Intraoral Scanners in Dentistry: A Review

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Abstract

An Intraoral Scanner (IOS) device captures direct optical impressions in dentistry. Harnessing state-of-the-art 3D imaging technologies, Intraoral Scanners accurately capture the shapes and contours of teeth. This advanced technology enables dentists to attain superior scanning results, offering clearer insights into patients' dental structures and ensuring precise and customized treatment. Essentially, these devices streamline the direct optical capture of dental impressions. The objective of the present review of literature is to discuss various Intraoral Scanners (IOS).

Keywords: Intraoral scanners, Intraoral Scanning, Digital impression, Digitalization.

Introduction

The trend of digitalization has led to advanced computer-aided design and computer-aided manufacturing technology (CAD-CAM) extensive use in the field of Prosthodontics. Intraoral scanners (IOS) have various benefits in daily clinical use, including selective repeatability and capture of relevant areas, chairside options, virtual follow-ups, and quick communication with dental technicians.[1,2] Dentists increasingly favor IOS (Intraoral Scanning) technology for implant impressions compared to traditional impression techniques.[3,4] The utilization of IOS streamlines the workflow, potentially minimizing clinical treatment duration, and simultaneously enhancing patient comfort when compared with analog protocols.[5-8] In 1973, Durethas introduced the concept of intraoral scanning for dental applications,[9] where scanners projected a light source onto objects like implant scan bodies and prepared teeth in dental arches. This mechanism shared similarities with other 3D scanners. Today a variety of intraoral scanners are employed in prosthodontics for crafting diverse prostheses. This review aims to assess the evolution of available intraoral scanners and recent advancements.

Intraoral Scanning System

The scanners consist mainly of

1) A machine handling probe movement,
2) A measurement probe,
3) A control or computing system, and
4) Measurement software.[10,11]

The scanning field size ranges minimally from 14x14mm up to optimally 25x14mm, with a scanning depth between 10mm and 14mm for clarity and proper scanner placement. The scanner resolution should be at least 25µm.[12]

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Scanner Types Based on Emission[10]

1) **Optical Scanner:** Projects white light or a laser source, with the source and receiving unit at a specific angle.
2) **3D Laser Scanners:** Emit laser beams and detect their return.
3) **Photographic Technology Scanners:** Have a conical field of view, limiting information collection from hidden surfaces.
4) **Mechanical Scanner:** Scans a gypsum model obtained conventionally from printing.
5) **Video Technology Scanners:** Record scanned areas in a sequential shot manner, similar to a video camera, using the open standard tessellation language.

Evolution of Intraoral Scanners

Impression techniques, model-making, and appliance construction date back to the 18th century. Various impression materials were developed, each with limitations. In recent years, intraoral digital scanners emerged as an alternative to conventional methods.[13] In 1973, Dr. Francois Duret proposed the CAD/CAM technique to the dental world.[14] In 1977, Young and Altschuler developed a complex and costly intraoral grid surface mapping system.[15] In the 1980s, Dr. Werner Mörmann, a Swiss dentist, and Marco Brandestini, an Italian electrical engineer, invented the first digital intraoral scanner. In 1987, the CEREC concept was introduced by Sirona Dental Systems at the University of Zurich.[16] The evolution of intraoral scanning technologies has resulted in improved techniques over time(Table 1).

Lava C.O.S system	Year 2006, principle of active wave-front sampling. It has the 13.2mm wide smallest scanner tip.[11]
The iTero	Year 2007, utilizes parallel co focal imaging technology with red laser to capture a color 3D digital impression.[16]
Planscan	Year 2008, Real time laser video-streaming technology along with blue light is used to capture the dental data. Built-in heated mirrors along with scanner tips. Powder free system.[16]
E4D system	Year 2008, principle of optical coherence tomography and co focal microscopy.[11]
CEREC Bluecam	Year 2009, Using a powerful light-emittingdiode, Camera can allow the acquisition of high resolution images. A thin layer of titanium dioxide powder as a contrast medium is needed.[10]
TRIOS	Year 2010, a powder free, ultra fast optical scanning technology was introduced, featuring an open file system consisting of the TRIOSR Pod and TRIOSR Cart. According to Nedelcu et al, TRIOS exhibited the highest level of distinctness at the finish line.[17] The system is designed to automatically detect and digitally remove unwanted objects from the digital impression in real-time.[16]
CEREC Omniscan	Year 2012, a digital streaming technology was introduced, generating a full-color digital cast.[16] This system creates images by seamlessly stitching together individual frames, resulting in a monochromatic digital cast reminiscent of yellow stone. The video camera employed in this process produces a 3D model with authentic colors and temporal dimensions. Additionally, the system allows for the export of STL files to external systems through a designated license. Notably, it operates as a powder free system.[10]

CS 3500	Year 2013, click-and-pointsystem, powder free, adequate overlapping of the single images which should be $\geq$50% of the previous image is essential.[16]
True Definition	Year 2016, System uses blue LED light and a video imaging system for data collection. It requires a light dusting with titanium oxide reflective powder.[16]
Virtuo vivo	Year 2017, Advanced Imaging Technology with Multiple Scans. The lightweight hand piece, constructed from metal, weighs approximately 105 grams.[10] A total of five types of 3D scanners have been integrated into the system, operating simultaneously to capture challenging-to-reach areas. The system also features the development of DWOS CAD software.
Mediti500	Year 2018, uses video photogrammetry. [10] Differentiation between the soft tissue and dental structure can be made.
WOW	Year 2019, video photogrammetric technology.[10] Images with hyperrealistic texture and color can be developed using open system which develops a complete digital workflow. Powder free.
CEREC Primescan	Year 2019, touch-panel and screen, with the all new CEREC 5 software processor of the scanner can process up to 10,00,000 of 3D points per second. Depth of scanning should be up to 20 mm.[10]

Table Summary chart based on year of manufacturing and properties

Limitations

Intraoral scanners face challenges in capturing metal and other reflective materials within the oral cavity. The accuracy of scans can be compromised in clinical situations involving edentulous areas. Acquiring precise digital impressions becomes challenging in regions lacking teeth due to the absence of clear anatomical landmarks.[18]

Comparison of Intraoral Scanners

In a study conducted by Bocklet C et al, the Planmeca Emerald, Planscan, 3-Shape Trios, iTero Element, iTero Element II, CEREC Omnicam, and Carestream 3600 were assessed for their ability to capture the trueness of substrates. The study found that PlanScan failed to reveal trueness differences among various substrates, whereas Emerald demonstrated precision variations between the substrates.[19] In another comparative study on trueness by Mangano F et al, including CS 3700, iTero Element 5D i-500, TRIOS 3, CS 3600, PRIMESCAN, VIRTUO VIVO, RUNEYES, EMERALD s, EMERALD, OMNICAM and DWIO, the best results were reported with ITERO ELEMENT 5D®, while DWIO exhibited the lowest trueness.

Discussion

A contemporary and innovative approach in dentistry involves the integration of 3D digitization methods into dental practice, serving as a viable alternative to traditional impression techniques, particularly within the realm of Prosthodontics. The formulation of treatment plans now considers both clinical and virtual evaluations.[20]

Presently employed technologies

1) **Triangulation:** This process involves determining a point's location in 3D space based on its projections onto two or more images.
2) **Parallel Co-focal Imaging:** In confocal imaging, a focused laser beam is utilized to create a small spot illumination on the specimen, resulting in a higher resolution image.

3) Accordion Fringe Interferometer (AFI): AFI is an active-triangulation, surface-profiling technique that projects interference fringes onto an object's surface from one location and captures them with a camera at another location.

4) Three-dimensional In-Motion Video: This method employs triangulation between corresponding points in two views of the same scene at different angles to continuously compute depth through video analysis.[21]

Factors influencing the precision of IOS

1) Scanning Software: The ease with which the software is handled plays a crucial role.

2) Scanner Technology: This pertains to the resolutions and image quality delivered by the scanning technology.

3) Powder Material Application: The thickness of the powder material applied to the scanning site can potentially distort the actual surface thickness being scanned.

4) Presence of Saliva and Blood: The clarity of scanning is adversely affected by the presence of saliva and blood.

5) Soft Tissue Movement and Limitedspace: Challenges arise in achieving accurate scanner positioning due to soft tissue movement and constrained space.[17,22]

Summary

The primary indication area for Intraoral Scanners (IOSs) is determined by their properties, and understanding the distinctions among various IOSs can assist practitioners in selecting the optimal device. The latest generations of IOSs exhibit superior properties compared to their predecessors, featuring more specialized capabilities and heightened accuracy. As new generations of IOSs and software versions emerge in the market, the differences among IOS devices are expected to diminish over time.

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