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Lecture 7: Digital Impressions

By Dr Cheryl Fu

Acknowledgements to Dr Nedelcu and Dr Matsubara for slides

Learning Objectives

- Methods of digitalization
- Benefits and disadvantages of intra-oral scanners
- What is accuracy?
- Clinical Protocols
- Different scanners: intra-oral vs extra-oral

No compulsory readings

Digital Impression

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THE JOURNAL OF PROSTHETIC DENTISTRY

JPD

THE GLOSSARY OF PROSTHODONTIC TERMS

Ninth Edition

dental impression \děn′tl ĭm-prĕsh′en**:** a negative imprint or a positive digital image display of intraoral anatomy; used to cast or print a 3D replica of the anatomic structure that is to be used as a permanent record or in the production of a dental restoration or prosthesis; *syn* IMPRESSION

Impression

Aim of impression: produce a dimensionally stable “negative”

- Mould for an analogue model

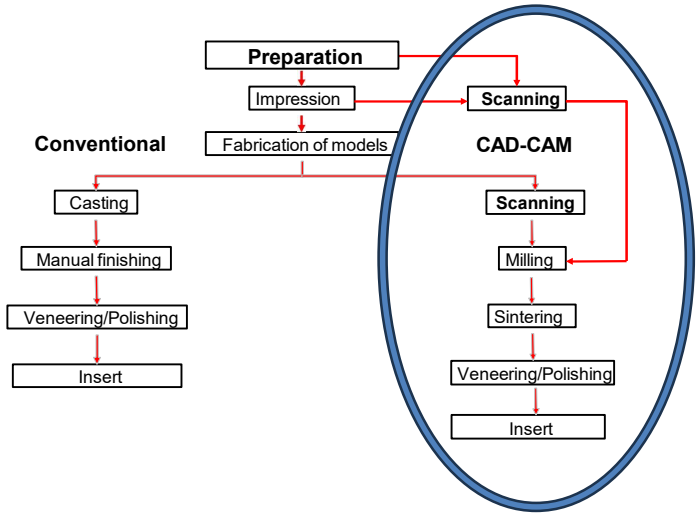
- Scanned with CAD/CAM model

Milled Model

3D Printed Model

Used not just for crowns. Have been increasingly used for other specialties. Including edentulous arches and orthodontic treatment.

Workflow


Preparation
Impression
Fabrication of models
Conventional
Casting
Manual finishing
Veneering/Polishing
Insert
Scanning
CAD-CAM
Scanning
Milling
Sintering
Veneering/Polishing
Insert

Benefits Vs Disadvantages

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Advantages
- Workflow improvements
- Patient acceptance (gag reflex)
- Time benefits
- Financial advantages
- Communication
- Record keeping/storage

Disadvantages
- New skills
- Digital confidence/mindset
- Initial costs
- Accuracy

One-time payment

$29,050

TRIOS 5 Wireless

Workflow: Tray selections + disinfection etc all need time. Additionally, the created digital impression is already a positive record (not a negative records like impression that needs to be poured up)l.
Some manufacturers claim that you can achieve a full arch impression in less than 60 seconds with extensive experience!

Record keeping. Many new scanners allow previous scans to be stored and compared against new scans. Poentially useful for patient education and monitoring changes, for example wear or erosion of teeth.

Table

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Issues	Conventional impression	Intra-oral scan/digital impression
Patient comfort, experience	Gag reflex, unpleasant smell from the impression material, and greater discomfort[34]	Some large scanning wands also have difficulty in gag reflex, distal end teeth, or limited mouth opening.
Quality of impression	Lacerations over the margin, large undercut area, or brackets when the impression is removed[3]	Less tearing laceration, but regional deviation in full mouth scans
Impression tray or scanner wand	Necessity of stocking different size impression trays, increased waste with disposable types	Some sleeves can tolerate auto-claving or can be disinfected whereas others are still disposable, one-size scanner wand of each brand only
Repeatability	Flaws require whole impression to be performed again, model must first be poured out before verification of whether a repeat is necessary	Instant zoom-in feature enables immediate correction, imperfect region alone can be rectified without a whole new scan
Real-time 3D information	Impression must be poured into gypsum casts, leading to dual dimensional changes (impression material shrinkage and gypsum stone expansion) and a long setting time	Real-time 3D information is clearly shown onscreen, facilitating communication among doctors, doctors and technicians, and patients and doctors.[5]
Technique sensitivity	High technique sensitivity and limited reproducibility for some high-precision impression materials	Scanning strategy, experience, and skill affect results; different machines / imaging principles with varying performance and learning curves[10,12,36]
Archiving/storage	Space required for numerous casts, risk of damage to fragile stone casts	Digital archiving saves space, caution required in storage back-up; 3D-printed resin models are stronger than stone models[8,9]
Treatment planning	Need more impressions or duplication for model set-up	Virtual set-up available for multiple treatment plans,[3] virtual surgical planning can be combined with cone-beam computed tomography
Efficacy, productivity	Higher productivity per unit time, multiple patients can have conventional impressions at the same time in clinics	Limit to the number of machines per clinic prevents scans on many patients simultaneously[17]
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 appointments	High cost of each unit as well as maintenance and upgrade fees, less chairtime and fewer patient visits required[36]
Workflow	Impression → cast pouring → model trimming → additional applications, more time-consuming (particularly when including shipping requirements)	Digital scan → post-processing → direct clinical application via digital data transmission, including online or cloud-storage communication with laboratories
Soft tissue and color recording	Border molding enables registration of soft tissue (frenum, vestibule, palate, mouth floor) but not color	Advantages in recording intraoral surrounding soft tissue, capable of color scans for shade selection reference and clinical finding documentation[37]
Application customization	Customizable, but more complex and less accurate during the customization process	Easier customization and wider applicability of customized applications (indirect bonding trays, clear aligners, appliances, retainers), and simpler re-order procedure for lost appliances/retainers (ahead of visit)
Clinical use history	Long-lasting clinical usage, more reliable for experienced dentists, more acceptable to most patients	New technology requiring more effort to gain the confidence of both doctors and patients, more accepted by dental students and newly graduated dentists[38,39]

Record keeping

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Comparison Slider

Swipe the slider to compare two selected scans and see the changes between them with an easy and intuitive visualization tool that is sure to impress your patients and enables you to focus on a specific area of interest.

Revamped left panel interface

The design of the left panel has been revamped to support touch screen users and provide faster and easier access to the full toolkit available within TRIOS Patient Monitoring. You are now able to collapse each category within the left panel and free up screen space when needed.

Time

ADA CE Program ARTICLE 2 The time efficiency of intraoral scanners: An in vitro comparative study

Sebastian B.M. Patzelt DMD, Dr med dent [1], Christos Lamprinos DDS [2], Susanne Stampf Dr rer nat [3], Wael Att DDS, Dr med dent habil, PhD [4]

Methods

The authors used three different intraoral scanners to digitize a single abutment (scenario 1), a short-span fixed dental prosthesis (scenario 2) and a full-arch prosthesis preparation (scenario 3). They measured the procedure durations for the several scenarios and compiled and contrasted the procedure durations for three conventional impression materials.

Time

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Sebastian B.M. Patzelt DMD, Dr med dent [1], Christos Lamprinos DDS [2], Susanne Stampf Dr rer nat [3], Wael Att DDS, Dr med dent habil, PhD [4]

Results

The mean total procedure durations for making digital impressions of scenarios 1, 2 and 3 were as much as 5 minutes 57 seconds, 6 minutes 57 seconds, and 20 minutes 55 seconds, respectively. Results showed statistically significant differences between all scanners ($P < .05$), except Lava (3M ESPE, St. Paul, Minn.) and iTero with foot pedal (Align Technology, San Jose, Calif.) for scenario 1, CEREC (Sirona, Bensheim, Germany) and CEREC with foot pedal for scenario 2, and iTero and iTero with foot pedal for scenarios 2 and 3. The compiled procedure durations for making conventional impressions in scenarios 1 and 2 ranged between 18 minutes 15 seconds and 27 minutes 25 seconds; for scenario 3, they ranged between 21 minutes 25 seconds and 30 minutes 25 seconds.

Time

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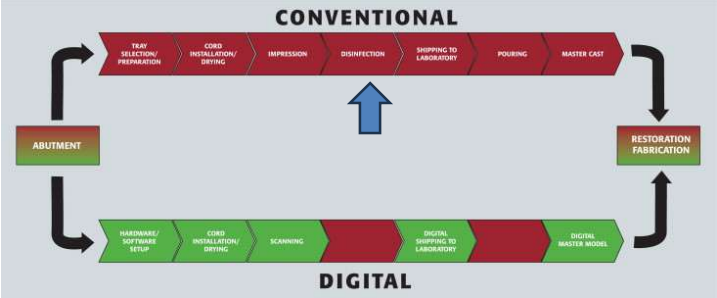


EQUIPMENT AND MATERIAL	CLINICAL SCENARIO		
	Single Abutment	Single-Span Fixed Dental Prosthesis Preparation	Full-Arch Prosthesis Preparation
	Total [illegible] (minute:second)		
Scanner[c]			
iTero	5:41	6:06	20:17
iTero with foot pedal	5:57	6:15	20:55
CEREC Acquisition Center with Bluecam	4:16[f]	5:05	N/A
CEREC Acquisition Center with Bluecam and foot pedal	4:30	5:02[f]	N/A
Lava Chairside Oral Scanner C.O.S.	5:51	6:57	17:20[f]
Material[g]			
Impregum Penta Soft		23:25	26:25
Impregum Penta Soft Quick Step		18:45	21:45
Affinis Precious and Affinis heavy body		20:55	23:55
Affinis Precious and Affinis fast heavy body		18:15	21:25
Identium Light and Identium Medium		27:25	30:25
Identium Light Fast and Identium Medium Fast		22:45	25:45

Extra-oral scanners vs Intra-oral scanners

Extra-oral scanners
- Scans conventional impression or casts

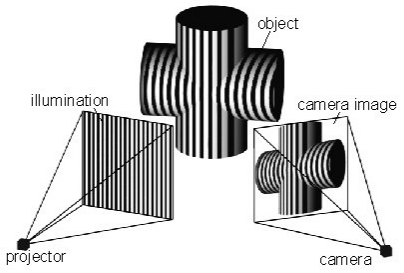
Intra-oral scanners
- Direct scan of the oral structures

Pinhole from confocal microscope works to reduce scattered unfocused light to increase accuracy

Extra-oral scanners

Extra-oral scanners

- Structured light scanners project a grid or other parallel scan pattern on the scan object. The distortions of the scan patterns are captured by the camera and processed by the software



Extra-oral vs Intra-oral scanners

Definitive restorations which were made based on intraoral digital impressions demonstrated significantly smaller marginal openings (from 86.09 µm ± 61.46 µm to 88.95 µm ± 54.46 µm) than those which were fabricated based on laboratory scanning procedures (143.29 µm ± 100.71 µm)

Others found no difference

Evaluation of the Accuracy of Digital Models Obtained Using Intraoral and Extraoral Scanners versus Gold Standard Plaster Model (Diagnostic Accuracy Study)

Mohammed Amr Labib*, Amr Ragab El-Beialy, Khaled Hazem Attia

Digital Impressions

Chapter | First Online: 02 April 2024

pp 25–46 | Cite this chapter

Which one is better? Mixed literature.

Lab based scanners are scanning a cast (which is not the original site). Impression 99% accurate. Then you pour up or scan the impression. Compounding errors. Extra-orla scanners still allow recrods keeping. Allow CADCAM technqiues on supplied physical models.

Intra-oral scanners

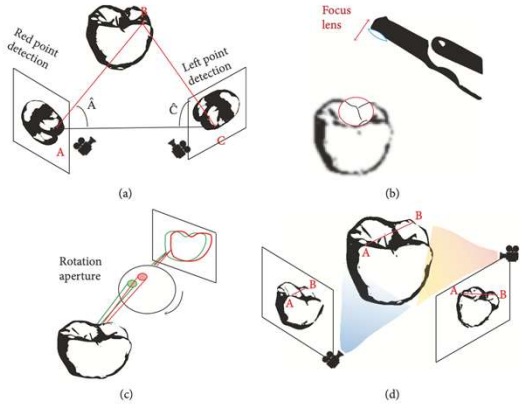


FIGURE 3: Determining distance to the object. (a) Triangulation: distance BC could be determined according to the formula $BC = AC \times \sin(\hat{A})/\sin(\hat{A} + \hat{C})$. (b) Confocal: distance to the object is determined according to the focal distance. (c) AWS requiring a camera and an off-axis that moves on a circular path around the optical axis and produces a rotation of interest points. (d) Stereophotogrammetry is a technology that generates files by algorithm analyzing numerous pictures.

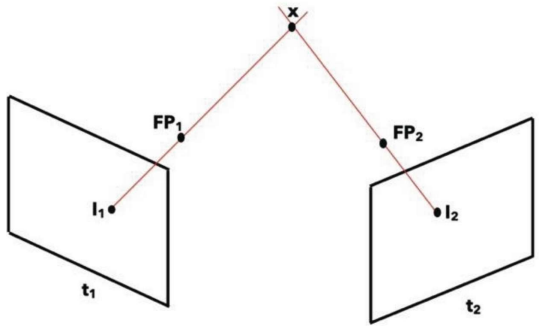
Review Article

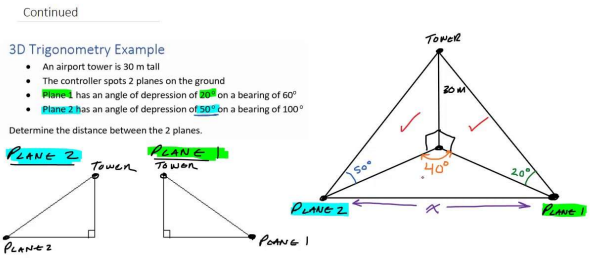
Intraoral Scanner Technologies: A Review to Make a Successful Impression

Raphaël Richert,[1,2] Alexis Goujat,[1,2] Laurent Venet,[1,2] Gilbert Viguie,[1,2] Stéphane Viennot,[1,2,3] Philip Robinson,[4] Jean-Christophe Farges,[1,2,5] Michel Fages,[6] and Maxime Ducret[1,2,5]

1. Triangulation
2. Confocal
3. Active wavefront sampling
4. Sterophotogrammetry

Intra-oral scanners: Triangulation

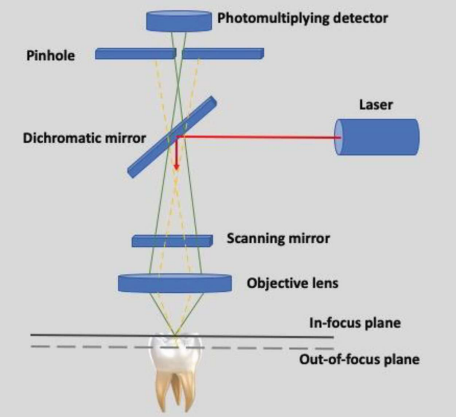




Triangulation. Triangulation is based on a principle that the position of a point of a triangle (the object) can be calculated knowing the positions and angles of two points of view (Figure 3(a)). These two points of view may be produced by two detectors, a single detector using a prism, or captured at two different points in time

Idea is that we can figure out the exact position of an object if we know the relative angle and distance from 2 different points. However noise, lens distoration can lead to inaccuracies. If there is an error, this could get carried forward to other calcuations
Used by sirona omnicam scanners

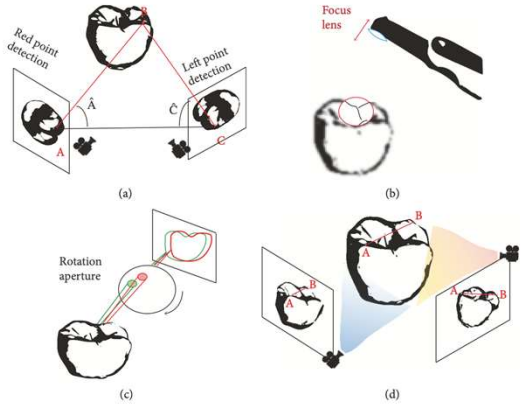
Intra-oral scanners: Confocal



Confocal. Confocal imaging is a technique based on acquisition of focused and defocused images from selected depths (Figure 3(b)). This technology can detect the sharpness area of the image to infer distance to the object that is correlated to the focal length of the lens. A tooth can then be reconstructed by successive images taken at different focuses and aperture values and from different angles around the object. The sharpness area is directly related to the dexterity of the operator who can generate motion blur and this technique also requires large optics that may lead to difficulties in clinical practice.

Eliminates abberant beams via pin hole.

Intra-oral scanners



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1. Triangulation
2. Confocal
3. Active wavefront sampling
4. Sterophotogrammetry

Active Wavefront Sampling (AWS) – Active wavefront sampling refers to getting 3D information from a single lens imaging system by measuring depth based on the defocus of the primary optical system. Three sensors capture the clinical situation from different perspectives. With these three images captured simultaneously, 3D surface patches are generated in real time by means of proprietary image processing algorithms using the in-focus and out-of-focus information. Used by Lava chairside Oral scanner.

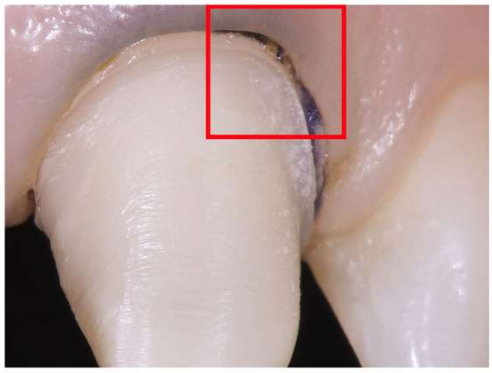
Stereophotogrammetry. Stereophotogrammetry estimates all coordinates (x, y, and z) only through an algorithmic analysis of images.. As this approach relies on passive light projection and software rather than
active projection and hardware, the camera is relatively small, its handling is easier, and its production is cheaper.

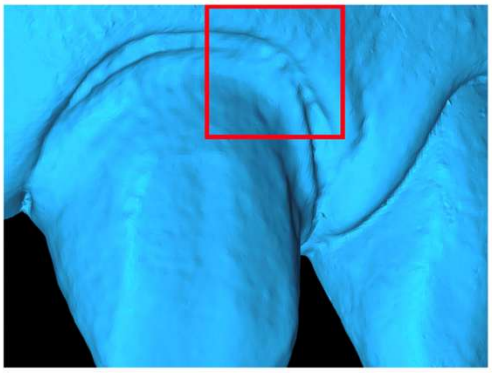
Intra-oral scanners

- Relatively obsolete technique of coating the intra-oral surfaces with an anti-reflective powder such as titanium dioxide

As mentioned in earlier slides, the light is an important feature of how the scanners capture information. Which is why impotant to not use overhead light. Additionally, saliva etc may reflect unwanted light. The earlier generations of IOSs required some opaquers in the form of sprays or powders for accurate recording, which have inherent disadvantages, including patient discomfort, time consumption, and technique sensitivity

Accuracy?

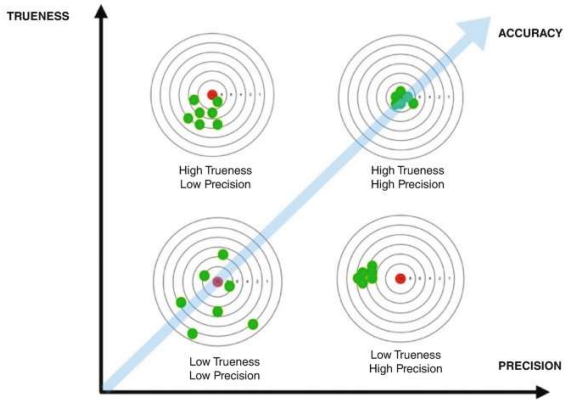




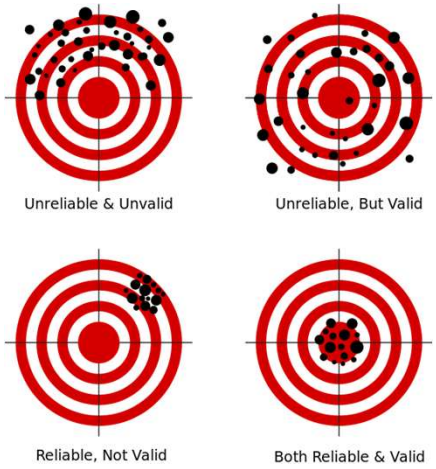
Accuracy

According to the International Organization for Standardization (ISO) 5725-1:

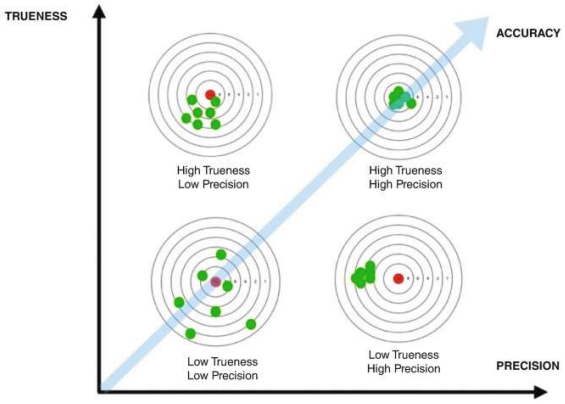
- The term *trueness* refers to the closeness between the arithmetic mean of a big number of test results and the true or accepted reference value.
- *Precision* is another term which is used widely for optical impressions. This term refers to how close several measurements of the same quantity are close to each other.
- *accuracy* refers to the combination of *trueness* and *precision*



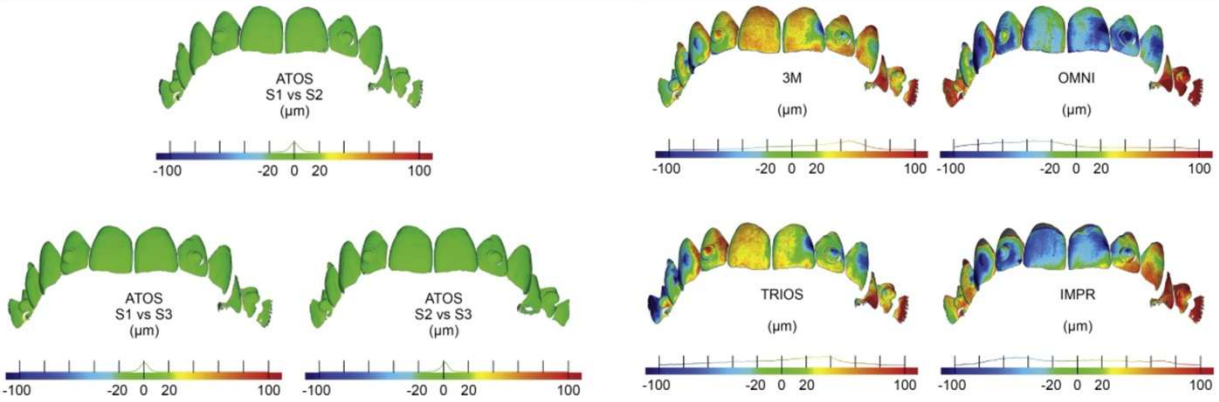
Accuracy



Psychology



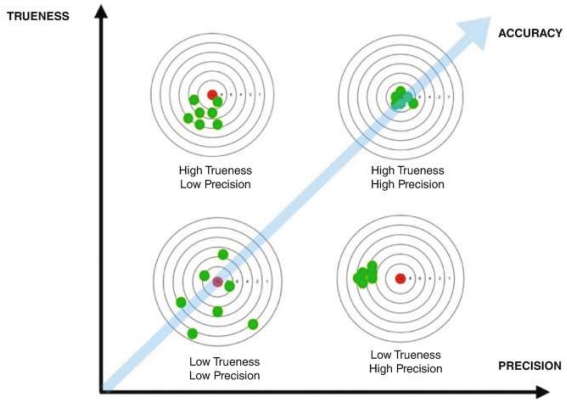
IOS accuracy



"It is vital that IOS has an equally or higher accuracy and precision than conventional impressions. 3M and TRIOS had a higher accuracy than OMNI. IMPR overlapped both groups. However, the deviations are within a similar magnitude for arches up to ten units." – *Accuracy and precision of 3 intraoral scanners and accuracy of conventional impressions: A novel in vivo analysis method (Nedelcu et. al., 2018)*

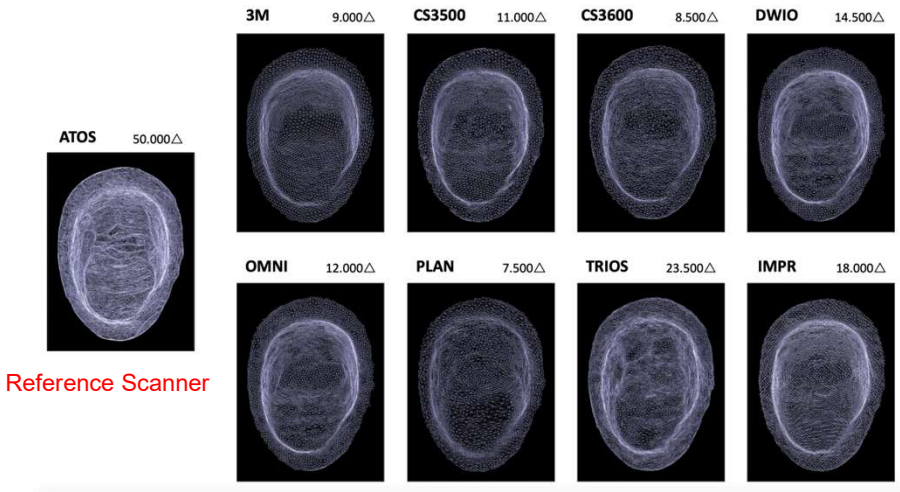
Accuracy

- Precision: assessed with multiple scans of the same object.
- Trueness assess with a reference scanner



Reference scanner needed to digitalise info

Accuracy



Images by Dr Nedelcu

So we know that some scanners may be better than other scanners.

Creation of a mesh network

360p vs 1080p vs 4k

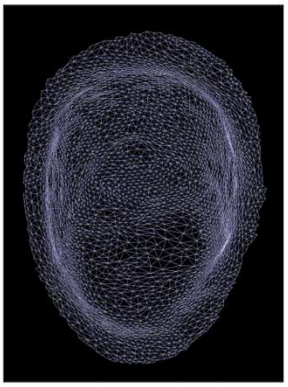
As the number of geometric entities (triangels) increase, so does the accuracy

Reference scanner has a LARGE amount of triangles

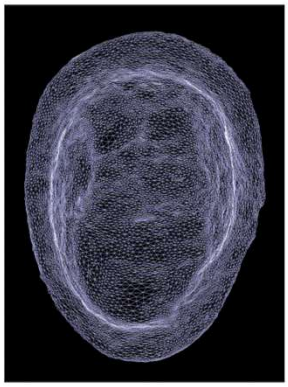
Look at OMNI vs trios vs reference scanner

Accuracy

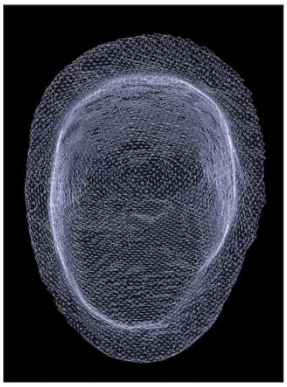
PLANSCAN 7.500△



TRIOS 23.500△

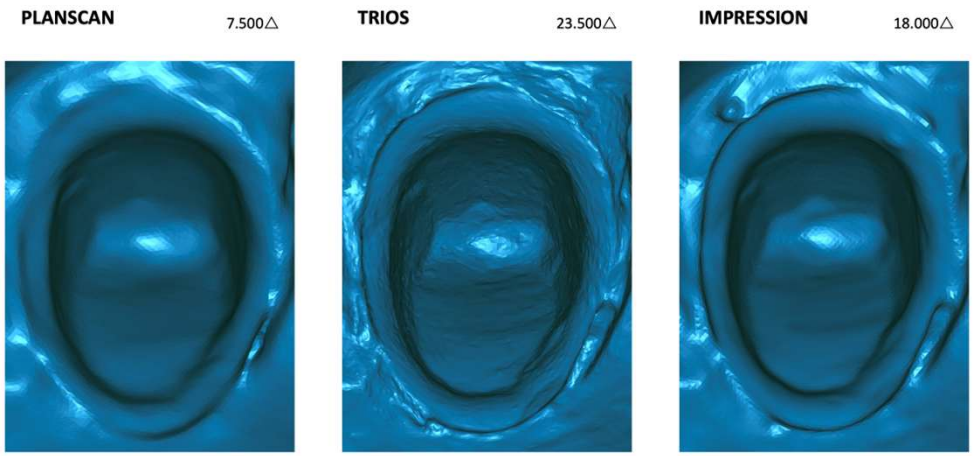


IMPRESSION 18.000△



Images by Dr Nedelcu

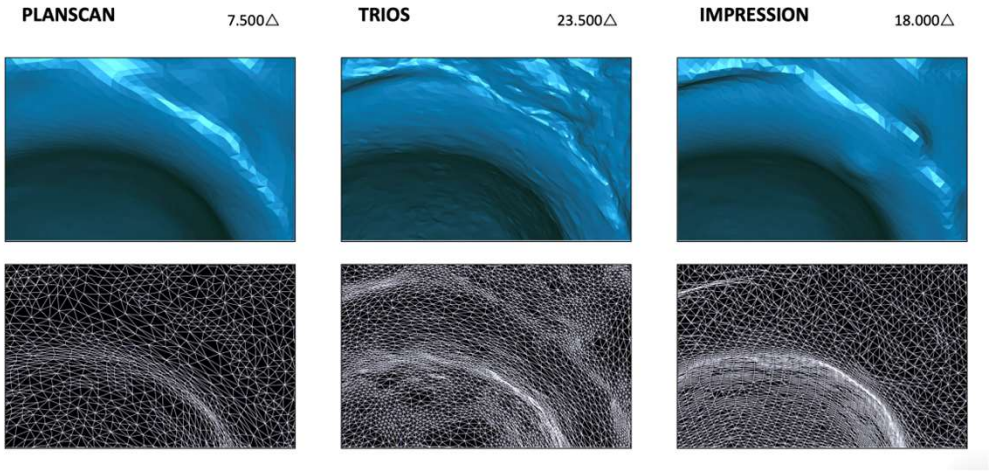
Accuracy



Images by Dr Nedelcu

Refelected in the finish line. Margins are very important. When we evaluate physical impressions we need to ensure we can see the finish line.

Accuracy



Images by Dr Nedelcu

Low resolution

Accuracy

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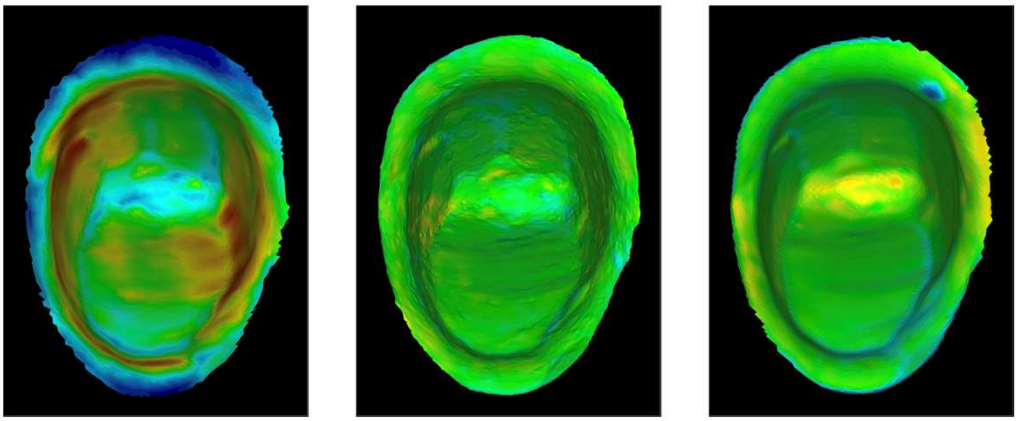
PLANSCAN 7.500△ **TRIOS** 23.500△ **IMPRESSION** 18.000△



Images by Dr Nedelcu

Finish Line

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Results: All IOS, except Planscan, had comparable overall accuracy, however, FLD and FLA varied substantially. Trios presented the highest FLD, and with CS3600, the highest FLA. 3M, and DWIO had low overall FLD and low FLA in subgingival areas, whilst Planscan had overall low FLD and FLA, as well as lower general accuracy. IMPR presented high FLD, except in subgingival areas, and high FLA.
Trios had the highest resolution by factor 1.6 to 3.1 among IOS, followed by IMPR, DWIO, Omnicam, CS3500, 3M, CS3600 and Planscan. Tessellation was found to be non-uniform except in 3M and DWIO. Topographic variation was found for 3M and Trios, with deviations below +/– 25 µm for Trios. Inclusion of color enhanced the identification of the finish line in Trios, Omnicam and CS3600, but not in Planscan.

Conclusions: There were sizeable variations between IOS with both higher and lower FLD and FLA than IMPR. High FLD was more related to high localized finish line resolution and non-uniform tessellation, than to high overall resolution. Topography variations were low. Color improved finish line identification in some IOS.
It is imperative that clinicians critically evaluate the digital impression, being aware of varying technical limitations among IOS, in particular when challenging subgingival conditions apply.

Images by Dr Nedelcu

Summary of the paper that previous slides were taken from.

Newer study

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Accuracy of 3 Intraoral Scanners in Recording Impressions for Full Arch Dental Implant-Supported Prosthesis: An In Vitro Study

Saurabh Jain [1,A,B,E,F], Mohammed E Sayed [1,A,B,E,G,*], Reem Abdullah A Khawaji [2,B,E,F], Ghada Ali J Hakami [2,B,E,F], Eman Hassan M Solan [2,B,E,F], Manal A Daish [2,B,E,F], Hossam F Jokhadar [3,A,B,E,F], Saad Saleh AlResayes [4,A,B,E,F], Majed S Altoman [5,C,D,E,G], Abdullah Hasan Alshehri [5,C,D,E,G], Saeed M Algahtani [5,C,D,E,G], Mohammad Alamri [6,C,D,E,G], Ahid Amer Alshahrani [7,C,D,E,G], Hind Ziyad Al-najjar [8,C,D,E,F], Khurshid Mattoo [1,B,C,D,E,*]

Results

The TRIOS 5 intraoral scanner displayed the lowest deviation for precision (37.8±4.53 µm) and trueness (54.9±11 µm), followed by Medit i700 (precision 40.6±4.17 µm, trueness 60.5±10.9 µm), whereas the highest deviation (precision: 49.1±8.31 µm, trueness: 72.3±10.4 µm) was reported when Primescan intraoral scanner was used for recording impressions of full arch implants. When the 3 intraoral scanners were compared, a statistically significant difference was observed in terms of precision ($P<0.005$) and trueness ($P<0.005$).

Conclusions

TRIOS 5 intraoral scanner displayed the lowest deviation values for precision and trueness (more accurate), followed by Medit i700 and Primescan intraoral scanners. However, deviation values of all scanners were within clinically acceptable limits.

Trios scanners

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Accuracy of 3 Intraoral Scanners in Recording Impressions for Full Arch Dental Implant-Supported Prosthesis: An In Vitro Study

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Results

The TRIOS 5 intraoral scanner displayed the lowest deviation for precision (37.8±4.53 µm) and trueness (54.9±11 µm), followed by Medit i700 (precision 40.6±4.17 µm, trueness 60.5±10.9 µm), whereas the highest deviation (precision: 49.1±8.31 µm, trueness: 72.3±10.4 µm) was reported when Primescan intraoral scanner was used for recording impressions of full arch implants. When the 3 intraoral scanners were compared, a statistically significant difference was observed in terms of precision (P<0.005) and trueness (P<0.005).

Conclusions

TRIOS 5 intraoral scanner displayed the lowest deviation values for precision and trueness (more accurate), followed by Medit i700 and Primescan intraoral scanners. However, deviation values of all scanners were within clinically acceptable limits.

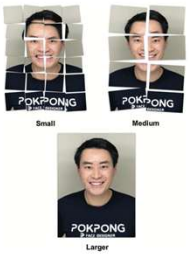


Figure 4: A small capture box requires more stitching images to scan, creating more errors, whereas large capture boxes need fewer stitching images showing fewer errors

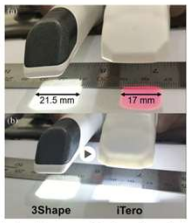


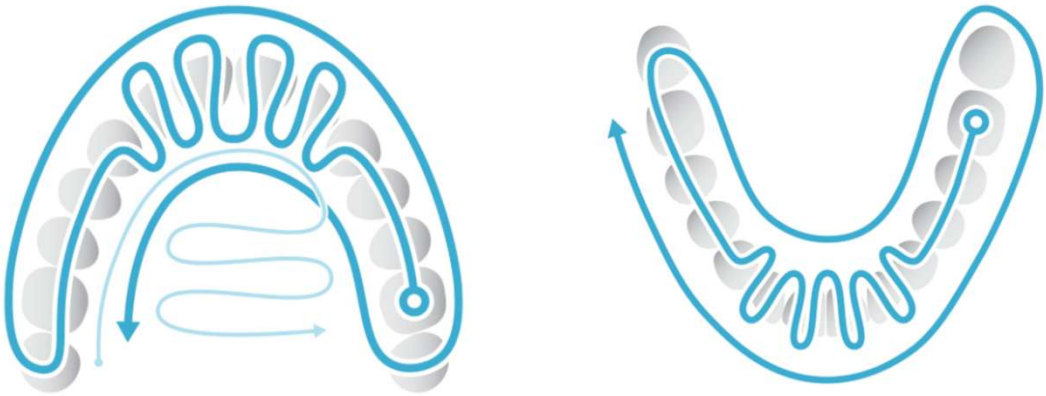
Figure 5: Capture box of Trios 3 and iTero measured by slow motion mode of a digital camera showing the white light by Trios 3 and the red light by iTero (a) and showing the white light by both scanners (b)

ATOS Core

- Industrial scanner (Not an intra-oral scanner)
- Can be accurate to 1um
- Often used as a “reference”

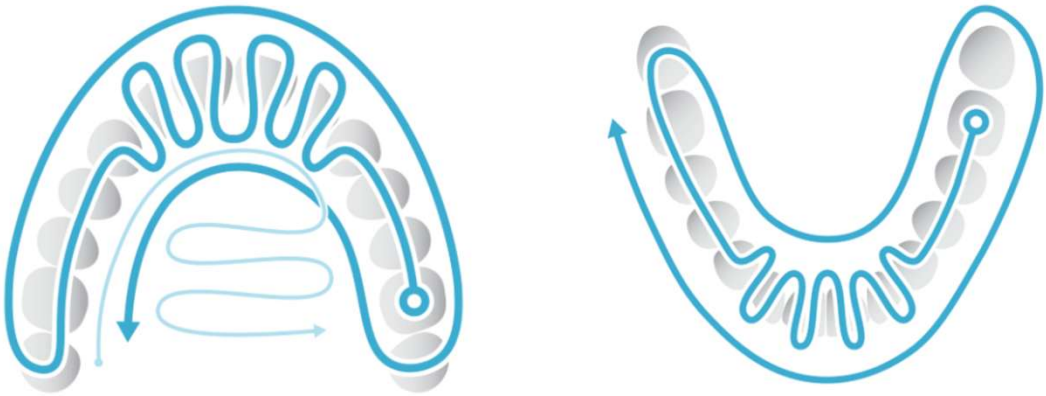
Digital scanners: Trios

Scan protocol:



Digital scanners: Trios

Scan protocol:

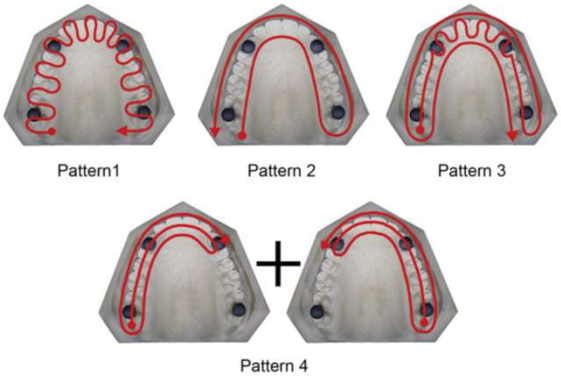


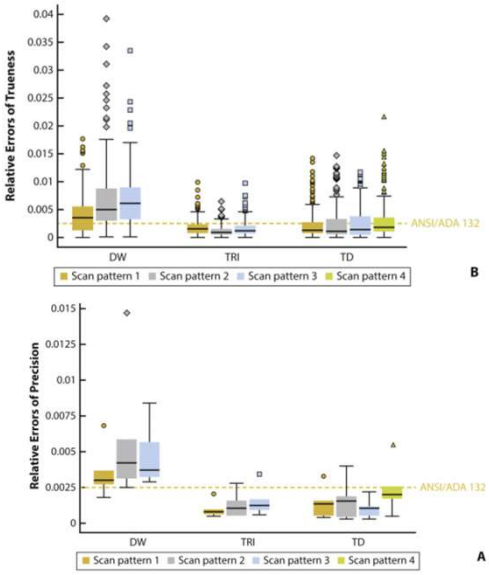
Scan Pattern

Research and Education

Accuracy of intraoral scanners in different complete arch scan patterns

Sakaorat Pattamavilai DDS [a], Chakree Ongthiemsak DDS, MSc [b]





Trios scan patterns all achieve similar results.

Digital vs Conventional Impressions

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Digital Versus Conventional Impressions in Fixed Prosthodontics: A Review

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- Efficiency of digital vs conventional impressions:
- Digital (248.48 ± 23.48 s) and conventional (605.38 ± 23.66 s)
- But when completing a full arch impression, conventional impressions more accurate

Abstract

Purpose: To conduct a systematic review to evaluate the evidence of possible benefits and accuracy of digital impression techniques vs. conventional impression techniques.
Materials and Methods: Reports of digital impression techniques versus conventional impression techniques were systematically searched for in the following databases: Cochrane Central Register of Controlled Trials, PubMed, and Web of Science. A combination of controlled vocabulary, free-text words, and well-defined inclusion and exclusion criteria guided the search.
Results: Digital impression accuracy is at the same level as conventional impression methods in fabrication of crowns and short fixed dental prostheses (FDPs). For fabrication of implant-supported crowns and FDPs, digital impression accuracy is clinically acceptable. In full-arch impressions, conventional impression methods resulted in better accuracy compared to digital impressions.
Conclusions: Digital impression techniques are a clinically acceptable alternative to conventional impression methods in fabrication of crowns and short FDPs. For fabrication of implant-supported crowns and FDPs, digital impression systems also result in clinically acceptable fit. Digital impression techniques are faster and can shorten the operation time. Based on this study, the conventional impression technique is still recommended for full-arch impressions.

Digital vs Conventional Impressions

Other studies have reached similar conclusions

Research and Education

Accuracy of complete-arch intraoral scans based on confocal microscopy versus optical triangulation: A comparative in vitro study

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Purpose

The purpose of this in vitro study was to compare the accuracy of 2 intraoral scanners, TRIOS 3 (TR) and CEREC Omnicam (OC). Accuracy was assessed from changes to reference distances defined along the complete arch of a reference cast including 3 precision balls and 3 prepared teeth. The local accuracy (trueness and precision) of the scanned surface of each prepared tooth was also assessed.

Results

The following mean absolute changes in distance were determined: ΔP_1P_2, TR: 74.4 μm, OC: 119.6 μm; ΔP_1P_3, TR: 24.7 μm, OC: 17.2 μm; ΔP_2P_3, TR: 68.6 μm, OC: 41.2 μm. The scanner did not have a statistically significant effect (P=.118) for distance, and the different distances differed significantly from each other (P<.001). Both scanners provided results acceptable for the fabrication of inlays and short-span FPDs. A complete-crown scan was more accurate than an inlay scan (P<.001). Accuracy and precision were better for TR than for OC (P<.001).

Conclusions

With maximum discrepancies of 192.5 to 294.6 μm across the dental arch, complete-arch scans cannot yet be recommended for the fabrication of long-span FPDs.

Questions?

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Most important: How to use intra-oral scanners. What are good traits of intra-oral scanners?

In Vivo Accuracy and Precision in Prosthodontics

ROBERT NEDELCU