



Review Article

Intraoral scanners in digital dentistry

Rachamalla Srilekha^{1*}, C Ravi Kumar¹, Y Ravi Shankar¹, AV Rajanikanth¹, G Harilal¹

¹Dept. of Prosthodontics and Crown & Bridge, Mamata Dental College, Khammam, Telangana, India

Abstract

The integration of intraoral scanners (IOS) into prosthodontics represents a transformative advancement in digital dentistry, offering significant improvements in clinical workflows, accuracy, and patient comfort. This review aims to evaluate the current evidence regarding the use, benefits, and limitations of intra oral scanners in prosthodontic procedures, including crown and bridge fabrication, implant prosthodontics, removable prostheses, and maxillofacial prostheses. Compared to conventional impression techniques, intraoral scanners demonstrate high precision and reproducibility. However, challenges remain in full-arch scanning and capturing edentulous areas due to limitations in soft tissue management and scanner software algorithms. Additionally, factors such as scanning strategies, operator experience, and the type of intra oral scanners used can significantly influence outcomes. The review highlights current technologies, discusses clinical applications, and suggests areas for future research to optimize digital workflows in prosthodontics.

Keywords: Intraoral scanners, Digital impressions, Prosthodontics, Digital dentistry.

Received: 24-07-2025; **Accepted** 30-08-2025; **Available Online:** 22-10-2025

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1. Introduction

The advent of digital technology has significantly transformed prosthodontics, with intraoral scanners emerging as a pivotal innovation. Intra oral scanners enables direct digitization of the oral cavity to produce accurate three-dimensional (3D) virtual models, offering a patient-friendly and efficient alternative to traditional impression techniques.¹ These scanners enhance precision in capturing oral structures for crowns, bridges, dentures, and implants, while improving clinical efficiency, reproducibility, and data management.² The digital workflow further facilitates immediate data transfer and CAD/CAM fabrication.

Despite these benefits, intra oral scanners faces limitations in full-arch and edentulous scanning due to soft tissue mobility, anatomical voids, and cumulative stitching errors.³ Performance is also influenced by operator skill, scanning protocol, and device-specific technology.⁴ This review explores the applications, advantages, and limitations of Intra Oral Scanners in prosthodontics and identifies areas for future advancement.

2. Applications in Dentistry

Intraoral scanners have broad applications in general dentistry, enhancing diagnostic accuracy, workflow efficiency, and patient comfort. They capture high-resolution 3D images useful for detecting caries, fractures, and gingival changes, and aid in monitoring oral health.¹ In orthodontics and pediatric dentistry, intra oral scanners facilitates the design of aligners, retainers, and space maintainers with improved patient tolerance.⁵ Intra oral scanners also supports enabling guided implant and orthognathic planning when combined with CBCT. In endodontics and periodontics, they assist in treatment planning, gingival contour assessment, and tissue healing evaluation. Additionally, intra oral scanners, along with AI (artificial intelligence), improved diagnostic procedures and communication through real-time visualization, aids in digital record-keeping, and supports tele dentistry⁶. Overall, intra oral scanners offers a precise, efficient, and patient-friendly alternative to conventional methods.

*Corresponding author: Rachamalla Srilekha
Email: rachamallasrilekha98@gmail.com

2.1. Principles of intraoral scanners

Digital intraoral scanning involves image capture, data processing, and onscreen visualization, with image capture being the most critical. Various technologies underpin intraoral scanners functionality:

1. Confocal laser scanning: A laser passes through a narrow aperture, capturing only in-focus areas across multiple 2D planes to build a 3D image—commonly known as the “point and stitch” method.
2. Triangulation: Involves a laser source, object surface, and sensor. The reflected beam’s angle is used to calculate distances via triangulation, forming a precise 3D model.
3. Active wavefront sampling (3D-in-motion): Uses a single-lens system to continuously record 3D surface data. Radiopaque scanning powder may be applied to improve contrast on reflective or texture-deficient surfaces, but overuse can obscure margins and reduce accuracy.
4. Structured light projection: Projects patterned light onto surfaces; distortions in the pattern are analyzed to reconstruct surface geometry. Known for its speed and accuracy in capturing complex anatomy.
5. Stereophotogrammetry: Uses stereo cameras and infrared flash to record x, y, and z coordinates of implant abutments. It generates STL files based on software algorithms rather than active projection, allowing for compact, cost-effective devices.
6. Reconstruction technologies: Align multiple points of interest (POIs) from various angles using similarity calculations or accelerometer data to accurately reconstruct the 3D model.

Among these, confocal laser scanning and structured light projection are the most commonly used due to their balance of speed, accuracy, and user-friendliness in routine prosthodontics.

2.2. Requirements for scanning

The accuracy and reliability of intraoral scanners are highly dependent on fulfilling certain clinical and environmental prerequisites during scanning, which include-

1. Dry Field – Control of saliva, blood, and crevicular fluid using suction, cotton rolls, or isolation systems.
2. Soft Tissue Retraction – Use of retraction cords, pastes, lasers, or scan bodies to expose margins and implant platforms.
3. Bleeding Control – Complete hemostasis must be achieved before scanning.
4. Clear Visibility of Margins – All preparation or implant margins should be fully visible and unobstructed.
5. Adequate Scanning Depth – Ensure 2–3 mm of subgingival area is accessible and exposed for accurate capture.

6. Absence of Calculus and Debris – Tooth surfaces must be clean, free of visible calculus, plaque, or remnants from procedures.
7. Patient Cooperation and Stability – The patient should remain still during the scanning process to avoid image stitching errors.
8. Proper Lighting Conditions – Minimize shadows or glare; avoid direct operator light over the scanning area.
9. Calibrated Scanner – The *intra oral scanners* should be periodically calibrated to maintain scanning accuracy.

2.3. Accuracy, Precision, Trueness, Scanning Speed, Time, and Weight of Intraoral Scanners

The clinical performance of intraoral scanners is evaluated using several critical metrics—accuracy, precision, trueness, scanning speed, scanning time, and device weight—all of which directly impact clinical outcomes, operator usability, and patient experience.

1. Accuracy: Accuracy is the overarching term used to describe how close the digital impression is to the actual intraoral structure.
 - a. For single crowns and short-span restorations, intraoral scanners demonstrate accuracy levels between 10–50 μm .^{2,4}
 - b. For full-arch impressions, accuracy may decline to 75–200 μm , particularly due to cumulative stitching errors and lack of reference points³.
2. Trueness: Trueness refers to the degree of deviation of a scan from the actual anatomical structure.
 - a. Studies report trueness values of 15–40 μm for anterior single units and 50–80 μm for posterior segments.¹
 - b. In full-arch scans, trueness drops to >100 μm , necessitating hybrid workflows or verification methods⁷.
3. Precision: Precision refers to the repeatability of a scan—how consistently the same scanner can replicate the same scan under identical conditions.
 - a. High-performance scanners show precision in the range of 5–30 μm for short spans.⁶
 - b. Precision may be compromised in larger spans due to intraoral movement, saliva interference, and scan strategy inconsistencies.
4. Scanning speed: Scanning speed plays a vital role in enhancing both clinical workflow efficiency and patient comfort. It is primarily influenced by the type of scanner technology used—confocal systems, for instance, capture multiple focal planes at once, allowing for fast and accurate data acquisition with minimal movement, unlike triangulation-based systems. Additionally, software performance and operator technique significantly impact overall scanning speed.
 - a. Most modern scanners (e.g., TRIOS, iTero, Medit i700) acquire up to 20–60 frames per second.

- b. Full-arch scans typically require 45 seconds to 2 minutes, while quadrant scans can be completed in 15–30 seconds, depending on user proficiency.⁸
- 5. Total scanning time: Clinical scanning time includes pre-scan setup, actual scanning, rescanning missed areas, and data export.
 - a. For a single crown: 1–3 minutes.
 - b. For full arch: 2–5 minutes, depending on intraoral conditions, tissue movement, and scanning protocol⁷.
- 6. Weight and ergonomics: The weight and balance of intraoral scanners impact clinician comfort and scanning precision, especially during longer procedures.

Ergonomically balanced, lightweight scanners reduce operator fatigue and improve intraoral access in posterior regions and pediatric or special needs patients.⁸

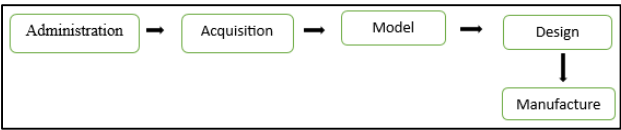
Table 1: Table showing various intra-oral scanners and their weight

Scanner	Approx. Weight (g)	Notes
3Shape TRIOS 4	~340 g	Wireless, lightweight, ergonomic
Medit i700	~245 g	Compact design, lightest in class
iTero Element 5D	~500 g (with wand)	Tethered design, built-in screen
Planmeca Emerald S	~230 g	Among the lightest, modular tip

2.4. Workflow

The workflow followed by the scanner involves the following phases (Chart 1)

- 1. Administration: In this phase, all the patient’s details are entered, such as the Patient’s name, Date of birth, Clinician’s name and purpose for scanning (i.e, crowns, implants etc.)
- 2. Acquisition: In this phase, scanning of the prepared tooth and arch is done. Scanning of the opposing arch as well as buccal scan is also done.
- 3. Model: Model is prepared, trimmed and edited from scanning.
- 4. Design: Design for the desired preparation is done according to the clinician's choice.
- 5. Manufacturing: From all the above data, the prosthesis is manufactured by milling, sintering and printing.



2.5. Workflow of intraoral scanner

Intraoral scanners store 3D digital impressions in file formats like STL, OBJ, and PLY.

- 1. STL – The clinical standard
 - a. Intraoral scanners commonly store 3D data in STL (Standard Tessellation Language) format, which captures only the surface geometry of scanned objects using a triangular mesh. STL remains the gold standard in restorative dentistry due to its small file size, high compatibility with CAD/CAM systems, and ease of processing. It is widely used for crown and bridge fabrication, where black &white and texture data are not critical.
- 2. OBJ – Enhanced visualization
 - a. OBJ (Object) files build upon STL functionality by incorporating surface detail, texture, and color information, often linked via associated MTL(material template library) files. This makes OBJ ideal for cases where visual accuracy is important, such as in orthodontics, digital smile design, and patient education. While not universally supported across all dental CAD systems, OBJ provides richer models for soft tissue visualization.
- 3. PLY – High-fidelity diagnostics
 - a. The PLY (Polygon File Format) supports per-vertex color and sometimes transparency, offering photorealistic renderings with high geometric accuracy. PLY is particularly useful in research settings, extraoral prosthetic design, and digital facial reconstruction. However, its larger file size and limited support in mainstream dental systems restrict its routine clinical use.

2.6. Clinical Implication

The choice between STL, OBJ, and PLY should be dictated by the specific clinical task, desired visual detail, and software compatibility. STL remains the most universally accepted for restorative workflows, while OBJ and PLY are gaining traction in visualization-heavy and research-oriented applications.

2.7. Advantages

- 1. Accuracy and Precision: Several studies have confirmed that intraoral scanners provide comparable accuracy to traditional impression materials.^{2,7}
- 2. Patient Comfort: Digital impressions eliminate the need for impression trays and materials, which can cause gagging and discomfort in some patient.⁹
- 3. Time Efficiency: The use of intra oral scanners can reduce the time required for impression-taking and minimize the number of clinical appointments needed.¹⁰
- 4. Improved Communication with Laboratories: Digital files can be easily shared with dental laboratories,

facilitating better communication and reducing the chances of errors in prosthesis fabrication.¹

5. Intraoral scanners provide real-time feedback, allowing immediate correction of errors like undercuts, voids, and inadequate clearance in FPDs, enhancing accuracy and reducing retakes.¹¹
6. Integration with Digital Workflow: intra oral scanners is easily integrated into a complete digital workflow that includes CAD/CAM systems, which streamlines the fabrication of prostheses and improves the predictability of outcome.¹²

2.8. Limitations

1. Learning Curve: Mastering the use of intraoral scanners can require a significant learning period, particularly for older practitioners accustomed to traditional methods.¹³
2. Initial Cost and Maintenance: The initial investment for intraoral scanners is relatively high, and they require regular software updates and maintenance.¹⁴
3. Limitations in Scanning Edentulous Areas: Intraoral scanners struggle to capture soft tissue details, undercuts, and mucosal compressibility in fully edentulous cases, limiting their accuracy in complete denture fabrication¹⁵.
4. Artifacts and Errors: Errors such as image stitching artifacts can occur, especially if the scanner is moved too quickly or if there is inadequate moisture control in the oral cavity.¹⁵

2.9. Applications in Prosthodontics

The application of intraoral scanners in prosthodontics has revolutionized digital workflows by enhancing impression accuracy, clinical efficiency, and patient comfort. Their use spans multiple prosthodontic domains, including implant-supported prostheses, fixed restorations, removable prosthodontics, and maxillofacial rehabilitation. However, the clinical performance and reliability of intra oral scanners vary based on the type and extent of the prosthodontic intervention, particularly between single-implant cases, full-arch implant prostheses, and maxillofacial prosthetic applications.

2.10. Removable prosthodontics

Intraoral scanners are increasingly used for designing cast partial dentures (CPDs), replacing traditional steps with digital impressions, virtual articulation, CAD-based design, and additive/subtractive manufacturing. Intra oral scanners demonstrate high accuracy in tooth-supported (Kennedy Class III) cases,⁴ but are less reliable in mucosa-supported areas (Class I & II) due to soft tissue compressibility. Hybrid techniques like intraoral relining and border moulding are advised for these cases. Benefits include greater patient comfort, faster workflow, and reduced analogue errors, though capturing flabby tissues and borders remains challenging. For complete dentures, intra oral scanners improves comfort and CAD/CAM integration, while

functional relining enhances accuracy. In TMD, intra oral scanners supports digital occlusal analysis, bite registration, and splint fabrication via jaw tracking systems.^{1,5}

2.11. Fixed prosthodontics

Intra Oral Scanners is widely adopted in fixed prosthodontics for capturing fine details in crowns, bridges, veneers, and onlays. The digital workflow—from tooth preparation to CAD/CAM fabrication—improves clinic-lab communication and eliminates physical models. Intra oral scanners excel in single crowns and short-span bridges, offering excellent fit and detail², with clinically acceptable marginal gaps (<100 µm).⁴ Accuracy depends on scanner type, technique, and tissue isolation. Advantages include patient comfort, real-time feedback, efficient workflow, and shade selection. Limitations include reduced accuracy in subgingival margins, long-span restorations, and reliance on clinician skill.¹

2.12. Implant prosthodontics

For single implants, intra oral scanners offers high accuracy, efficiency, and patient comfort, often surpassing conventional methods. The digital workflow captures scan body orientation and enables CAD/CAM fabrication³, with enhanced results using chairside milling². Full-arch implant scanning remains challenging due to stitching errors and a lack of landmarks, risking misfit¹⁹. Accuracy improves with cross-arch scanning, splinted scan bodies, segmented scans, and hybrid approaches²⁰. While intra oral scanners can be reliable in ideal conditions, splinted open-tray techniques remain more predictable³.

2.13. Maxillofacial prosthodontics

Intra oral scanners enables minimally invasive, accurate capture of intraoral and craniofacial defects for prosthesis design. It supports scanning of palatal defects (e.g., cleft palate, post-maxillectomy) and, when merged with CBCT and facial scans, facilitates extraoral prosthesis fabrication (e.g., nasal, orbital, auricular). The digital workflow enhances patient comfort and prosthesis fit through reproducible data, though challenges in scanning mobile tissues and large facial areas persist, often addressed using a hybrid imaging technique.⁸

3. Recalibration of Intraoral Scanners (Intra Oral Scanners)

Recalibration is essential for maintaining the accuracy and reliability of intraoral scanners, as frequent use, environmental factors, and hardware wear can cause sensor drift. It corrects optical deviations, ensuring precise data capture for dental applications.

1. Pre-Recalibration Assessment- involves evaluating scan quality, inspecting the scanner for damage or contamination, and following manufacturer prompts—

- especially after software updates, extended inactivity, or before critical procedures.¹⁴
2. **Calibration Setup-** uses manufacturer-specific tools (e.g., jigs or blocks) and dedicated software. The scanner must be on a stable surface with proper lighting, and calibration devices must be clean and correctly positioned. Systems like TRIOS, iTero, and Medit follow proprietary protocols, with some offering automated guidance.¹
 3. **Execution-** involves projecting structured light or lasers onto a reference object. The scanner compares this data to preset standards and adjusts internal settings to restore baseline accuracy. Recalibration is typically recommended every 1–2 weeks for routine use.⁷
 4. **Error Handling-** includes automated adjustments for minor deviations. If calibration fails, users may need to clean the scanner, replace the calibration tool, or contact support. Most systems provide feedback and error codes to guide corrections.
 5. **Post-Recalibration Validation-** is done using a test scan on a typodont or reference model to verify trueness, stitching accuracy, and marginal integrity.¹
 6. **Documentation of recalibration**—date, outcome, tool used, and operator ID—is crucial for quality assurance, traceability, and regulatory compliance.¹⁴

3.1. Future directions

Future research on intraoral scanners should enhance accuracy in edentulous arches and improve full-arch scan trueness. Integration with CBCT, AI-based diagnostics, and real-time error correction will expand clinical applications. Focus on material differentiation and standardization will support broader adoption and interoperability.

3.2. Care and disinfection of intra-oral scanners

Proper care and disinfection of intraoral scanners are vital for infection control and maintaining device performance. Adhering to recommended cleaning protocols prevents cross-contamination and extends scanner longevity¹.

1. **Routine Handling**
 - a. Handle the scanner carefully.
 - b. Inspect the scanner tip after each use for debris, smudges, or condensation.
2. **Scanner Tip Disinfection**
 - a. Autoclavable tips (e.g., TRIOS, Medit): Steam sterilize at 121–134°C for 3–10 minutes.
 - b. Non-autoclavable tips: Clean with 70% isopropyl alcohol wipes, ensuring full surface coverage and sufficient contact time.
3. **Scanner Body Cleaning**
 - a. Use non-abrasive, alcohol-free disinfectant wipes.
 - b. Avoid entry of liquids into ports, lenses, or optical components.
4. **Barrier Protection**

- a. Use single-use scanner sleeves during each patient appointment.
 - b. Change sleeves between patients.
 - c. Maintain strict glove hygiene when handling the device.
5. **Storage and Environment**
 - a. Store the scanner in a clean, dry, temperature-controlled area.
 - b. Avoid direct sunlight, dust, and moisture exposure.
 6. **Post-Sterilization Handling**
 - a. Allow sterilized tips to cool and dry completely before reuse to prevent fogging or image distortion.
 7. **Manufacturer Protocols**
 - a. Follow device-specific instructions for cleaning, disinfection, calibration, and software updates as provided by the manufacturer.

4. Conclusion

Intraoral scanners are an invaluable tool in contemporary prosthodontics, offering numerous benefits over traditional impression techniques. Despite some limitations, ongoing advancements in technology are likely to overcome these barriers, leading to broader adoption and more widespread use in various prosthodontic applications. The digital revolution in dentistry, spearheaded by intra oral scanners, promises enhanced patient outcomes, streamlined workflows, and improved prosthetic accuracy.

5. Source of Funding

None.

6. Conflict of Interest

None.

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Cite this article: Slilekha R. Intraoral scanners in digital dentistry. *IP Ann Prosthodont Restor Dent.* 2025;11(3):210-215.