# Classification of Intraoral Scanners in Dentistry: Technologies, Clinical Applications, and Recent Advancements—A Narrative Review

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## ABSTRACT

**The adoption of digital workflows has fundamentally transformed contemporary prosthodontic practice, with intraoral scanners (IOS) playing a central role in impression making, diagnosis, treatment planning, and prosthesis fabrication. Intraoral scanning offers multiple advantages over conventional elastomeric impressions, including improved patient comfort, enhanced clinical efficiency, digital data storage, and seamless integration with computer-aided design and computer-aided manufacturing (CAD/CAM) systems. However, the wide variety of commercially available IOS systems—differing in optical principles, scanning strategies, accuracy, workflow integration, and clinical indications—poses challenges for evidence-based selection and optimal clinical use. The purpose of this narrative review is to present a comprehensive classification of intraoral scanners based on scanning technology, data acquisition and tracking methods, ergonomics, and workflow characteristics, while highlighting recent technological advancements that influence prosthodontic outcomes. Emphasis is placed on developments such as artificial intelligence–assisted scanning, cloud-based data processing, wireless systems, and emerging optical technologies, with a focus on their clinical relevance in prosthodontics.**

**Keywords: Intraoral Scanners, Digital Impressions, CAD/CAM Dentistry, Prosthodontics, Optical Scanning**

## INTRODUCTION

Digital dentistry has rapidly evolved over the past two decades, reshaping conventional clinical and laboratory workflows in prosthodontics. Among digital innovations, intraoral scanners have emerged as a pivotal technology, enabling direct acquisition of three-dimensional (3D) dental and oral structures without the need for traditional impression materials. IOS systems generate digital impressions that can be immediately used for diagnosis, virtual treatment planning, prosthesis design, and fabrication using subtractive or additive manufacturing techniques[1,2].

Compared with conventional impressions, intraoral scanning offers several clinically significant advantages, including improved patient acceptance, reduced gag reflex, elimination of material distortion, and enhanced communication between clinicians and dental laboratories[3]. Additionally, digital impressions facilitate data storage, duplication, and transfer, thereby supporting long-term patient record management and interdisciplinary collaboration[4]. These advantages have contributed to the increasing adoption of IOS systems in fixed prosthodontics, implant dentistry, orthodontics, and, more recently, complete denture workflows[5].

Despite their widespread use, IOS systems are not homogeneous. Variations exist in optical principles, image acquisition strategies, tracking algorithms, and integration within digital ecosystems. These differences influence scanning accuracy, learning curve, cost, and clinical applicability[6]. Consequently, a structured classification of intraoral scanners is essential for clinicians to understand system-specific strengths and limitations, enabling informed decision-making and evidence-based clinical application.

### Methodology of the Narrative Review

This narrative review was conducted to synthesize current knowledge regarding the classification and technological evolution of intraoral scanners used in dentistry, with particular emphasis on prosthodontic applications. A comprehensive literature search was performed in electronic databases including PubMed/MEDLINE, Scopus, and Web of Science, focusing on publications related to intraoral scanning technologies, digital impressions, and prosthodontic accuracy. Keywords included *intraoral scanner*, *digital impression*, *optical scanning*, *prosthodontics*, and *CAD/CAM dentistry*.

Priority was given to peer-reviewed articles published in leading prosthodontic and dental journals, including clinical trials, in vitro accuracy studies, systematic reviews, and seminal technical papers. Additional references were identified through manual screening of bibliographies of relevant articles. The included literature was critically analysed and organized into thematic categories reflecting scanner classification, technological principles, and clinical implications.

**Classification Based on Scanning Technology**

The fundamental distinction among intraoral scanners lies in their optical scanning technology. These technologies determine how surface geometry is captured, reconstructed, and converted into digital 3D models. The primary scanning principles include laser triangulation, structured light projection, confocal microscopy, and emerging optical modalities[7].

**1 Laser Triangulation Technology**

Laser triangulation is one of the earliest optical principles applied in intraoral scanning. This method involves projecting a laser beam or laser line onto the dental surface and capturing the reflected light at a known angle using a sensor. The distance and geometry of the surface are calculated through triangulation algorithms[8].

Laser triangulation scanners are capable of high precision when scanning limited areas, such as single prepared teeth or short-span restorations. However, they are particularly sensitive to reflective, translucent, or moist surfaces, which may scatter laser light and reduce data accuracy[9]. Earlier systems often required surface powdering to reduce reflectivity, increasing chairside time and patient discomfort.

Recent advancements in laser triangulation include the use of multi-line lasers, improved optical filters, and enhanced image processing algorithms, which have reduced the dependency on powder application and improved scan consistency[10]. Despite these improvements, laser triangulation has largely been superseded by other optical technologies in newer IOS systems.

**2 Structured Light Scanning**

Structured light technology has become one of the most widely adopted scanning principles in modern intraoral scanners. This technique involves projecting a predefined pattern of light—such as stripes or grids—onto the dental surface. Cameras capture the distortion of the projected pattern, and specialized software reconstructs the 3D surface geometry based on this deformation[11].

Structured light scanners offer rapid image acquisition and high surface detail, making them suitable for full-arch scanning and orthodontic applications. Unlike laser-based systems, structured light scanners are less sensitive to surface reflectivity and can capture colour and texture information simultaneously[12].

Recent developments include cross-polarized and multispectral structured light systems, which reduce glare from enamel and restorative materials while enhancing soft tissue visualization. These improvements have expanded the clinical applicability of structured light scanners in prosthodontics, particularly for margin detection and esthetic evaluation[13].

**3 Confocal Microscopy**

Confocal microscopy–based intraoral scanners acquire images by focusing light at specific depths and capturing only the in-focus reflections. By recording multiple focal planes, these systems reconstruct accurate surface geometry without requiring surface powdering[14].

Confocal scanners demonstrate high trueness and precision for single-unit restorations and short-span fixed dental prostheses. Historically, limitations included slower scanning speed and reduced accuracy for long-span or full-arch scans due to cumulative stitching errors[15].

Technological improvements such as extended depth-of-field optics, higher frame rates, and advanced stitching algorithms have significantly enhanced confocal scanner performance. As a result, confocal technology remains highly relevant in contemporary prosthodontic practice[16].

**4 Emerging Optical Technologies**

Emerging scanning modalities, including optical coherence tomography (OCT) and active wavefront sampling, represent potential future directions for intraoral scanning. OCT enables subsurface imaging and has shown promise in detecting subgingival margins and soft tissue contours, although its use remains largely experimental[17]. Active wavefront sampling employs dynamic optical modulation to capture depth information and may offer advantages in motion compensation and scanning stability[18].

**Data Acquisition and Image Reconstruction Strategies**

Beyond optical principles, intraoral scanners differ significantly in their data acquisition modes and image reconstruction strategies, which directly influence scanning efficiency, learning curve, and accuracy.

**1 Video-Based Continuous Scanning**

Most contemporary IOS systems employ continuous video-based scanning, wherein a sequence of overlapping images is captured as the scanner tip moves across the dental arch. These images are stitched together in real time using proprietary algorithms to generate a 3D virtual model[19].

Video-based scanning offers an intuitive workflow and reduced scanning time, particularly for full-arch impressions. However, accuracy is dependent on consistent scanner movement, adequate overlap between frames, and robust stitching algorithms. Operator experience plays a critical role, as abrupt movements or loss of tracking can introduce cumulative errors[20].

Recent developments in artificial intelligence (AI)–driven reconstruction algorithms have improved real-time error detection and auto-correction, thereby reduced operator dependency and enhanced scan reliability[21].

**2 Single-Shot and Hybrid Image Capture**

Single-shot imaging systems capture discrete images of the scanned surface rather than continuous video. These systems historically demonstrated high trueness for localized areas but were slower for full-arch scanning[22]. Hybrid systems combining single-shot accuracy with continuous capture speed have recently emerged, leveraging high-speed sensors and parallel processing to optimize both precision and efficiency[23].

**Tracking Methods and Spatial Orientation**

Accurate spatial tracking is fundamental for successful image stitching and 3D reconstruction.

**1 Marker-Based Tracking**

Marker-based tracking systems rely on artificial reference markers placed intraorally or on scan bodies to facilitate spatial orientation. These systems have demonstrated improved accuracy in challenging scenarios such as edentulous arches and full-arch implant scans[24]. However, the need for additional clinical steps and materials limits their routine use.

**2 Marker-Free Tracking**

Marker-free tracking systems utilize natural anatomical landmarks, surface texture, and geometric features for spatial orientation. Advances in machine learning and pattern recognition have significantly improved the reliability of marker-free tracking, making it the preferred method in modern IOS systems[25].

**Powder Requirement and Surface Treatment**

Early-generation intraoral scanners required application of reflective powder to standardize surface reflectivity and enhance optical capture. Powder application increased chairside time, compromised patient comfort, and introduced an additional source of dimensional error[26].

Contemporary IOS systems are predominantly powder-free, utilizing advanced illumination control, optical filtering, and image processing to compensate for reflective enamel and restorative materials. Powder-free scanning has been shown to improve patient acceptance and streamline clinical workflows[27].

**Ergonomics, User Interface, and Connectivity**

**1 Scanner Design and Ergonomics**

Ergonomic considerations such as scanner size, weight, balance, and tip design influence operator comfort and scanning efficiency. Modern scanners feature lightweight handpieces, smaller scanner tips, and autoclavable components to improve access in posterior regions and enhance infection control[28].

**2 Wired and Wireless Systems**

While earlier IOS systems relied on wired connections for data transfer and power supply, wireless scanners have gained popularity due to improved mobility and ease of use. Advances in battery technology and low-latency wireless protocols have addressed earlier concerns regarding data loss and scanning interruptions[29].

**3 User Interface and Real-Time Feedback**

Modern IOS software provides real-time visual feedback, color-coded data density maps, and scanning guidance to assist clinicians during image acquisition. These features reduce scanning errors and shorten the learning curve, particularly for inexperienced users[30].

**Clinical Applications in Prosthodontics**

**1 Fixed Dental Prostheses**

Intraoral scanners have demonstrated high accuracy for single crowns, inlays, onlays, and short-span fixed dental prostheses. Multiple studies have reported comparable or superior marginal and internal fit of restorations fabricated from digital impressions compared with conventional impressions[31,32].

**2 Implant Prosthodontics**

IOS systems capture implant position using scan bodies, enabling fully digital workflows for implant-supported restorations. While high accuracy has been reported for single implants and short-span restorations, full-arch implant scanning remains challenging due to cumulative stitching errors[33]. Recent improvements in scan body design and alignment algorithms have enhanced accuracy in complex implant cases[34].

**3 Edentulous and Full-Arch Scanning**

Edentulous arch scanning presents inherent challenges due to the lack of stable anatomical landmarks. AI-assisted stitching algorithms and marker-assisted approaches have improved scan reliability, expanding the role of IOS systems in complete denture fabrication and full-arch implant rehabilitation[35].

**Workflow Integration and Data Output Formats**

**1 Open and Closed Digital Systems**

IOS systems may operate within open or closed digital ecosystems. Open systems allow export of standard file formats such as STL, PLY, and OBJ, facilitating laboratory flexibility and interoperability. Closed systems offer seamless integration with proprietary CAD/CAM platforms but may limit cross-platform compatibility[36].

**2 Colour and Texture Data**

Modern IOS systems capture full-colour and texture information, enhancing communication with dental laboratories and improving shade selection and esthetic planning. Emerging AI-based shade analysis tools further support prosthodontic decision-making[37].

**Accuracy, Trueness, and Precision**

Accuracy of intraoral scanners is commonly evaluated in terms of trueness and precision. While high trueness has been consistently reported for short-span restorations, full-arch accuracy remains system- and technique-dependent[38]. Continuous improvements in software algorithms and validation protocols have progressively enhanced full-arch scanning performance[39].

**Artificial Intelligence, Cloud Computing, and Recent Advancements**

Artificial intelligence (AI) has emerged as a transformative component in contemporary intraoral scanning systems. AI-driven algorithms are increasingly incorporated to enhance image stitching, identify missing data, and provide real-time scan guidance to clinicians[40]. These systems can automatically detect scanning errors, incomplete coverage, and distortions, thereby improve scan quality and reduce operator dependency[41].

Machine learning–based margin detection and tooth segmentation have further improved the accuracy and efficiency of prosthodontic workflows, particularly in crown and implant restorations[42]. AI-assisted analysis has also demonstrated potential in improving full-arch scan accuracy by compensating for cumulative stitching errors, a longstanding limitation of IOS systems[43].

Cloud-based platforms represent another significant advancement, enabling remote data processing, storage, and collaboration between clinicians and dental laboratories. Cloud integration facilitates real-time case sharing, software updates, and access to advanced computational resources without reliance on high-performance local hardware[44]. Concerns regarding data security and patient privacy have been addressed through encrypted data transmission and compliance with international data protection standards[45].

**Multimodal Data Integration and Digital Prosthodontic Planning**

The integration of intraoral scanner data with cone-beam computed tomography (CBCT) has enabled comprehensive digital treatment planning. Superimposition of surface scan data with volumetric radiographic information allows precise evaluation of hard and soft tissues, implant positioning, and prosthetic design[46].

This multimodal approach has proven particularly valuable in implant prosthodontics and full-arch rehabilitation, supporting prosthetically driven implant placement and guided surgery[47]. The continued refinement of registration algorithms and data fusion techniques is expected to further enhance treatment accuracy and predictability.

**Clinical Implications for Prosthodontic Practice**

Understanding the classification and technological capabilities of intraoral scanners is essential for prosthodontists when selecting an IOS system. Scanner selection should be guided by clinical indications, required accuracy, workflow integration, and economic considerations[48].

For single-unit and short-span restorations, most contemporary IOS systems demonstrate clinically acceptable accuracy. However, for full-arch implant-supported prostheses and edentulous cases, clinicians should carefully consider scanner-specific limitations and adopt adjunctive strategies such as scan bodies or markers[49].

Additionally, training and experience remain critical factors influencing scanning outcomes. Despite advances in AI and automation, proper scanning protocols and operator competence are essential for achieving optimal results[50].

**Limitations of Intraoral Scanning Technologies**

Despite ongoing technological improvements, IOS systems present inherent limitations. Optical scanning remains sensitive to saliva, blood, and reflective materials, which may compromise data acquisition in certain clinical scenarios[51]. Furthermore, discrepancies in full-arch accuracy across systems and scanning strategies highlight the need for continued validation and standardization[52].

Economic barriers, including high initial investment costs and recurring software fees, may limit widespread adoption in some clinical settings[53]. Long-term clinical studies evaluating prosthesis survival and patient-centred outcomes remain limited and warrant further investigation.

**Future Directions**

Future advancements in intraoral scanning are expected to focus on further integration of AI, enhanced full-arch accuracy, and improved soft tissue capture. Emerging optical technologies such as optical coherence tomography may enable subsurface imaging, offering new diagnostic possibilities[54].

Continued development of open digital ecosystems and standardized data formats is anticipated to enhance interoperability and foster innovation in prosthodontic workflows[55].

## CONCLUSION

Intraoral scanners have become an indispensable component of modern prosthodontic practice. Classification based on scanning technology, data acquisition strategies, workflow integration, and clinical application provides a structured framework for understanding current IOS systems and their limitations. Ongoing advancements in artificial intelligence, cloud computing, and multimodal data integration continue to expand the clinical potential of intraoral scanning. Evidence-based selection and appropriate clinical application remain essential to fully realize the benefits of this evolving technology.

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