices and software for improved efficiency.
5. Patient-Centered Innovations: Future scanners will be more comfortable and affordable, benefiting both patients and practitioners.[1]

Table 1: Comparison of digital vs. traditional impressions in implant dentistry

Factor	Digital Impressions	Traditional Impressions
Accuracy	Higher accuracy, micron-level precision, no material distortion.	Prone to distortion and errors due to material handling and setting.
Time Efficiency	Faster procedure, immediate feedback, reduced re-impressions.	Slower procedure, material setting time, and risk of re-impressions.
Cost Effectiveness	High initial investment, but long-term savings in materials, labor, and fewer re-impressions.	Lower initial cost, but higher long-term costs due to material and labor needs.
Patient Experience	More comfortable, faster, reduces gag reflex and discomfort.	Often uncomfortable, longer procedure, more likely to induce gag reflex.

2. Discussion

Much of the existing literature on digital impressions in implant dentistry stems from experimental studies, particularly in vitro research, which provides useful insights but has limited applicability to clinical settings. Only a few in vivo studies have been included, and these generally lack precise measurements of accuracy that would allow direct comparison with in vitro results. Therefore, additional in vivo studies with reliable outcome reporting are necessary to gain a better understanding of the accuracy of digital impressions in real-world clinical situations. When comparing conventional and digital impression techniques, available evidence indicates that digital impressions offer comparable accuracy for fixed partial prostheses. However, high-quality evidence supporting the preference of digital impressions over conventional methods for full-arch rehabilitation is still lacking, despite promising in vitro results.[10-12]

Regarding patient preference, all the reviews examined agree that patients prefer digital impression technology over traditional impressions.[8] Digital workflow enhances clinical efficiency in terms of impression time, patient preference, and time-saving (De Oliveira et al.,2020).[5] Intraoral scanning causes less discomfort for patients compared to traditional methods and improves the overall patient experience in terms of comfort(Bishti et al.,2021).[6] García-Gil et al. evaluated the efficiency, accuracy, and economic feasibility of digital impressions for implant-supported restorations. Their review of 27 studies showed similar passive fit outcomes between digital and conventional methods, with various factors influencing accuracy. Digital impressions are viable for single or adjacent implants, but further research is needed for full-arch restorations. In vitro data indicates that the accuracy of 3D digital impressions is comparable to that of conventional implant impressions, though more in vivo studies are required to assess accuracy in clinical practice.[3,7]

Studies suggest that the accuracy of digital impressions may decrease as the number of implants increases or the edentulous span widens due to errors in image stitching. However, the literature has not yet defined the exact threshold at which these errors become clinically significant.[9] Number of implants, scanning protocol, Intra-oral scanners and edentulous span affects accuracy of digital impressions but all provide clinically acceptable results, with only minor variations in precision.[10,11]

The scanning protocol, especially the starting point for scanning, plays a critical role in ensuring accuracy. Starting the scan from the restoration area may reduce distance and angular deviations, leading to better outcomes. Regarding

implant angulation, most studies suggest that digital impressions are not significantly affected by different implant angulations, especially in controlled laboratory conditions. However, in vivo factors such as patient movement and saliva may influence accuracy, and further studies are necessary to assess these variables.[12]

3. Conclusion

Digital impressions in implant dentistry offer key benefits such as enhanced accuracy, improved patient comfort, and increased efficiency. Technologies like intraoral scanners integrated with CAD/CAM systems enable precise implant placement and restoration design, resulting in better-fitting restorations and more predictable outcomes. The elimination of traditional impression materials reduces patient discomfort, minimizes gagging, and shortens chair time. A fully digital workflow, integrating CBCT data and real-time communication with labs, streamlines treatment. Challenges include high initial costs, the need for ongoing training, and limitations in certain scans. In conclusion, although digital impressions show potential in implant dentistry, further in vivo research is needed to clarify the impact of factors such as implant depth and angulation, scanning protocols, and overall impression accuracy. These studies will be crucial for determining the best workflows for digital implant dentistry.

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5. Conflicts of Interest

None

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