Section A -Research paper

EVOLUTION OF INTRAORAL SCANNERS IN DENTISTRY: AN OVERVIEW

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Abstract: Intraoral scanners (IOS) are devices for capturing direct optical impressions in dentistry. The aim of present review of literature was to discuss various facts in detail about Intraoral scanners.

Keywords: Intraoral scanners, Impression, Digital impression

Introduction: In the recent years, digitization has been the upcoming trend in various fields of health sciences Dentistry. The field of Prosthodontics in particular has benefitted to a great extent from the advent of digital technologies. The steps of fabrication of prostheses by conventional procedures are tedious and complicated. These steps can be simplified using digital techniques at various steps in the procedure. It is now possible to eliminate all fabricating errors encountered by conventional methods, such as the distortion of impression material, expansion of plaster, deviation when attaching a model to an articulator and casting shrinkage. [1]

3D scanning of the dental arch was first introduced for its use with CAD/ CAM technology in order to produce dental restorations approximately three decades ago whose its application within dentistry has grown considerably over this time not least within prosthodontics. In 1973 Durethas introduced the concept of intraoral scanning for a dental application.[2]

These scanners project a light source onto the object to be scanned like implant scan bodies and prepared teeth in the dental arches. This mechanism is similar with other three-dimensional scanners. The use of CAD-CAM systems enables us to mill frameworks designed by a computer and to use aesthetic materials, especially those that cannot be cast.[1]Intraoral scanners (IOS) capture direct optical impressions in dentistry. Point clouds gets generated after software processes the obtained images. These clouds are then triangulated by the same software in order to form a 3D surface model. This 3D virtual cast serves the same purpose as the conventional gypsum cast.[3]

Today various intraoral scanners are being used in the field of prosthodontics for the fabrication of all kinds of prosthesis. This review aims at using optical impressions compared to conventional impressions, evaluating the differences between the various IOS currently available commercially and determining actual use and limitations of IOS in patients.

Intraoral Scanning Technologies: Intraoral scanner consists of software, hardware which is a handheld camera and a computer.[4]Obtaining data and speed of measurements acquisition in addition to the resolution is one of the most important in the choice of the system and its broad applicability. Size of the scanning field is minimally 14x14mm, and optimally 25x14mm. The range of scanning depth should be at least 10 mm to get the adequate clarity and for proper placement of scanner in desired area, but should not be greater than 14 mm, if so then the image may not be clear or there will be fog on the scanning surface. Scanner resolution should be at least 25μm.[5]

Parts of intraoral scanning system[6,7]

The scanners mainly composed of:

- Machine Handling The Movement Of The Probe
- Measurement Probe
- Control Or Computing System
- Measurement Software

According to the emission used, following are the available scanner types[6]

Intraoral scanners	**Emission used**
Three-dimensional laser scanners	Emits laser beam of light source and detect its return.
Optical scanner	Projects white light or a laser source. Source and the receiving unit in this type are at the certain angle to each other.
Mechanical scanner	Gypsum model is obtained from a conventional printing is scanned and used. The master model is read mechanically line by line and structure is measured using a ruby ball.
Photographic technology Scanners	A field of view in this type is in the form of a cone, making it unable to collect information from those hidden surfaces. It records individual images of the denture.
Video technology scanners	Open standard tessellation language is the most used digital format. They record scanned areas working in a through sequential shots at high speed similar way as a video camera.

Evolution of Intraoral Scanners: In past, many researchers have conducted a research in the dental field for making prosthesis through 3D digitization.

In 1973, Dr. Francois Duret was the first one to propose the CAD/CAM technique to the dental world. Later along with Dr. Christian Termoz, they patented the method and apparatus for making prosthesis, especially a dental prosthesis .[8]Young and Altschuler developed an intraoral grid surface mapping system by suggesting the idea of using optical instrumentation to in 1977. However, this system was not successful in the dental market because of its complexity and cost.[9] In the 1980 a Swiss dentist, Dr Werner Mörmann in association with Marco Brandestini, an Italian electrical engineer invented first digital intraoral scanner. The developed concept was

introduced in1987, CEREC by Sirona Dental Systems at the University of Zurich.[10]After which, evolution continued and resulted into the many intraoral scanning technologies with better techniques.

Some of these technologies are discussed below,

Lava C.O.S. system is given by Lava Chair-side Oral Scanner; 3M ESPE, Seefeld, Germany. This system is invented in 2006 and launched in market by 2008. By emitting pulsating visible blue light, scanner works with a mobile host computer and a touch-screen display. It works under the principle of active wave-front sampling. It has the 13.2-mm wide smallest scanner tip. [7]

The iTero intraoral scanner came in market in 2007 which utilizes parallel co focal imaging technology with red laser to capture a color 3D digital impression. Up to 3.5 million data points per arch will be obtained using this scan. A total of 1,00,000 points of laser light can be generated at 300 focal depths of the tooth structure. Use of this system is limited for digital impression making since it doesn't come with a milling machine.[10]

Planscan was driven in market by E4D Technologies in 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. Main advantage of this is a high level of disinfection and patient's compliance. This is a powder-free system. [10]

E4D system by D4D Technologies, LLC (Richardson, TX) developed in 2008. It uses red laser as a light source. Micro-mirrors provided can vibrate at the speed of 20,000 Hrz under the principle of optical coherence tomography and co focal microscopy. [7]

CEREC Bluecam being first Sirona system use photography for intraoral protocol after the ideally originated in 2009. One quadrant of the digital impression can be captured within 1 minute and the antagonist in a few seconds using this system.[7]Using a powerful light-emitting diode, Camera can allow the acquisition of high resolution images. Nowadays this scanner is not popular in the market due to more recent systems. A thin layer of titanium dioxide powder as a contrast medium is needed. [6]

TRIOS In 2010, 3SHAPE (Copenhagen, Denmark) launched this system. System uses ultrafast optical scanning technology and is presented to market in 2011.[7]It is a powder-free, open file system composed of-

- TRIOSR Pod
- TRIOSR Cart

TRIOSR Pod has a simple construction with a handheld scanner only which makes it more mobile and flexible. It is compatible with iPad or other computers. It also takes digital intraoral photographs which could be useful for documentation shade matching is now automated with this system, which or communication purposes. Nedelcu et al stated that TRIOS displayed the highest level of finish line distinctness. [11]system will detect unwanted objects and digitally removed from the digital impression automatically in real time.[10]

CEREC OmniCam is Sirona's most recent system which was released in the summer of 2012. System creates a full-color digital cast with digital streaming.[10]creates images via stitching together individual images to create monochromatic yellow stone-like digital cast. This scanner is a next level of CEREC BlueCam. Its video camera generates a 3Dmodel with real color and time. Also, export the STL files can be exported to external systems through a specific license. It's a powder free system.[6]

CS 3500, is one of the recently available powder-free intraoral scanners released in market in 2013. The wand is supposed to keep still during capturing since it is a click-and-point system. Additionally, adequate overlapping of the single images which should be ≥ 50% of the previous image is essential.[10]

True Definition which was introduced into the market in 2016 by 3M. System uses blue LED light and a video imaging system for data collection. It requires a light dusting with titanium oxide reflective powder and the scanning area should be properly isolated.[10]

Virtuo vivo is another name of DWIO (Dental Wings Intraoral) Straumann Canada. This system came in market in 2017 and uses open architecture files to capture digital impressions. Total five types of 3D scanners were incorporated into the system which works simultaneously to capture areas of difficult access. System has developed DWOS CAD software used for the designing of restoration. The small tip helps to make 3D capture easier, using a "Multi-scan Imaging Technology". The light weighted hand-piece is made of metal and is around 105grm.[6]

CEREC PrimeScan It is the latest evolution of the IOS of this manufacturer which contains touch-panel and screen, with the all new CEREC 5 software and was available in market since 2019. With a higher scanning speed, processor of the scanner can process up to

10,00,000 of 3D points per second. To make the impressions of the sulcus in sub-gingival preparations or post extraction sockets feasible, Depth of scanning should be up to 20 mm.[6]

ZFX IntraScan The concept is to be as portable as possible. This system, launched in the year 2012, comes with hardware and light scanner that can be adapted to any other computer. Working distance of this optical scanner is 18mmand can capture 18 images per second. The digital files do not require specific systems to decode them.[6]

WOW was launched in the year 2019 by Biotech Dental (France). Images with hyper realistic texture and color can be developed using open system which develops a complete digital workflow. Scanning process is powder free to use its video photogrammetric technology.[6]

Mediti500 developed by Dent Core (Spain)in the year 2018, whose main focus was on productivity, costs and efficiency. Pause site can be resumed using two high-speed cameras. Differentiation between the soft tissue and dental structure can be made using video photogrammetry.[6]

Accuracy of digital techniques as compared to conventional impressions: There are studies which compared conventional and digital techniques for the fabrication of dental prosthesis. In the comparison of accuracy of full ceramic crowns obtained from intraoral scans with Lava C.O.S. (3M ESPE), CEREC (Sirona), and iTero (Straumann) with conventional impressions, Seelbach P *et al*[12] found the fabrication of fixed prosthetic restorations with similar accuracy as that of conventional impression methods. Syrek *et al*[13] in his comparative study found marginal gap of conventional impression was 71 μm and in the digital impression using Lava C.O.S. (3M ESPE) group was 49 μm stated both of the impression techniques resulted in clinically acceptable fit but as compared to the one obtained from conventional impressions, the zirconia single crowns fabricated from a digital impression had a better fit. Additionally, inter-proximal contacts and marginal discrepancies were better for the digital group than the conventional group.

Digital impression and implant position: To capture the correct implant position with a digital impression it is necessary to use a specific transfer post called an intra-oral scan body (ISB). Edentulous areas can be difficult to read and mathematically interpret for IOS due to the lack of distinguished anatomic references which is why having are liable ISB design is so important to improving the accuracy of implant digital casts.[14] The design and material of the cast and the

design of the scan bodies as well as its light reflection properties can affect the precision of the digital impressions.

Effect of Tooth Type on the Accuracy of Dental 3D Scanners: Tooth type significantly affects the accuracy of 3D scanners. In the anterior teeth intraoral scanners show better accuracy whereas in the second molar region it shows significantly poor accuracy. The increased inaccuracy in the posterior region is probably due to the tendency of the complete arch to broaden in the buccal direction with respect to the midline.[15]

Which IOS system is better?

Each intraoral scanning system is different from other for capturing the different substrates like dentin, enamel, restorations, prosthesis or soft tissue. Metal and other reflective materials can be difficult to capture intraorally. The powder technique is a perfect solution to improve scanning accuracy by generating surface homogeneity. Presence of edentulous areas is another clinical situation that can compromise accuracy. It is difficult to acquire digital impressions accurately in the area with lack of teeth due to the apparent anatomical landmarks.[16]Bocklet C et al in his study compared the Planmeca Emerald, Planscan, 3-Shape Trios, iTero Element, iTero Element II, CEREC Omnicam and Carestream 3600 for capturing the trueness of the substrates. According to the study, PlanScan was unable to reveal trueness between the different substrates, while precision differences between the substrates was revealed by Emerald.[17] Another comparative study of truness by Mangano F et al between CS 3700, ITERO ELEMENTS 5D i-500, TRIOS 3, CS 3600, PRIMESCAN, VIRTUO VIVO, RUNEYES, EMERALD s, EMERALD, OMNICAM and DWIO stated best results by ITERO ELEMENTS 5D® and lowest trueness with DWIO.

Discussion: In the field of dentistry, the change to digital technology will result in reduction in the burden of having to improve procedures.[18]The modern and new option for dentistry is use of the methods of 3D digitization in dental practice which will be an alternative to the method of conventional impressions, especially in the field of Prosthodontics.[9]

Determination of the state of occlusion suitable for each patient will be enabled by the use of digital technology. The treatment plan is established by taking consideration of clinical as well as virtual evaluation nowadays.[19]

Currently employed technologies are:[20]

1. Triangulation: refers to the process of determining a point in 3D space given its projections onto two or more images.
2. Parallel co focal imaging: in confocal imaging a focused laser beam is used to produce a small spot illumination on the specimen which results in a higher resolution image.
3. Accordion fringe interferometer (AFI): is an active-triangulation, surface-profiling technique based on projecting interference fringes onto the surface of an object from a source at one location and viewing with a camera at another location
4. Three-dimensional in-motion video: uses triangulation between matching points in two views of the same scene at different angles to compute depth by continuous video.

Several factors affecting the accuracy of IOS are-

- Software for scanning- ease of the software handling
- Scanner technology- in terms of its resolutions and quality of image
- Use of powder material- thickness of the powder material sprayed on the scanning site may mislead the actual thickness of surface being scanned
- presence of saliva and blood- will interfere with the clarity
- Soft tissue movement and the limited space-with cause the difficulty in accurate position of scanner.[11,21]

Ahlholm et al. conducted a systematic review whose conclusion stated that in terms of accuracy for single crowns and short-span fixed partial dentures, digital impression techniques are clinically acceptable and can be compared to conventional impression techniques taking in consideration that for complete dental arch their accuracy will be less.[21]

In the study conducted by D'ARienzo L intra-oral scanners and conventional impression were compared for the suitability in edentulous maxilla. They concluded that with the use of the Trios scanner digitization of edentulous jaw was feasible. Optical scanners are valid to replace the preliminary impression only. Unlike In functional impression selective pressure cannot be exerted on peripheral areas which are necessary for success of prosthesis.[19]

Chiu A et al use different Intraoral Scanner Parameters like high resolution (HR), standard resolution (SR), and combined resolution (SHR) to access the accuracy of CAD/CAM Digital Impressions (3Shape TRIOS 3). He came to conclusion that there was Significant

difference in terms of numbers of images captured per scan and time with different scanning resolution settings in those three resolution groups.[21]

Aswani K et al reviewed Accuracy of an intraoral digital impression. This study indicated that accuracy of IOS systems is comparable to conventional methods but could be promising and is still vulnerable. Intraoral scanning systems can be used for short span scanning and diagnostic purposes but at the same time there are more chances of deviation especially in full arch scans.[11]

Summary: IOS have some disadvantages with the advantages like difficulty in detecting deep or subgingival finish lines while presence of blood and saliva.[6] As prices come down and more health care providers embrace the technology, we can expect digital scanners and computer-assisted design and manufacturing to become standard in dentistry.[22]

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