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TRANSFORMING DENTISTRY: THE RISE OF INTRAORAL SCANNERS – A REVIEW

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ABSTRACT
Intraoral scanners (IOS) have transformed the landscape of dental impression taking, offering a modern, digital alternative to traditional methods. By utilizing advanced optical imaging technology, these devices capture precise 3D representations of the oral cavity, significantly enhancing patient comfort and procedural efficiency. This review explores the various types of intraoral scanners, their technological underpinnings, and the multitude of benefits they provide, including improved accuracy, reduced treatment times, and streamlined workflows in dental practices. Despite their advantages, challenges such as high initial costs, learning curves, and limitations in certain clinical scenarios remain. This review underscores the importance of embracing these innovations to enhance patient outcomes and practice efficiency.

Keywords : Scanners, Software, iTero, Trios

INTRODUCTION

Since the eighteenth century, traditional impression techniques have been employed to capture the three-dimensional structure of dental tissues. However, these methods have notable drawbacks, including volumetric changes in the impression materials and expansion of the dental stone, as well as a reliance on a skilled dental laboratory.

Figure 1

Figure 2

To address these challenges, Intraoral scanners (IOS) were developed for use in dental practice.

IOS and CAD/CAM offer several advantages, including:

- Simplified treatment planning
- Improved case acceptance
- Enhanced communication with laboratories
- Decreased operative time

- Lower storage requirements
- Shorter overall treatment durations.

	CONVENTIONAL	DIGITAL
Patient comfort	Gag reflex	Some large scanning wands can trigger a gag reflex in patients.
Impression tray	The need to stock various sizes of impression trays and the increased waste from disposable types pose challenges	sleeves can tolerate autoclaving or can be disinfected & disposable.
Repeatability	If there are flaws, the entire impression may need to be redone, and the model must be poured before confirming whether a repeat is necessary.	The instant zoom-in feature allows for immediate corrections, enabling the adjustment of only the imperfect areas without the need for a complete rescan.
Real-time three-dimensional data	Impressions must be poured into gypsum casts, which results in dual dimensional changes—shrinkage of the impression material and expansion of the gypsum stone—along with a prolonged setting time.	Real-time 3D information is displayed clearly on-screen, enhancing communication between doctors, technicians, and patients.
Technique sensitivity	High technique sensitivity and limited reproducibility for some high-precision impression materials	The results are influenced by the scanning strategy, experience, and skill, as well as the varying performance and learning curves of different machines and imaging principles.
Archiving/Storage	Space required for numerous casts, risk of damage to fragile stone cast.	Digital archiving conserves space, but careful attention is needed for backup storage; 3D-printed resin models are stronger than traditional stone models.
Cost, time	High cost of impression materials and gypsum, more time required for clinical and lab work (from tray selection to pouring stone) and patient-visit appointment	While each unit has a high cost, along with maintenance and upgrade fees, they reduce chair time and the number of patient visits required.

INTRA ORAL SCANNER

It enables the dentist to capture a 3D digital impression (or "optical impression") directly from the patient's mouth in the dental clinic, without any physical contact with the dental structures or preparations, using a chairside device.

IOS = 3 components - Handheld camera, computer and software

Handheld camera -

- **Active** (light with selected wavelength spectrum)(400-850 nm) or
- **passive** (ambient light) camera.

Computer : The models are directly connected to a touchscreen, allowing the practitioner to monitor the progress of the 3D impression in real time, along with other pertinent patient information.

Figure 3

SOFTWARES

The system in use is designed to compile static images or video frames to create a 3D point cloud of the scanned object. This 3D point cloud is generated by the software's recognition of points of interest (POIs), with each POI defined by three coordinates: x and y for position in a plane, and z for the distance from the object. The developed software includes various tools for 3D design and manipulation of digital models. The data can be saved in STL (Standard Tessellation Language or Stereolithography) format, which consists of a series of triangulated surfaces and is the most commonly used format in the field of dentistry.

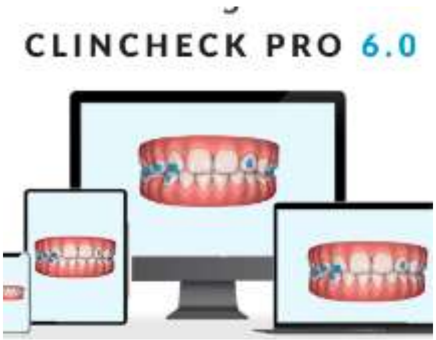

Figure 4

Figure 5

The scanning field size is a minimum of 14x14 mm, with an optimal size of 25x14 mm. The scanning depth should be at least 10 mm to ensure adequate clarity and proper placement of the scanner in the desired area, but should not exceed 14 mm, as this may result in unclear images or fogging on the scanning surface. Additionally, the scanner's resolution should be no less than 25 µm.

MECHANISM OF ACTION

To collect surface data points, energy from either laser light or white light is emitted from the wand onto an object and then reflected back to a sensor or camera within the wand. Using algorithms, tens or hundreds of thousands of measurements are captured per inch, creating a 3D representation of the object's shape.

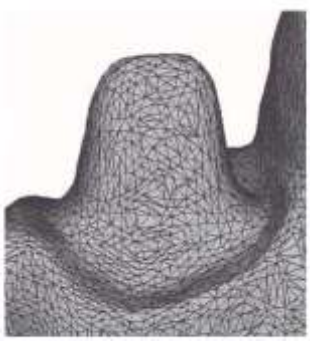

Figure 6

IOS Technologies

Regardless of the imaging technology used by the IOS, all cameras necessitate the projection of light, which is then captured as individual images or video. The software compiles this information after recognizing the points of interest (POIs). The first two coordinates (x and y) of each point are assessed in the image, while the third coordinate (z) is calculated based on the distance to the object, depending on the technology of each camera.

Light Projection & Capture

Image capture, data processing and onscreen results:

Active and passive technologies:

In active techniques, a light point is projected onto an object, and the distance to the object is determined through triangulation. Another method involves projecting light patterns, such as lines or meshes.

A) TRIANGULATION:

The triangulation method has been utilized in the CEREC system for a long time. It involves three points: the laser emitter, the sensor, and the object's surface. The distance between the laser source and the sensor is known, as well as the angle between them. As light reflects off the object, the system calculates the angle of reflection, allowing it to determine the distance from the laser source to the object's surface using the Pythagorean theorem.

With the known distance and angles, surface information can be obtained. However, to enhance detail and minimize unpredictable light dispersion, a thin layer of radiopaque powder may need to be applied to the tooth surface, which helps to standardize the texture (e.g., Optispray® by CEREC, primarily composed of titanium oxide).

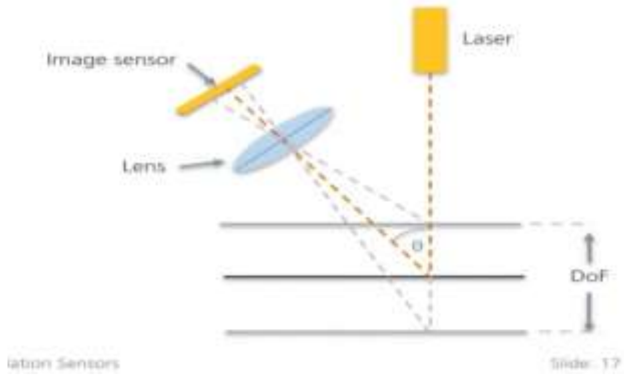

Figure 7

B) Confocal :
The emitting laser is projected through a filter with tiny pinholes onto the target. The confocal imaging plane is established because only the light reflected from the focused object will be captured, while out-of-focus data is excluded. This allows for the reconstruction of the entire 3D structure by collecting 2D images at various confocal planes. This imaging process is also referred to as "point-and-stitch reconstruction." Scanners such as iTero and TRIOS utilize this technique.
This technology can detect the sharpness of the image to infer the distance to the object, which is related to the lens's focal length. A tooth can then be reconstructed using successive images taken at different focal points and aperture settings from various angles around the object.

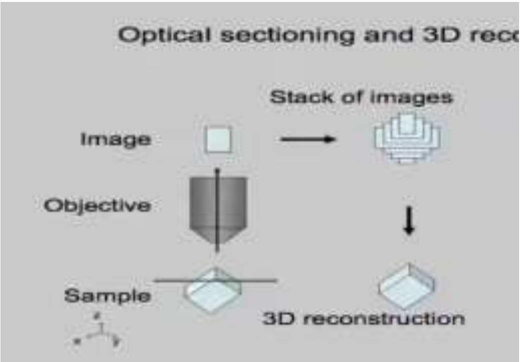

Figure 8

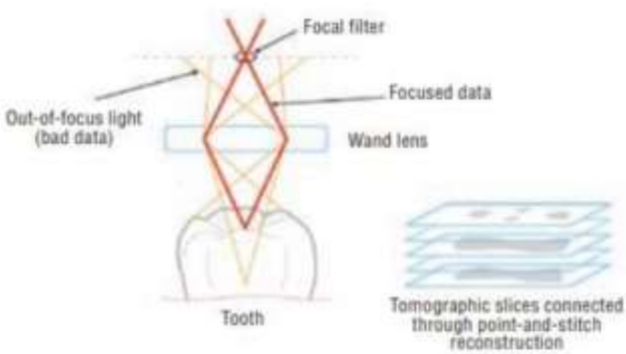

Figure 9

C) **Active wave-front sampling (3D-in-motion video recording)**:
This optical sampling method involves gathering 3D information using a single-lens imaging system that measures depth based on the defocus of the primary optics. Both the Lava Chairside Oral Scanner (COS) and True Definition utilize this technique in their 3D-in-motion video recording technology.
According to 3M ESPE, their active wave-front sampling has advanced into a next-generation technique known as 3D-in-motion technology. This new approach features three key elements: active wave-front sampling, advanced image processing algorithms, and real-time model reconstruction.

RECONSTRUCTION:

A significant challenge lies in matching points of interest (POIs) captured from different angles. Algorithms are employed to calculate similarities, determining which POIs coincide across various images. A transformation matrix is then calculated to assess the similarity among all images. Each coordinate (x, y, and z) is extracted from the projection matrix, resulting in the generation of a file.

HISTORY

In 1973, Dr. Francois Duret was the first to introduce the CAD/CAM technique to dentistry. In the 1980s, Swiss dentist Dr. Werner Mörmann, along with Italian electrical engineer Marco Brandestini, developed the first digital intraoral scanner. This concept was unveiled in 1987 with the CEREC system by Sirona Dental Systems at the University of Zurich.

EVOLUTION OF SCANNERS

The Lava C.O.S. system is provided by the Lava Chair-side Oral Scanner; 3M ESPE, Seefeld, Germany. This system was developed in 2006 and introduced to the market in 2008.The scanner communicates with a mobile host computer and a touch-screen display via pulsating visible blue light. It has the tiniest scanning tip, measuring 13.2 mm wide.
The iTero intraoral scanner, introduced to the market in 2007, employs parallel confocal imaging technology and a red laser to capture 3D digital impressions.
The CEREC Bluecam, the first Sirona system to use photography for intraoral protocols, was introduced in 2009. It can capture a digital impression of one quadrant in just one minute.
Meanwhile, **the True Definition system**, launched by 3M in 2016, utilizes blue LED light and a video imaging system for data collection. This system requires a light dusting of titanium oxide reflective powder, and the scanning area must be properly isolated.
The first edition of **TRIOS** was released in 2010, followed by the launch of TRIOS 3 in 2015, which featured significant enhancements. TRIOS 3 employs the Ultrafast Optical Sectioning technique, based on the confocal laser principle. At the 2017 International Dental Show, this innovative company unveiled the world's first wireless intraoral scanner**.**

Virtuo vivo, also known as DWIO (Dental Wings Intraoral), was launched by Straumann, Canada, in 2017. This system captures digital impressions using open architecture files and incorporates five types of 3D scanners that work together to access challenging areas. It features DWOS CAD software for designing restorations, and its small tip enhances the 3D capturing process through "Multi-scan Imaging Technology." The lightweight handpiece, made of metal, weighs approximately 105 grams.
CEREC PrimeScan: This represents the latest evolution of the manufacturer's intraoral scanner, featuring a touch panel and screen, along with the new CEREC 5 software, available since 2019. With an increased scanning speed, the scanner's processor can handle up to 1,000,000 3D points per second. To effectively capture impressions of the sulcus in sub-gingival preparations or post-extraction sockets, the scanning depth must reach up to 20 mm.
The **Medit i500**, developed in South Korea in 2018, prioritizes productivity, cost-effectiveness, and efficiency. It features two high-speed cameras that allow users to resume scanning from a paused site. Additionally, it employs video photogrammetry to distinguish between soft tissue and dental structures.

EVIDENCES

Miran Kwon et al. evaluated the trueness and precision of full-arch scans obtained with five intraoral scanners (i500, CS3600, Trios 3, iTero, and Omnicam), using an industrial-grade scanner (Solutionix C500) as the reference. The study found that the Omnicam exhibited greater dimensional errors in trueness, particularly for the intermolar distance and the distance from the canine to the contralateral molar. Additionally, both the Omnicam and CS3600 displayed higher precision errors for the linear distance from the canine to the molar within the same quadrant compared to the other scanners.[11]

Pokpomg Amornvit et al. aimed to assess the accuracy of 10 different intraoral scanners (IOS) developed between 2015 and 2020. They printed a maxillary dental model with reference points and performed five scans with each IOS. The resulting 3D scanned files were analyzed, measuring various distances along the X, Y, Z, and diagonal axes. The findings indicated that accuracy decreased with longer scanning distances across all scanners. While trueness varied among the scanners, precision remained consistent. Additionally, diagonal scanning exhibited lower accuracy for all devices, highlighting the need for dentists to adopt effective scanning patterns when capturing full arches. Among the scanners tested, the Trios series demonstrated the best overall performance.[12]

One study indicated that iTero and True Definition exhibit higher accuracy than TRIOS and Omnicam; however, no research has directly compared iTero and True Definition against each other.[13]

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