

INTRAORAL SCANNERS AS A TOOL IN PROSTHODONTIC REHABILITATION – A NARRATIVE REVIEW

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Abstract

Statement of Problem: Conventional impression techniques used in prosthodontics may be associated with patient discomfort, material distortion, and workflow inefficiencies. Intraoral scanners (IOS) have emerged as a digital alternative that enables the capture of accurate three-dimensional images of intraoral structures and facilitates digital prosthodontic workflows.

Purpose: The purpose of this review was to evaluate the evolution, scanning technologies, accuracy, clinical applications, advantages, limitations, and future perspectives of intraoral scanners in prosthodontic rehabilitation.

Material and Methods: A narrative review of the literature was conducted by analyzing previously published studies related to intraoral scanners, digital impression systems, and CAD/CAM technologies in dentistry. The review examined the development of IOS technology, principles of scanning, commercially available systems, factors influencing scanning accuracy, and their clinical applications in various prosthodontic procedures.

Results: Intraoral scanners use optical technologies such as triangulation, confocal imaging, active

wavefront sampling, and stereophotogrammetry to generate digital impressions. Contemporary IOS systems demonstrate clinically acceptable trueness and precision for single-unit and short-span restorations. Their use enhances patient comfort, reduces chairside time, enables real-time visualization and selective rescanning, and improves communication between clinicians and dental laboratories through digital workflows. Integration with CBCT and CAD/CAM technologies also supports prosthetically driven implant planning and fabrication of restorations. However, limitations remain, including high initial costs, technique sensitivity, and difficulties in capturing subgingival areas or extensive edentulous regions.

Conclusions: Intraoral scanners have significantly improved digital prosthodontic workflows by enhancing accuracy, efficiency, and patient comfort. Continued technological advancements, including artificial intelligence integration and improved scanning algorithms, are expected to expand their clinical applications and reliability in prosthodontic rehabilitation.

Keywords: Intraoral scanners, digital impressions, CAD/CAM, digital prosthodontics, prosthodontic rehabilitation

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Introduction

The rapid advancement of digital technologies has revolutionized the field of dentistry, significantly enhancing diagnostic accuracy, treatment planning, and clinical outcomes. Among these innovations, intraoral scanners (IOS) represent a milestone, offering a digital alternative to conventional impression techniques. By providing precise three-dimensional (3D) images of the oral cavity, IOS have streamlined workflows, improved patient comfort, and increased the predictability of prosthetic and restorative procedures.

The foundation of digital dentistry was laid in 1973, when Dr. François Duret first proposed the application of computer-aided design and computer-aided manufacturing (CAD/CAM) in dentistry. Since then, intraoral scanning technology has evolved from bulky and limited early prototypes into compact, ergonomically designed, and highly accurate devices. Modern IOS utilize light-based systems, such as structured light or laser, to capture detailed images of teeth and soft tissues, which are processed in real time by advanced software to generate virtual 3D models.

Compared with traditional impression methods, intraoral scanning eliminates common sources of error such as material distortion, stone expansion, and casting shrinkage. It also reduces chair time, enhances patient experience, and allows selective rescanning of deficient areas without repeating the entire procedure. Furthermore, IOS are increasingly integrated into prosthodontics, orthodontics, and implantology, supporting a fully digital workflow from impression to final restoration.

Despite their advantages, intraoral scanners are not without limitations. Challenges remain in capturing subgingival areas, reflective surfaces, and narrow spaces, while the high cost

and learning curve may limit their widespread adoption. Nevertheless, ongoing improvements in artificial intelligence, scanning speed, and software integration are expanding their capabilities. With future developments in augmented reality and cloud-based platforms, intraoral scanners are expected to become an indispensable component of routine dental practice worldwide.

Review of Literature

Evolution of intraoral scanners: The concept of CAD/CAM in dentistry was first proposed in 1973 by Dr. François Duret, who, along with Dr. Christian Termoz, later patented a method and apparatus for manufacturing dental prostheses¹. Around the same time, Young and Altschuler developed an intraoral grid surface mapping system that utilized optical instrumentation, although its complexity and cost prevented widespread clinical adoption².

Significant progress came in the 1980s, when Swiss dentist Dr. Werner Mörmann, in collaboration with engineer Marco Brandestini, invented the first digital intraoral scanner³. This innovation led to the introduction of the Chairside Economical Restoration of Esthetic Ceramics (CEREC) system in 1984⁴. CEREC 1, launched in 1986, became the first chairside CAD/CAM system in dentistry⁵. Over the following decades, the technology evolved into CEREC 2, CEREC 3, and CEREC 3D, introduced in 1994, 2000, and 2003 respectively, each generation offering enhanced functionality and accuracy⁶.

The 2000s marked an era of rapid expansion in intraoral scanning systems. In 2001, Cadent introduced the OrthoCAD system for 3D digital orthodontic models, while in 2006, it launched the iTero digital impression system, which by 2008 could perform full-arch scans. In parallel, Brontes Technologies developed the Lava™ Chairside Oral Scanner, later acquired by 3M

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ESPE in 2006. Soon after, D4D Technologies introduced the E4D Dentist system in 2008, further diversifying the digital scanning market.

Corporate consolidation also shaped the field. In 2011, Align Technology acquired Cadent, enabling clinicians to submit iTero digital scans for Invisalign aligner fabrication. This integration of intraoral scanning with clear aligner therapy represented a milestone in orthodontic practice. The following years saw the release of new systems such as 3M ESPE's True Definition scanner in 2012 and Ormco's Lythos scanner in 2013, both expanding the interoperability of scanning technologies across orthodontic and restorative applications. By 2014, interoperability had further improved, with True Definition scans being accepted for Invisalign cases and iTero scans compatible with Incognito lingual appliances⁶.

Scanning Technology: Intraoral scanners (IOS) are medical devices composed of a handheld camera, computer, and software, designed to capture precise three-dimensional geometry of dental tissues⁶. Data is typically exported in STL format, though alternatives such as PLY files also allow recording of color and texture. Critical factors in system selection include acquisition speed, resolution ($\geq 25 \mu\text{m}$), scanning field size (optimal $25 \times 14 \text{ mm}$), and depth range (10–14 mm)⁸.

Light Projection and Capture: 3D reconstruction in intraoral scanners can employ passive or active methods⁷. Passive systems rely on ambient light and surface texture, while active systems project structured light (white, red, or blue) in points, lines, or meshes, enabling more accurate depth calculation. Data acquisition may be image-based, video-based, or wave-based⁹.

Distance-to-Object Technologies: Triangulation which determines point position using geometric principles from two viewpoints, often via detectors or prisms. Confocal Imaging that

reconstructs objects by capturing images at varying depths of focus; accuracy depends on operator dexterity but requires larger optics⁶. Active Wavefront Sampling (AWS) uses an off-axis rotating aperture to derive depth from the rotational patterns of projected points¹⁰. Stereophotogrammetry relies on passive light and software algorithms rather than structured light, producing smaller, more affordable scanners¹⁰. Reconstruction Technologies that are generating accurate 3D models depends on matching points of interest (POI) across multiple images¹¹. Algorithms integrate accelerometer data to determine viewpoints, detect features such as curvatures or grey-scale transitions, and calculate similarity transformations. Noise reduction techniques refine the final model, producing clinically usable STL or related digital files¹².

Parts of intraoral scanning system: The scanners mainly composed of machine handling the movement of the probe, measurement probe, control or computing system and measurement Software

Mainstream Commercial Products: The development of intraoral scanners has been marked by progressive innovations from multiple manufacturers. Early systems such as Lava C.O.S. (3M ESPE, 2008) introduced Active Wavefront Sampling (AWS) to capture 3D data in motion, while iTero (Cadent, 2007) utilized parallel confocal imaging to obtain powder-free scans with high accuracy⁹. Other early entrants included Planscan and the E4D system (2008), both employing laser-based scanning technologies⁶. Around the same time, CEREC Bluecam (2009) pioneered LED-based imaging, though its dependence on powder limited popularity once newer powder-free systems such as CEREC Omnicam (2012) emerged⁸.

In the 2010s, scanner technology advanced significantly. 3Shape TRIOS (2010 onward) revolutionized clinical practice with ultrafast

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optical sectioning, real-color imaging, and wireless scanning, offering flexibility with cart and pod configurations⁷. Carestream CS 3500 (2013) added portability with a USB-powered handheld wand, while 3M True Definition (2016) combined video imaging with cloud-based data management, though it required contrast powder. Later, Virtuo Vivo (Straumann/Dental Wings, 2017) and CEREC PrimeScan (2019) enhanced speed, resolution, and CAD/CAM integration, with PrimeScan capturing up to one million 3D points per second and enabling subgingival impressions¹².

Recent products focus on improving ergonomics, cost-effectiveness, and workflow integration. ZFX IntraScan (2012) emphasized portability, while newer systems like WOW (Biotech Dental, 2019) and Medit i500 (2018) deliver realistic texture reproduction and high-speed scanning using photogrammetry, supporting full digital workflows¹³. Collectively, these mainstream scanners demonstrate a clear trajectory toward powder-free imaging, real-time processing, portability, and open architecture, making digital impressions increasingly accessible and efficient in everyday dental practice¹⁴.

Scanning accuracy: The accuracy of intraoral scanners is typically evaluated based on two parameters: trueness, which reflects how closely the scan corresponds to the actual geometry, and precision, which indicates the consistency of repeated scans⁸. Accuracy is influenced by scanner type, resolution, software algorithms, and operator technique⁶. Other factors, such as substrate material, span length, tooth morphology, scanning strategy, powder thickness, saliva or blood contamination, and soft tissue movement, can reduce accuracy⁹. Errors are more likely to increase when scanning larger spans or complex surfaces¹⁵.

Studies have shown that modern powder-free scanners can achieve clinically acceptable

accuracy for single-unit and short-span restorations. Full-arch digital impressions, while improving, still demonstrate slightly lower trueness compared to conventional impressions, particularly in edentulous arches or highly angulated surfaces¹². Operator experience and adherence to optimized scanning protocols significantly impact scan quality¹³. Despite these challenges, advancements in scanning hardware, software algorithms, and real-time error correction have progressively improved scanner reliability for prosthodontic applications.

Intraoral scanners provide numerous clinical and operational benefits, improving both patient experience and workflow efficiency⁷. Enhanced patient comfort is achieved by eliminating the discomfort and gag reflex associated with conventional impression materials and trays⁸. Reduced operator stress results from simplified procedures and decreased manual handling errors. Digital workflows also lower infection risk by avoiding physical impression materials and disinfectants, and promote eco-friendly practice by minimizing material waste.

Intraoral scanners offer real-time visualization, allowing clinicians to identify and correct errors instantly. Selective rescanning of deficient areas prevents repetition of the entire impression¹³, while easy data storage and sharing supports secure archiving and instant transmission to laboratories or specialists. Integration with advanced imaging, such as facial scans or CBCT, enhances diagnostic accuracy and facilitates prosthetically driven implant planning¹⁶.

Furthermore, IOSs improve efficiency by reducing chairside time and eliminating temporary restorations, enable long-term digital monitoring for follow-up assessments¹⁷, and provide accurate shade and colour matching, enhancing esthetic outcomes¹⁸. The high-resolution surface mapping also aids in the early detection of pathologies such as carious lesions,

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enamel cracks, and wear facets. Collectively, these advantages support a comprehensive digital workflow, enhancing precision-driven prosthodontic rehabilitation.

Discussion

Intraoral scanners (IOS) have transformed prosthodontics by replacing conventional impressions with fast, accurate, and patient-friendly digital impressions. Modern scanners eliminate the need for powder application, allow selective rescanning of deficient areas without repeating the entire impression, and generate 3D models through structured light projection and advanced software algorithms. These features reduce patient discomfort, shorten clinical procedures, and provide clinicians with real-time visualization for immediate error correction.

In fixed prosthodontics, IOS improve restorative workflows by enhancing accuracy and efficiency in crown, bridge, and veneer fabrication²². The ability to capture fine details and transfer data digitally reduces the need for stone models, minimizes distortions, and supports seamless CAD/CAM integration. Chairside systems further allow single-visit restorations, offering patients improved convenience while ensuring clinicians maintain full control over preparation margins, morphology, and occlusion through digital design tools.

In implant dentistry, IOS are increasingly combined with cone-beam computed tomography (CBCT) to create "digital clones" of the patient's oral structures²³. This integration enables prosthetically driven implant planning, the design of surgical guides, and precise placement of implants, improving long-term outcomes. Use of scan bodies and digital wax-ups supports accurate implant positioning and custom abutment fabrication, while guided protocols reduce surgical risks and enhance predictability.

In removable prosthodontics, IOS are used to capture edentulous arches, mucosal morphology, and border extensions, enabling fabrication of CAD/CAM dentures²⁴. Although challenges remain in scanning soft tissue movement and accurately recording denture borders, techniques such as soft tissue stretching and optimized scanning pathways are improving accuracy. The digital workflow also streamlines laboratory communication and reduces the need for physical records, significantly improving clinical efficiency.

Maxillofacial prosthodontics has also benefitted from IOS technology. Scanners enable precise, non-invasive impressions for designing facial prostheses, obturators, and surgical guides, which is valuable for patients with extensive defects or sensitive tissues²⁵. Beyond clinical applications, intraoral scans of palatal morphology have shown strong reproducibility, reinforcing their value in prosthodontic rehabilitation and forensic odontology for human identification²⁶.

Despite their numerous advantages, intraoral scanners (IOS) are not without limitations. Accurate and consistent results require operator training and experience, as improper handling can compromise scan quality. Moisture control is essential because saliva and oral fluids can distort optical readings¹⁹. Reflective or shiny surfaces, such as metallic restorations, may interfere with image capture, affecting scan accuracy²⁰.

In implant dentistry, impressions demand compatible scan bodies and proper software integration for reliable outcomes. Additionally, dynamic occlusion cannot yet be fully replicated without virtual articulators. The high initial investment cost can be a barrier for smaller practices, while ongoing expenses include software updates, maintenance, and cloud storage fees²¹. Finally, closed system architectures may limit data transfer between

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different CAD/CAM platforms, though the adoption of open STL file formats is improving interoperability and digital data sharing.

Future Scope of Intraoral Scanners

Advancements in Scanning Accuracy and Speed: The future of intraoral scanners lies in achieving even higher accuracy, faster image acquisition, and improved usability. Ongoing developments in optical sensors and artificial intelligence (AI) algorithms are expected to enhance image stitching, reduce scanning time, and improve data precision²⁷. These refinements will enable clinicians to capture complete digital impressions with minimal operator variability, leading to more consistent clinical outcomes and greater confidence in fully digital workflows.

Integration with Artificial Intelligence and Automation: Artificial intelligence and machine learning are set to play a transformative role in the next generation of IOS. AI-driven analysis can automatically detect margin lines, identify undercuts, and suggest optimal preparation designs²⁸. Automated error detection during scanning will minimize rescanning and improve efficiency. Furthermore, predictive algorithms may assist clinicians by interpreting digital impressions to identify early signs of caries, gingival recession, or occlusal discrepancies, expanding the diagnostic potential of these devices beyond impression capture.

Interconnectivity and Cloud-Based Data Management: With the growing emphasis on digital interoperability, future intraoral scanners will likely feature seamless integration with cloud-based storage, CAD/CAM systems, and digital treatment platforms. Real-time data transfer will facilitate collaborative planning among clinicians, dental technicians, and specialists, regardless of location²⁹. Secure cloud systems will enable instant case sharing, version control, and long-term record maintenance, promoting

efficiency and accuracy in prosthodontic and implant workflows.

Enhanced Applications in 3D Printing and Virtual Treatment Planning: Digital data obtained from next-generation IOS will further enhance the precision of 3D printing and virtual treatment simulations. High-resolution digital impressions will serve as the foundation for fabricating restorations, surgical guides, and aligners with superior fit and aesthetic. Integration with augmented and virtual reality (AR/VR) platforms will allow clinicians to visualize and rehearse treatment procedures before actual execution, improving predictability and patient communication.

Accessibility, Training, and Sustainability: As technology advances, intraoral scanners are expected to become more compact, cost-effective, and user-friendly, enabling wider adoption in general dental practice and education³⁰. Training modules using virtual reality and haptic feedback will help new practitioners master digital impression techniques with greater ease. Moreover, digital workflows supported by IOS significantly reduce material waste, aligning with the global movement toward environmentally sustainable dental practice³¹. The future of intraoral scanning, therefore, extends beyond precision—it represents a shift toward intelligent, interconnected, and eco-conscious dentistry.

Conclusion

Intraoral scanners have revolutionized modern dentistry by providing a precise, efficient, and patient-friendly alternative to traditional impression techniques. Utilizing advanced optical and digital technologies, these devices capture highly detailed three-dimensional images of the oral cavity, enhancing diagnostic accuracy, treatment planning, and prosthetic fabrication through seamless integration with computer-aided design and manufacturing

(CAD/CAM) systems. While challenges such as high initial costs, software maintenance, and the need for clinician training persist, ongoing technological advancements continue to make scanners more versatile, accessible, and reliable. Modern intraoral scanners support fully digital workflows, improve patient comfort, reduce operator stress, enable eco-friendly practices, and facilitate integration with advanced imaging modalities and 3D printing. Future developments in intraoral scanning are anticipated to center on advancements in optical acquisition systems and computational processing to achieve greater trueness and reproducibility. The application of artificial intelligence is expected to enable real-time quality assessment, adaptive scan correction, and automated identification of clinically relevant landmarks. Improved integration with digital design and manufacturing ecosystems may facilitate seamless data transfer and more efficient restorative and implant workflows. Additionally, refinements in hardware ergonomics and software algorithms are likely to reduce technique sensitivity, supporting consistent clinical performance across diverse treatment scenarios.

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