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Review Article

Digital impressions in contemporary prosthodontics: an overview of intraoral scanning technology, applications and future trends

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ABSTRACT

Digital technology has progressed significantly in recent years, resulting in substantial advancements in dentistry. The integration of computer-aided design and computer-aided manufacturing (CAD/CAM) has simplified clinical procedures while improving precision, efficiency, and communication between clinicians and dental laboratories. The introduction of intraoral scanners (IOS), together with advances in CAD/CAM technology, has further transformed conventional impression procedures. Digital impressions improve patient comfort, facilitate immediate visualization of the scanned area, simplify data storage, and enable rapid electronic transfer of information to dental laboratories. Recent investigations have demonstrated that digital impressions can provide clinically acceptable accuracy for many fixed prosthodontic and implant-supported restorations. However, their accuracy is influenced by scanner characteristics, scanning strategy, scan length, operator experience, surface characteristics, and intraoral conditions. Recent advances in artificial intelligence, photogrammetry, cloud-based platforms, and three-dimensional printing are expected to further expand their clinical applications.

Keywords: Intraoral scanner, Digital impression, Digital dentistry, CAD/CAM, Prosthodontics, Intraoral scanning

INTRODUCTION

The introduction of CAD/CAM systems in the 1980s represented a major milestone in dentistry. These technologies enabled the fabrication of inlays, onlays, crowns, bridges, and implant-supported restorations with increasing levels of precision.[1,2] Digital technologies have subsequently become increasingly integrated into restorative and prosthodontic workflows, facilitating the transition from conventional laboratory procedures to digitally coordinated clinical and laboratory processes.[3-5] Intraoral scanners (IOS) facilitate the acquisition of three-dimensional digital images of teeth and surrounding oral structures. Unlike conventional impression procedures, IOS do not require impression materials or trays and allow the clinician to visualize the acquired data immediately.[6-7]

Digital records can be stored electronically and incorporated directly into CAD/CAM workflows. The accuracy of IOS is described in terms of trueness and precision. Trueness refers to the closeness of a measurement to the reference, whereas precision refers to the reproducibility of repeated measurements. The accuracy of digital impressions may be influenced by the scanner system, scanning strategy, scan range, operator experience, surface characteristics, and environmental conditions.[8]

Pugalendhi et al reported that IOS performance in full-arch digital impressions varied in accuracy and precision, with outcomes influenced by the scanning region and IOS system used.[9] Ma et al similarly found that the accuracy of in vivo digital implant impressions varied with scanning strategy and clinical conditions.[10] Husein et al demonstrated that digital techniques can provide clinically useful three-dimensional records, although accuracy may differ according to the scanning method and clinical conditions.[7] These findings demonstrate that digital

impressions have become an important component of contemporary prosthodontics, although appropriate case selection and operator training remain essential. A comparison between conventional and digital impressions is given in Table 1.

Digital impressions provide several advantages over conventional impressions, including immediate visualization, easier data storage, electronic transfer, and integration with CAD/CAM systems.[6,7] Yuzbasioglu et al reported that digital impressions provided greater patient comfort and improved patient perception and clinical workflow compared with conventional techniques.[6] Husein et al found that both digital and conventional full-arch impressions can provide clinically useful results, although the accuracy of digital impressions varies with the scanner and scanning conditions.[7] Kaitatzidou et al evaluated 28 systematic reviews comparing digital scans with conventional impressions for tooth- and implant-supported fixed restorations. They reported that digital and conventional techniques generally showed no significant differences in accuracy or marginal and internal adaptation for crowns, fixed partial dentures, and implant-supported fixed restorations. However, conventional impressions demonstrated better accuracy in some complete-arch fixed dental prosthesis situations.[11]

WORKING PRINCIPLE OF IOS SYSTEMS

Digital impression systems can broadly be classified into open and closed systems. Open systems use standardized file formats, such as STL, allowing digital files to be transferred between compatible scanning, CAD, and manufacturing systems. Closed systems operate within proprietary hardware and software environments and may restrict interoperability with other platforms. Open systems therefore provide greater flexibility with different CAD/CAM systems and dental laboratories. The development of digital prosthetic workflows has increasingly emphasized integration between clinical scanning, CAD design, and manufacturing technologies.[4,5]

Intraoral scanners (IOS) capture intraoral structures using different optical technologies, including triangulation, confocal imaging, and structured light. The captured images are processed and combined by software to create a three-dimensional digital model. The quality of the scan can be affected by factors such as the scanning sequence, image overlap, surface characteristics, saliva, blood, reflective areas, and operator handling. Full-arch scanning may be more challenging because errors can accumulate as the scanning area increases, potentially affecting the accuracy of the final digital model.[5,8]

Sacher et al reported differences in the trueness and precision of commercially available IOS, highlighting the effect of scanner characteristics on digital impression accuracy.[8] Similarly, Lee found significant differences in scanning accuracy between two IOS using three-dimensional surface analysis, indicating that the performance of IOS may vary between different scanner systems.[12]

DIFFERENT SYSTEMS FOR DIGITAL IMPRESSIONS

Intraoral scanners such as CEREC, 3Shape TRIOS, iTero, carestream, true definition, planscan, and lythos form an important part of contemporary digital dentistry. Each system differs in optical technology, scanning speed, software interface, colour acquisition, bite registration, artificial intelligence integration, and CAD/CAM compatibility.[5] Contemporary commercially available scanning systems include iTero, lythos, PlanScan, True definition, TRIOS, carestream, and CEREC. These IOS systems incorporate features such as real-time scanning feedback, automated image stitching, colour visualization, digital bite registration, scan-quality assessment, and cloud-based data transfer.

Lee demonstrated that commercially available IOS systems may differ in their three-dimensional accuracy, suggesting that scanner selection should be based on the intended clinical application rather than on scanning speed alone.[12] Therefore, the selection of an IOS should be based on the clinical indication, required accuracy, scanning range, software compatibility, laboratory workflow, and operator experience. Major clinical applications of different types of intraoral scanners are given in Table 2.

APPLICATIONS OF INTRAORAL SCANNERS IN PROSTHODONTICS

Fixed prosthodontics

IOS technology is widely used in fixed prosthodontic workflows. Applications include digital impressions for crowns, bridges, inlays, onlays, and veneers; accurate recording of preparation margins and finish lines; CAD/CAM fabrication of restorations; digital occlusal analysis; virtual articulation; and digital communication with dental laboratories.

Davidowitz and Kotick described the development and clinical applications of CAD/CAM technology, emphasizing its importance in the digital fabrication of indirect restorations.[2] The prosthetic workflow in the digital era has further expanded the integration of digital impressions, CAD design, and computer-assisted manufacturing in fixed prosthodontic treatment.[5] Kaitatzidou et al reported that digital and conventional impressions generally showed comparable accuracy and restoration fit for crowns and fixed partial dentures, although conventional impressions may be more accurate in some complete-arch cases.[11]

Removable prosthodontics

Digital technologies are increasingly being incorporated into removable prosthodontic workflows. Applications

include digital impressions for complete dentures, digital impressions for removable partial dentures, recording edentulous ridges and tissue morphology, digital design of removable partial denture frameworks, digital denture workflows, milling and three-dimensional printing of dentures, and digital duplication of existing dentures.

Cepic et al reported a trend toward improved clinical efficiency with digital dentures, although patient satisfaction did not differ significantly from conventional dentures.[13] Similarly, Peroz et al found comparable clinical outcomes between digital and conventional complete dentures, with no significant effect of fabrication method on the parameters evaluated.[14]

However, digital impressions of edentulous arches remain challenging due to mobile soft tissues and limited anatomical landmarks. Wang et al reported that IOS accuracy is influenced by patient anatomy and scanning conditions.[15] Thus, conventional impressions remain valuable, particularly when functional border molding and accurate recording of movable tissues are required.

Implant prosthodontics

IOS technology has become increasingly important in implant prosthodontics. Applications include recording implant positions using scan bodies, fabrication of implant-supported crowns, implant-supported fixed partial dentures, full-arch implant-supported prostheses, overdentures, recording peri-implant soft-tissue contours, digital workflows for guided implant surgery, and communication with dental laboratories.

Digital implant impressions are influenced by the number and distribution of implants, scan-body design, IOS characteristics, scanning strategy, and operator experience.[10,16]

Ma et al evaluated the accuracy of digital implant impressions using IOS in vivo and found that accuracy was influenced by the scanning strategy and other clinical variables. Their findings emphasized that careful selection of the scanning protocol is important for achieving accurate implant position records.[10] Dos Reis et al investigated the clinical outcomes associated with digital scans and conventional impressions for complete-arch implant-supported fixed prostheses and evaluated scanning and impression times as well as clinical outcomes.[17]

Joensahakij et al compared conventional impressions with IOS and photogrammetry for full-arch implant-supported prostheses and highlighted the potential of digital techniques for recording implant positions, while noting that accuracy depends on the technology and clinical protocol used.[18]

Ribeiro et al compared intraoral scanning with conventional impression techniques for implant prostheses and found similar prosthetic outcomes and precision between the two approaches. They also reported shorter impression and adjustment times with digital impressions, while patients generally preferred the digital technique.[19] These findings support the increasing role of IOS in implant prosthodontics, although conventional impressions remain clinically relevant in selected complex full-arch cases.

Maxillofacial prosthodontics

IOS and other digital scanning technologies can be used in selected maxillofacial prosthodontic applications, including capturing intraoral and extraoral defects, designing obturators, designing facial prostheses, treatment planning for traumatic defects, treatment planning for oncological defects, digital fabrication of prostheses, and integration with CAD/CAM and 3D printing. Digital techniques can provide a non-invasive alternative to conventional impression procedures in selected cases and facilitate digital storage and reproduction of anatomical information.[4,5]

Occlusion and jaw relation

IOS systems can be used for digital bite registration, recording maxillomandibular relationships, occlusal contact analysis, dynamic occlusal assessment, integration with virtual articulators, and digital evaluation of occlusal changes. Digital bite registration can be incorporated into CAD/CAM workflows and may facilitate the design and fabrication of restorations with appropriate occlusal relationships.[4,5]

Esthetic dentistry/smile design

IOS technology can be integrated with facial photographs, facial scanning, CAD software, and other digital records for digital smile design (DSD), previsualization of treatment outcomes, esthetic treatment planning, patient communication, simulation of restorative treatment, and improved patient understanding and case acceptance. The integration of intraoral scanning with facial scanning, CAD/CAM, and three-dimensional imaging is contributing to increasingly comprehensive digital esthetic workflows.[4,5]

BENEFITS AND LIMITATIONS

Benefits

Digital impressions can reduce chairside time by eliminating several clinical and laboratory steps associated with conventional impressions. Ribeiro et al found that digital impression procedures required less scanning and adjustment time than conventional techniques in implant prosthodontic workflows. They also reported a significant patient preference for digital impressions among the studies included in their review.[19]

Unlike conventional impression techniques, IOS do not require impression materials or trays. This can reduce discomfort and gag reflex and may improve patient acceptance.[6] Ribeiro et al reported that patients generally preferred digital impressions over conventional impressions in implant prosthodontic procedures, supporting the potential patient-centered advantages of IOS.[19]

A major advantage of digital impressions is the ability to visualize the scanned area immediately. Inadequate or missing areas can be identified and rescanned without repeating the complete impression procedure. This immediate feedback can improve clinical workflow and allow deficiencies in the digital record to be corrected before the patient leaves the clinical setting.[6,5]

Digital impressions can eliminate several conventional laboratory procedures, including impression pouring and cast fabrication, particularly when a completely digital workflow is adopted. Digital records can be stored electronically without the physical storage requirements associated with conventional impressions and casts. Digital files can also be transmitted electronically to dental laboratories, facilitating rapid communication between clinicians and dental technicians. CAD/CAM integration allows IOS data to be transferred directly to CAD software and subsequently used for milling or additive manufacturing.[1,2,4,5]

Limitations

A lack of knowledge and familiarity with IOS technology may affect scanning efficiency and accuracy. Appropriate training is therefore essential for predictable clinical results. Scanner selection and familiarity with the individual system are important because commercially available IOS may differ in their accuracy and clinical performance.[8,12]

Deeply positioned gingival margins can be difficult to visualize and capture, particularly in the presence of bleeding or inadequate gingival retraction. Moisture and contamination may also interfere with optical scanning. Blood, saliva, and crevicular fluid may affect the acquisition of optical data, and appropriate isolation and soft-tissue management are therefore essential.[8]

IOS primarily captures visible surfaces and may not accurately reproduce mobile or displaced soft tissues. This limitation is particularly important in edentulous patients. Wang et al emphasized that mobile soft tissues and the absence of stable anatomical landmarks are important factors affecting the accuracy of IOS in edentulous arches.[15]

Full-arch scanning remains challenging because cumulative stitching errors may occur as the scanning area increases. Pugalendhi et al reported variability in the accuracy and precision of IOS used for full-arch digital impressions, emphasizing that scanner selection and scanning protocol are important determinants of scan quality.[9] Sacher et al similarly demonstrated differences in the accuracy of commercially available IOS.[8]

The initial investment for IOS equipment, software, computer hardware, maintenance, and staff training can be substantial. The learning curve is another consideration. Although contemporary IOS systems have become increasingly user-friendly, adequate training and clinical experience remain necessary to achieve predictable results.

FUTURE TRENDS

Future developments in digital impression technology are expected to improve clinical efficiency, accuracy, and integration with other digital technologies. Advances in artificial intelligence (AI) and machine learning may improve automated margin detection, image segmentation, scan-quality assessment, caries detection, and treatment planning. These developments may reduce operator dependency and improve consistency in digital workflows.[20]

The development of faster and more accurate scanners is expected to reduce chairside scanning time and improve patient comfort. Future systems may demonstrate improved performance in challenging clinical situations, including full-arch scanning, subgingival margins, moisture contamination, and soft-tissue recording. Ma et al highlighted the importance of scanning strategy in determining the accuracy of digital implant impressions, suggesting that future improvements in scanning algorithms and workflow guidance may contribute to more predictable implant scanning.[10]

Joensahakij et al emphasized the potential of photogrammetry and IOS for full-arch implant-supported prostheses, indicating that continued development and standardization of digital implant recording technologies may improve their clinical applicability.[18] Integration with cloud-based digital platforms will facilitate rapid transfer of digital impressions between dental clinics and laboratories and may allow real-time collaboration.[4,5]

The combination of IOS, facial scanning, CBCT, CAD/CAM, artificial intelligence, virtual articulators, and three-dimensional printing is likely to create increasingly comprehensive digital workflows. The continued development of three-dimensional printing may further expand the range of digitally fabricated prosthodontic appliances and restorations, although technological, economic, and workflow-related barriers remain.[21] Digital scanning already provides clinically comparable outcomes to conventional impressions for many fixed prosthodontic applications, supporting the continued integration of digital technologies into routine restorative workflows.[11]

Table 1: Comparison between conventional and digital impressions.

Parameters	Conventional impressions	Digital impressions
Impression material	Required	Not required
Impression tray	Required	Not required
Patient comfort	May cause discomfort and gag reflex	Generally, better tolerated
Immediate visualization	Not possible	Possible
Identification of errors	Usually after impression removal	Immediate
Correction of errors	New impression may be required	Deficient areas can be rescanned
Physical storage	Impressions and casts require storage	Digital storage
Laboratory communication	Physical transfer	Electronic transfer
Cast fabrication	Usually required	Not required in a completely digital workflow
Infection-control requirements	Impression disinfection required	Digital data can be transferred electronically
Initial investment	Relatively low	Relatively high
Learning curve	Familiar technique	Requires training and experience

Table 2: Different IOS systems.

IOS systems	Major clinical applications
iTero	Prosthodontics, orthodontics, implant dentistry
TRIOS	Restorative dentistry, prosthodontics, orthodontics
CEREC	Chairside CAD/CAM restorations
PlanScan	Restorative and CAD/CAM workflows
True definition	Restorative and prosthodontic applications
Carestream	Restorative and prosthodontic workflows
Lythos	Digital impression and CAD/CAM workflows

CONCLUSION

Intraoral scanning offers significant advantages, including improved patient comfort, efficient workflow, and seamless CAD/CAM integration. Although digital impressions provide clinical outcomes comparable to conventional techniques in many prosthodontic applications, their accuracy remains influenced by scanner characteristics, scanning strategy, clinical conditions, and operator expertise.

Limitations are particularly evident in full-arch and completely edentulous cases due to reduced anatomical landmarks and mobile soft tissues. Therefore, digital impressions should be considered a complementary alternative rather than a universal replacement for conventional techniques, with the choice guided by the clinical indication, restoration type, and patient-specific factors.

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