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EXPLORING THE REVOLUTIONARY TECHNOLOGY OF INTRAORAL SCANNERS: THE FUTURE OF DENTAL IMPRESSIONS

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Abstract-
Impression technologies using CAD/CAM (computer-aided designing and manufacturing) and IOS (intraoral scanner) have been developed for dental practice to address challenges with traditional methods. The choice of technology influences clinical application since there have been more optical IOS devices developed during the past ten years. This article initially provides an overview of the currently employed technologies to enable educated decision-making before acquiring or renewing an IOS. The advantages, and disadvantages, are covered in the second part. The last part pays attention to the accuracy of IOS. Although there are variances in the technologies used, the analysis suggests that the current IOS has been tuned for widespread use. The decrease in hardware volume that has increased the significance of software-based technologies is a significant factor that has been highlighted in this research.

Key words- intraoral, scanner, digital, impression.

Introduction

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Intra-oral scanners (IOSs) are an innovation to the dentistry that have the potential to revolutionise the way we make dental impressions. Intra-oral scanners are a form of digital technology that makes digital impressions of teeth and oral tissues in three dimensions (3D). These digital tools enable dentists to take non-invasive and very precise dental impressions. The requirement for stone casts, impression trays, and impression materials may be eliminated by IOSs, and shipping to a laboratory may no longer be necessary.[1]

The history of IOSs traced back to when Dr. Francois Duret (1971) created the first Computer aided design/ Computer aided manufacturing (CAD/CAM) system, made the crowns based on an optical impression of the abutment tooth and utilising a numerically controlled milling machine. Mormann and Brandestini came up with the CEREC system in 1987. It was the first dentistry system to combine digital scanning and a milling unit. [2] Over the course of the past ten years, there has been a rise in the number of optical IOSs, each of which is founded on a unique technology; the selection of which may influence clinical application. As their application in the field of dentistry increases rapidly, dental practitioners are increasingly turning towards intra-oral scanners as an essential tool.

Methods

The electronic literature search was conducted from 1988 to 2023 using MEDLINE (PubMed), EBSCO, Scopus and Google Scholar for articles in the English language published in journals of dentistry using the following search terms: "intraoral scanners and accuracy," "digital impression," "computer aided impression," "virtual impression," and "optical impression." A manual search was also done from Journal of Prosthetic Dentistry, Journal of Indian Prosthodontic Society and American College of Prosthodontics. Thus, the aim of this review is to explore the revolutionary technology & most frequently used IOSs, clinical applications, advantages, disadvantages, limitations, and the criteria to consider while choosing an Intraoral Scanner.

Intra-Oral Scanning Technologies

Intraoral scanners are portable devices which utilise digital imaging technology to create a three-dimensional image of teeth and oral tissues. They consist of a wand-shaped gadget that the operator inserts into the patient's mouth to scan the oral cavity. The scanner captures the hard and soft tissues of the oral cavity, resulting in a virtual model that can be displayed in real time on a computer screen.[3] Figure-1 summarises the key features of a few frequently used intraoral scanners. These intraoral scanners use either laser light or visible light to illuminate an object, or they use field sampling, which is subsequently collected and digitised using digital sensors.

(a) Laser beam based IOSs Systems

The key benefit of a laser beam IOS system is that no reflecting agent is required. These systems use either still image or continuous image capturing technique.

1. Parallel confocal imaging - In this imaging method, parallel laser beams are directed towards the object that is to be scanned by using the scanning wand that is part of the IOS system. The laser beams that contact the target at a certain focal length cause it to reflect and then return via a tiny pinhole before colliding with the laser sensor (Figure -2). The data from this collision is then translated into a digital image. The iTero is a good example of a system that puts this concept into practise.[4]

2. Laser triangulation imaging - In this method, the scanner employs a red laser beam and micro-mirrors that spin at a rate of 20,000 cycles per second to collect a sequence of still photographs from numerous angles surrounding the item to build a 3D model. These images are then combined to create a single three-dimensional model (Figure -3). [4-5] The E4d Dentist and PlanScan system is a fantastic example of a system that puts this principle into action.

3. Structured light imaging and laser triangulation - Combining the imaging methods described above makes it possible to take continuous images, which can then be used to generate an accurate three-dimensional depiction of the teeth that have been prepared. This technology is currently being used in the CS 3500 & CS 3600. A complementary metal oxide semiconductor (CMOS) sensor is used to receive the data that is acquired from the acquisition process. The designer of the scanner claims that the working depth of the device ranges from 1 mm to 15 mm, and that the field of vision of the device is roughly 16 mm x 12 mm. The scanner does not need any powder at all and can do full-arch scanning.[5]

b) Light Beam-based IOS Systems

The large number of IOS systems in this category require the use of titanium dioxide as a reflecting agent.

1. Still image capture technique-This method makes use of a technology that is known as active triangulation (Figure 4). In this method, a specific location in 3D space is located by detecting the meeting point of three linear light beams. On the other hand, uneven surfaces, like the surfaces of teeth, have a negative impact on the precision of a scan based on triangulation since they do not reflect light equally. This technique is implemented in Omnicam/ BlueCam intraoral scanners. Because of this, an opaque powder coating made of titanium dioxide is necessary to produce uniform light dispersion and to improve the scan's accuracy. [6]

2. Video capture technique - The active wavefront sampling (AWS) technology is the sole method that can record three-dimensional data in a video sequence as well as three-dimensional models in real time. AWS is the process of recovering 3D information from a single lens image system by detecting depth based on the main optical systems defocusing (Figure 5). Data is being recorded by the operator within a field of vision that measures around 10 mm x 13.5 mm. True Definition Scanner's scanning wand is equipped with six LEDs for lighting, three optical lenses, and a CMOS sensor for picture capture and data acquisition. [6]

3. Ultrafast optical sectioning technique - Continuous picture capture is made easier with the help of this technology, which is like the method of video capture. The scanner [e.g., Trios (3 shape) & Bluescan- I] is motionless and positionless, and it may be supported by placing it on the teeth while it is being scanned.[6]

- **The scanner normally utilizes one of two techniques to capture images:**

1. Active scanning- The scanning wand is moved across the teeth surface, the light emitted from the wand gets reflected from the teeth and soft tissue in the oral cavity, which is then captured by the camera, and after this, it is turned into a digital image.

2. Passive scanning- This technique uses a sensor that is inserted in the patient's mouth and captures pictures while the patient remains motionless. To construct a thorough digital model using this technique, numerous photographs of the teeth and gums are often taken from various angles and locations.

Workflow of IOSs [7]

An intraoral scanner's workflow includes preparation of the patient, taking and processing images, reviewing the obtained 3D model, treatment planning, and fabrication of final prosthesis.

The following is a list of common steps in this procedure:

1. To get a satisfactory scan, the IOS is calibrated first. After this, the patient is asked to sit comfortably & the oral cavity is dried out, and any debris if present is removed from the region of interest.

2. The next step is image acquisition, which can be accomplished using either an active or passive scanning technique.

3. Select indicators from the case information interface and then transferred to the scan interface for image processing.

4. After the models has been trimmed out, the models are aligned at the buccal interface for the 3D model of the teeth and gums. After that, choose the software's stitching option to combine the photos.

5. The created 3D model is next checked to make sure the model is accurate and that all relevant areas have been recorded. To fill any missed areas, further scans may be conducted if necessary.

6. Next, the data can be sent to a lab accompanied by the case summary and pictures.

7. A 3D model is produced that is commonly utilized for restorative dentistry, implant placement, and orthodontic therapy.

Purpose Of Digital Impression

1. Diagnostic purpose & treatment planning: To identify problems affecting intraoral structures, including missing teeth, tooth fractures, bone loss, caries, fractured restorations etc.

2. Orthodontic treatment: Digital models of the teeth and gums can be made using intraoral imaging, and these models can be used to plan and track orthodontic treatment.

3. Patient education: Dental problems and treatment alternatives can be demonstrated and explained to patients using intraoral imaging. In cases, where aesthetic treatment is required, we can show the preoperative and postoperative pictures to the patients.

Clinical Applications of IOSs

Intraoral scanners are extremely useful and are used in many dental specialties, including prosthodontics, implantology, maxillofacial prostheses, surgery, and orthodontics.

IOSs are used for making impressions of natural tooth preparations and associated structures to fabricate a variety of prosthetic restorations. Computer-aided impressioning (CAIs) generate 3D diagnostic models that are particularly valuable for diagnostic purposes. These models can assist us in communicating with patients and allowing us to perform mock surgeries. IOS can be used satisfactorily to capture the 3D position of dental implants with the help of scan body and to produce implant-supported restorations. However, IOS can be utilized successfully for digital smile design applications, fabrication, aligners, and obturator fabrication.

Scanning protocol –Various scan strategies were described including occlusal-palatal-buccal or lingual-buccal-occlusal, circular scan, zig-zag scanning, stitching halves etc. The commonly used scanning technique is occlusal-palatal-buccal or lingual-buccal-occlusal at an angle of 45 degrees to lingual and buccal surfaces. [7]

Advantages

1. Clinical Efficiency: The use of intraoral scanners replaces the requirement for conventional impression materials, which may be messy, cumbersome, and even painful for patients. The time required for dentist appointments is decreased by IOS's speed.

2. Greater Patient Comfort: Since there are no physical impressions involved with intraoral scanners, the digital impressions are more comfortable to the patients.

3. Faster Processing: The use of IOS in dentistry makes the data instantly available for processing, which minimise the chair-side time and the requirement for numerous sessions and therefore, speed up treatment planning and dental care execution.

4. Improved Accuracy: When compared to conventional impression materials, which may impair the accuracy of the findings, intraoral scanners offer excellent levels of accuracy.

5. Enhanced Communication: The use of intraoral scanners improves interaction among dentists, lab technicians, and patients.

6. Enhanced record-keeping: Digital scans can be easily stored and retrieved online via an encrypted cloud platform, which makes it simpler for dentists to maintain track of patient records. This is particularly helpful for people who need continuous dental care or who visit several dentists for various procedures.

Disadvantages:

1. Cost: Their high price is one of the main drawbacks, which may prevent some people from implementing them.

2. Technical failures: Software crashes and technical failures can occur while using IOS, which may affect the accuracy of the treatment.

3. Learning curve: Additionally, they need advanced knowledge and training to operate, which may restrict their usage in certain dental offices. This can take a lot of time and might cost more money.

4. Inability to capture some elements: Even while IOS can capture every component of a tooth, some may be difficult to access. The tongue, cheeks, and lips may obscure the scanner's field of vision, making it challenging to record some portions of the mouth.

5. Patient discomfort: Although intraoral scanning is typically more comfortable than conventional impressions, some patients may still feel uneasy or anxious while scanning. The intraoral scanning procedure may take substantially longer for inexperienced specialists, which could make patients feel more uncomfortable.

Limitations:

1. Only a few research have addressed the use of IOS for producing partially and entirely removable prostheses; this application still poses some challenges due to the lack of reference points and the inability to detect soft tissue dynamics.

2. In case of maxillofacial defect, sometimes, digital impression is not sufficient. We have to make a conventional impression as well.

3. In case of bleeding either from trauma to gingiva or while tooth preparation, margins cannot be captured accurately.

4. In case of limited mouth opening, it is difficult to capture the palatal and occlusal surface and sometimes buccal surface also, as there is insufficient space for scanning wand.

5. In case metal restorations, shining surface of metal reflect the light while scanning. This might affect the accuracy of the scan. So, anti-reflective agents such as titanium dioxide sprayed on the restoration in such cases.

Criteria to consider while choosing an IOS:

1. Accuracy- The accuracy of laboratory work is determined by the quality of the image scanned. The perfect scanner can record barely noticeable details and is accurate enough to enable all forms of restorative work, including crowns, bridges, dentures, night guards, clear aligners, and more.

Accuracy is defined as the "closeness of the discrepancy between an accurately measured value and the actual quantity value of an object" and can be demonstrated by trueness and precision. Trueness is the proximity of the measurement to the accepted reference value, whereas precision is the proximity of repeated readings of the same object.[8]

- The accuracy and precision of two commonly used intraoral scanners (Trios 3, 3Shape, and CS 3600, Carestream) were assessed by Winkler J. and Gkantidis N. using an industrial scanner (Artec Space Spider) as a standard of reference. Utilising the iterative closest point algorithm (ICP), surface-based matching was put into practise. Trios 3 had significantly greater accuracy (about 10 µm) than CS 3600, but only after superimposition on the whole dental arch ($P < 0.05$). Both intraoral scanners demonstrated high performance and comparable trueness.[9]

- A study by Arakida T et al. (2017) showed that illuminance and colour temperature have an impact on the accuracy and trueness of intraoral scanners. The conclusion of this review article was that the best lighting conditions for obtaining digital impressions were 3900K and 500 lux.[10]

2. Software Speed and Capability - The scanner is powered by software, which directly affects how well it works. There should be no delay between scanning and the results appearing on your screen with the ideal intraoral scanner. The best scanner we investigated scanned in less than 90 seconds and automatically identified particular spots that need corrections and rescans.

3. Ease of Use- You need a user-friendly software user interface that supports your workflow. We rapidly rejected those scanners with complicated digital user interfaces that were too difficult for dentists to use while patients were in their chairs when we were investigating the top scanners available. The greatest intraoral scanner enables you to scan naturally—without feeling uncomfortable.

4. Price- Digital scanners used to be costly for the majority of dental practises, but now they can be purchased for less money with high-quality scanners. However, certain scanners come with additional expenditures, such as the necessity for auxiliary equipment, software subscriptions, training, and customer support. Combine your best interests and your practice's needs with what is prudent from a fiduciary standpoint.

Conclusion:

Intra-oral scanners are becoming necessary equipment nowadays in dentistry. They are incredibly precise and have the capacity to raise patient satisfaction and comfort. In spite of their benefits, they have several drawbacks and are difficult to operate without comprehensive instruction. Intra-oral scanners have the potential to revolutionize the way we capture dental impressions, and their adoption is likely to increase in the future.

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Figure 1- Most commonly used intraoral scanners

Intraoral scanner	Place of manufacture	Year of manufacture	Scan type	Size	Output format	Light source	Weight (incl. battery)	Acquisition technique
3Shape Trios 3 Pod®	Copenhagen, Denmark	2015	True colour	4,2 x 27,4 cm / 1 x 2 inches	PLY, DCM and STL	LED	340g	Ultrafast optical sectioning
Carestream CS3600®	Atlanta, GA, U.S	2016	True colour	220 x 38 x 58 mm	STL & PLY	LED, Amber, Blue, Green	325 g	Structured light imaging & laser triangulation
GC Aadva®	Leuven, Belgium	2017	Monographic (true colour planned)	20 cm (Length)	STL & PLY	Structured blue light	120 gm	Confocal microscopy
Planmeca Emerald®	Helsinki, Finland	2017	True color	41 x 45 x 249 mm	STL, PLY, OBJ & OFF	Red, green, and blue lasers	339 g	Projected pattern triangulation
Medit i500®	Seoul, South Korea	2018	Vivid color (3D full color streaming capture)	266 mm (Length)	STL	White & Blue light	280 gm	Structured light
3Shape Trios 4 ®	Copenhagen, Denmark	2019	True color	4.9 x 4.0 x 27.8 cm	STL, PLY, and DCM	LED	375 g	Ultrafast optical scanning
3Shape Trios 5	Copenhagen, Denmark	2022	True colour	1.52 x 1.47 inches (3.85 x 3.74 cm)	PLY, DCM and STL	LED	299g	Confocal

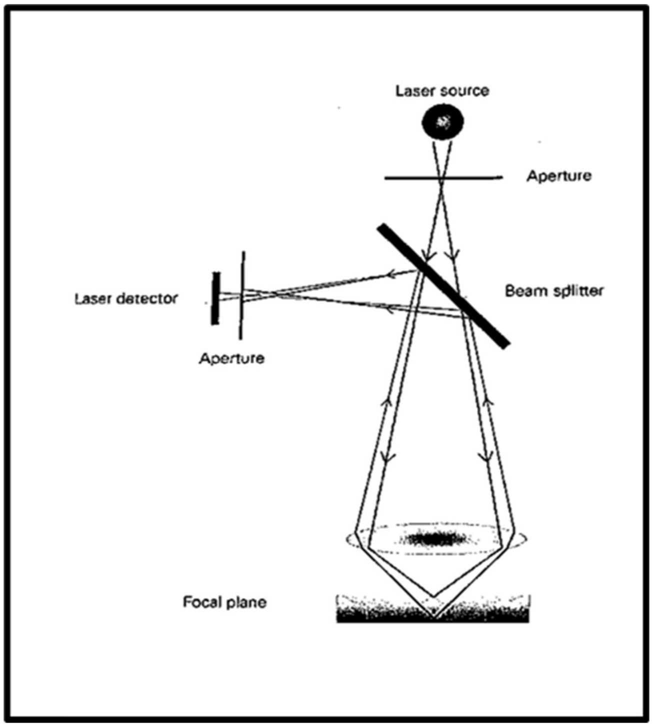

Figure 1- Parallel confocal microscope

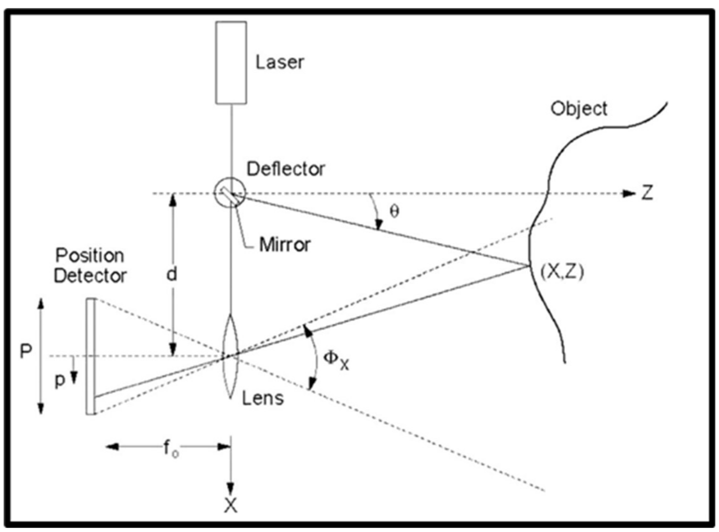

Figure 2- Laser triangulation imaging technique

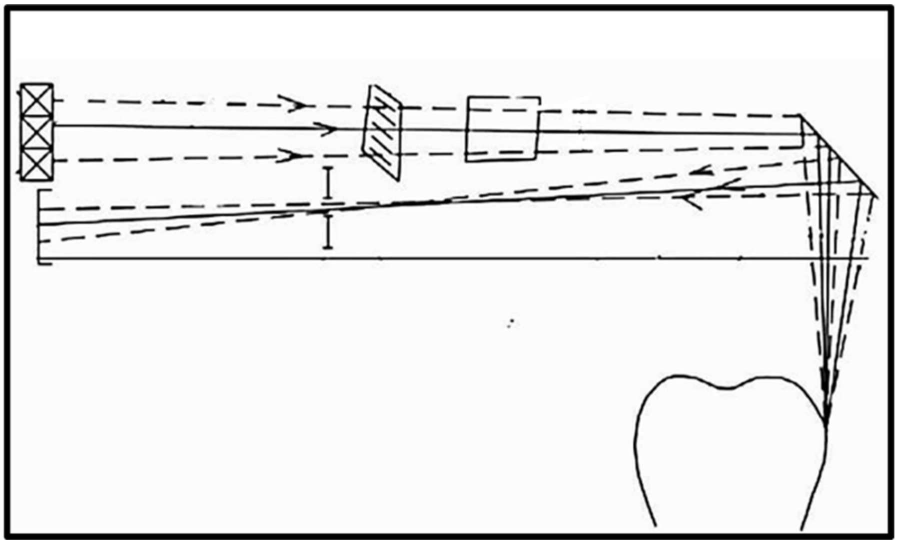

Figure 3- Active triangulation technique

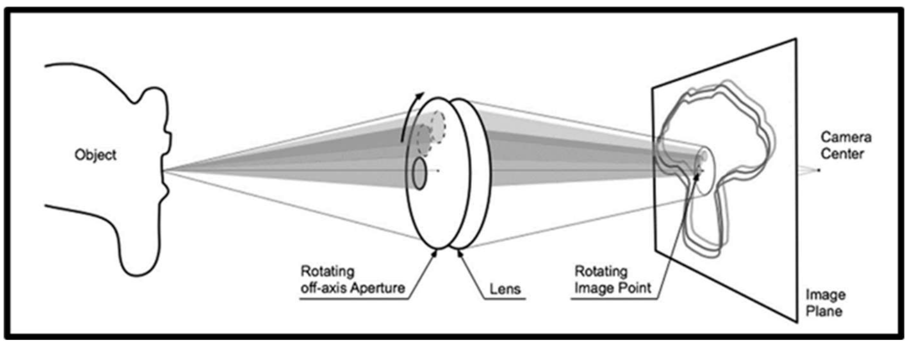

Figure 4- Active wavefront sampling principle