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DIGITAL INTRAORAL SCANNERS AND CLEAR ALIGNERS – A NARRATIVE REVIEW

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ABSTRACT

The advent of digital technology has transformed dentistry and the most significant advancement is digital intraoral scanners (IOS). IOS replaced the conventional impressions with fast, precise, and patient-friendly digital scanning, simplifying the workflow. They offer precise calculations for computer-aided virtual treatment planning, in vivo error detection and correction, and direct interfacing to CAD/CAM systems, which may increase patient satisfaction and clinical success. Evidence has shown that the IOS are as precise as or more precise than traditional impressions, are more convenient for the patient, and save chairtime and lab time. Scanners such as iTero, TRIOS, 3M True Definition, and CEREC Omnicam offer treatment simulation, occlusion analysis, and prosthetic integration. With barriers such as expense, learning curves, and technical constraints, future developments in imaging, artificial intelligence, and 3D printing increasingly enhance the availability and precision of digital dentistry.

Keywords: Digital dentistry, Intraoral scanner, Clear aligner therapy, CAD/CAM, Orthodontics, Prosthodontics, Implantology, Digital workflow

Introduction

Dentistry has been transformed in recent decades with the advent of digital technology. Perhaps one of the most significant changes has been digital intraoral scanners (IOS) that have changed impressions, storage, and use in practice.[1] IOS replace conventional impression material with rapid, precise, and patient-comfortable digital scanning. They are being used more and more in

orthodontics, prosthodontics, implantology, and restorative dentistry, simplifying workflows and improving outcomes.[1,2]

This has been accompanied by the development of clear aligner therapy, which has changed orthodontic treatment since it offers patients esthetic and removable options to traditional brackets.[3] The expansion in the use of IOS has also encouraged the adoption of clear aligners, which enable highly personalized treatment planning, real-time simulation, and lower-appliance fabrication.[4]

This is an in-depth overview of intraoral digital scanners: history, technologies, clinical use, benefits and pitfalls, and orthodontic application. A brief review of clear aligners and IOS synergy with them is added.

Historical Evolution of Intraoral Scanners

CAD/CAM dentistry is traced back to the early work of François Duret in the early 1970s, who first conceived its potential use in clinical practice.[5] Its original concept of using digital technology for designing and manufacturing dental restorations formed the foundations of what would actually revolutionize the dental workflows of today. The game-changer came in 1987 with the introduction of the first commercial CAD/CAM restorative system, CEREC, by Sirona Dental Systems. This permitted chairside milled ceramic restorations as well as the clinician to plan indirect restorations all within one sitting.[6] This was the starting point of the application of digital dentistry to daily practice.

Although this was the game-changer step, the early CAD/CAM systems were not very pragmatic. First-generation technologies were generally most in demand for accuracy, very technically sophisticated, and prohibitively costly, and therefore out of reach for extensive use. Unrelenting technological advancements during the 1990s and early 2000s further enhanced system stability. The largest milestone of 2006 was iTero (Cadent, eventually acquired by Align Technology) bringing the ability to capture full-arch intraoral scans and, more significantly, directly integrate with Invisalign clear aligner technology.[7] Not only did this fill in the earlier gaps, but it launched the digital revolution of orthodontics by pairing precise digital impressions with uniquely tailored aligner manufacturing.

As iTero became more widely accepted, various leading dental firms deluged the market with their own high-end scanners. 3Shape introduced TRIOS, 3M introduced the True Definition Scanner, and Dentsply Sirona introduced Omnicam, each of which had increased scanning speed, precision, ergonomics, and software compatibility. Together, these improvements democratized intraoral scanning by allowing clinicians to have more access to a series of devices that accommodated various practice needs.[6-8]

The technology of intraoral scanners has multiplied many times over the past decade. Greater accuracy of imaging, greater volumes of data capture, usability and more compliant digitization established IOS as a landmark in orthodontics, prosthodontics, dental implants, and restorative dentistry. Now, more than a dozen commercially employed systems are available worldwide, thereby cementing their central role in framing the future of digital dentistry.[8,9]

Imaging Technologies of IOS

Intraoral scanners (IOS) rely on many different optical principles, each with its own strengths and limitations that dictate their use in the clinic. Three of the most commonly used technologies are confocal laser scanning, triangulation, and active wavefront sampling, or 3D-in-motion video.[9,10]

Confocal laser scanning employs a converged laser light beam to its point of incidence to record sequential images at different focal depths and eliminate out-of-focus information to a certain extent. Selective imaging is used to reconstruct three-dimensional models with high accuracy and is hence most suited for intricate restorative and orthodontic procedures. Some of the such technology includes iTero and 3Shape TRIOS scanners, which have demonstrated consistent performance in both clinical and laboratory setups.[10]

The triangulation method, on the other hand, is based on geometric computation between a sensor, light, and dental structure surface to identify spatial position. Triangulation-scanner designs in early models used radiopaque powder to reduce reflective artifacting, which has been eliminated to a large degree from modern devices. CEREC Omnicam is one demonstration of how the principle has been adapted in terms of accurate and faster scanning for clinicians with less preparation.[11]

Active wavefront sampling, or 3D-in-motion video, records uninterrupted sequences of images with the assistance of complementary sensors, creating highly redundant datasets that allow precise and dynamic reconstructions of intraoral surfaces. It is through such systems, like the 3M True Definition scanner, that apply this method to provide improved resolution and reproducibility.[11,12]

There have been newer technology improvements that have yielded powder-free high-speed capture and full-colour scanning, further improved the differentiation between hard and soft tissues and further improved the precision of digital impressions. These improvements collectively highlight the changing capabilities of IOS because they are demonstrating their fundamental purpose in modern digital dentistry.

Digital vs. Conventional Impressions

Various studies have contrasted the relative accuracy of intraoral scanners (IOS) with conventional impression techniques, in areas such as accuracy, patient comfort, and workflow efficiency. Accuracy is a most important consideration in restorations and orthodontics. Ender et al. asserted that complete-arch digital impressions had an accuracy of approximately 50 μm, considerably higher than the 162 μm of alginate impressions.[13] This is supported by many systematic reviews, which reach the conclusion that IOS generally have an accuracy comparable to or superior to that of conventional impressions in a variety of clinical scenarios.[14,15] The high trueness and reproducibility of IOS enable clinicians to acquire restorations and appliances that are closer fitting and therefore enhance clinical success.

Patient comfort is a very important advantage of digital impressions. Traditional methods of impression are likely to cause gag reflex, unpleasant tastes, and cause discomfort regarding

tray size and consistency of the material. IOS largely minimize these issues, making it a more patient-friendly procedure. There are problems, however, with large scanner tips, particularly in the posterior regions or in patients with a tight oral opening.[16] Workflow efficiency is much improved with computerized systems. Classic impressions have many steps of tray selection, handling of material, pouring of cast, and storing, each with a risk of error and delay. IOS eliminates all this by providing real-time visualization so that correction of error instantly is feasible, and digital files can be sent directly to labs. This not only conserves chairside and laboratory time but also facilitates digital storage and integration into CAD/CAM systems.[17] Table 1 summarizes these distinctions, illustrating the obvious advantages of IOS over conventional impressions regarding comfort, accuracy, workflow, storage, time conservation, and long-term cost considerations.

Table 1. Comparison of Conventional vs. Digital Impressions

Parameter	Conventional Impressions	Intraoral Scanners
Patient Comfort	Gag reflex, unpleasant taste, anxiety	Generally more comfortable, except for large wands
Accuracy	Material distortion/shrinkage possible	High trueness (40–80 μm) and reproducibility
Workflow	Multiple manual steps	Direct digital workflow, instant error correction
Storage	Bulky stone casts, risk of breakage	Digital archiving, cloud storage, 3D print capability
Time Efficiency	Longer chairside + lab time	Reduced chairside and lab involvement
Cost	Low upfront, ongoing materials	High upfront investment, software/licensing fees

Commercially Available Intraoral Scanners

iTero (Align Technology) employs confocal laser technology and offers a completely powder-free scan procedure. Its best advantage lies in its easy integration with Invisalign, making it the first-choice scanner for clear aligner therapy. It includes an outcome simulator to encourage patients and ensure treatment tracking via monitoring tools for progress measurement. Its slightly more bulky wand and its more easing learning curve for new operators are functional disadvantages.[7] TRIOS (3Shape) relies on confocal-based ultrafast optical sectioning, famed for its high scan rate and accuracy. Wireless models provide ergonomic advantages, and high-level features such as dynamic occlusion recording and patient engagement simulators accompany clinical convenience.[10] 3M True Definition Scanner utilizes active wavefront sampling and is highly precise. It has the smallest wand size, with similarities to dental

handpieces, but powder coating is required in order to give optimal results. CEREC Omnicam (Sirona), with the longest CAD/CAM history, uses triangulation with video streaming in the absence of powder. Its prosthodontic integration is its advantage facilitated by orthodontic software extensions for applications across the board.[11]

Table 2. Selected Digital Intraoral Scanners and Features

Scanner	Imaging Principle	Notable Features	Integrations
iTero (Align)	Confocal laser scanning	Outcome simulator, Invisalign link	Invisalign
TRIOS (3Shape)	Optical sectioning	Wireless, occlusion tracking	Ortho Analyzer, appliances
True Definition (3M)	Wavefront sampling	Small wand, high accuracy	Open STL, ClearCorrect
CEREC Omnicam (Sirona)	Triangulation	Chairside CAD/CAM	CEREC Ortho, restorative dentistry

Clinical Applications of IOS

Orthodontics has been greatly impacted by digital impressions, which have become a standard over stone models. Intraoral scanners enable precise virtual treatment planning due to the fact that indirect bonding trays, individualized appliances, and clear aligners can be manufactured for patient-specific anatomy.[15] This digital process not only raises the predictability of treatment but also leads to higher compliance and comfort for the patient.

In prosthodontics, IOS are increasingly being employed in the design of crowns, bridges, and implant-supported prostheses. High-resolution digital scans allow for excellent fit of restorations, minimizing chairside adjustments to an absolute minimum and remakes, thereby optimizing clinical efficiency and patient satisfaction.[18] In implantology, computer scanning improves the accuracy of implant abutments and surgical guides. A number of studies confirm that IOS provide accuracy comparable to, or better than, that of conventional implant impressions for predictable restorative outcomes.[19,20]

Beyond clinical application, there is enhanced communication since it facilitates the real-time 3D scanning with immediate visualization for both patients and dental labs, with better understanding of treatment progression and outcomes.[21] In addition, the integration of IOS with CBCT and CAD/CAM technologies forms the basis of fully digital workflows, which justify the diagnostic, planning, and manufacturing processes in modern dentistry.[22,23]

Advantages of Digital Intraoral Scanners: [8, 13-17,24]

- Improved patient comfort and acceptance.
- Enhanced accuracy and reproducibility.

- Reduced chairside and laboratory time.
- Digital data archiving and easy transfer.
- Facilitates clear aligner therapy and 3D-printed appliances.
- Supports environmentally friendly workflows (less disposable waste).

Limitations and Challenges: [14,16-18, 25,26]

- High cost of acquisition and maintenance.
- Learning curve for operators, with variability in scanning speed and accuracy.
- Technical issues: reflective surfaces, edentulous areas, saliva, and intraoral motion can affect precision.
- Data management: large file sizes and compatibility issues between systems.
- Patient factors like limited mouth opening or gag reflex can challenge scanner access.

Clear Aligners

Clear aligner therapy, launched by Align Technology with Invisalign in the late 1990s, has become one of the most popular orthodontic treatment modalities at an incredible pace. The success of this method is fundamentally tied to intraoral scanners (IOS), which capture digital impressions with high accuracy necessary for successful appliance fabrication, virtual treatment planning, and outcome simulation.[3,7] By allowing highly individualized treatment, IOS have greatly boosted the predictability and efficiency of aligner therapy.

Clear aligners provide esthetic, comfortable options to traditional fixed appliances. Removability enables enhanced oral hygiene and unrestricted diet. Digital planning enables clinicians and patients to see anticipated treatment results, while the decreased number of emergency visits versus traditional braces contributes to patient convenience.[26]

Although these advantages exist, clear aligners might be less successful in patients with large movements of teeth, rotations, or large skeletal discrepancies. Success depends highly on patient compliance, and the increased cost is still a limiting factor as compared with fixed appliances.[27]

On-trend developments are in-office 3D printing of aligners to reduce production times, artificial intelligence–aided predictive planning, and compatibility with hybrid orthodontic methods, including aligner and temporary anchorage device combinations, for increased treatment applicability.

Conclusion

Intraoral scanners (IOS) have revolutionized dentistry as precise, fast, and patient-friendly substitutes for traditional impressions. Their applications in orthodontics, prosthodontics, and implantology and stress-free compatibility with clear aligner systems have increased the trend towards complete digital workflows at a more rapid pace. With disadvantages like prohibitive

cost, learning curves, and compromised accuracy in a few instances, ongoing improvement in imaging technology, artificial intelligence, and 3D printing keeps improving them. Synergy of IOS and clear aligners is revolutionizing orthodontic treatment with more accurate, esthetic, and comfortable treatments, leading to the adoption of these technologies in contemporary clinical practice.

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