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REVIEW

Accuracy of digital impression scanning strategies for free-end edentulous

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Keywords: Free end, IOS, Precision, Scan strategy, Trueness

ABSTRACT

Scanning using intraoral scanners (IOS) offers better accuracy and time efficiency compared to conventional impression methods, especially in overcoming the challenges of free end edentulous cases. The quality of IOS scans is measured by accuracy, which is influenced by scan strategy. Scan strategies include scanning paths, sequences, and combinations. Study conducted that the right scan strategy can affect accuracy as assessed by trueness and precision. However, there is no manufacturer's standard and only a few studies on scan strategies in edentulous free end cases. This literature review aims to describe scan strategy in improving digital impression accuracy in free end edentulous case. A zig zag scanning path will help the IOS to capture the tooth morphology better and a linear scanning path will result in smaller deviations. Scanning sequences from the teeth to ridge will reduce the jigsaw effect at the fulcrum point, resulting in a more stable framework during removable denture fabrication. (IJP 2025;6(1):71-76)

Introduction

Technological developments in dentistry have undergone significant changes since digital workflow was first introduced in the early 1970s. At that time, Dr. Duret and Termoz patented the first procedure for indirect restorations.[1,2] Today, digital processes in prosthodontics involve the use of intraoral scanners (IOS) for various purposes, such as crowns, implants, partial dentures, and complete dentures. IOS technology simplifies and speeds up the workflow in the fabrication of various types of dental restorations, and provides advantages in terms of accuracy and time efficiency.

Various types of IOS are available in the market with their own advantages, such as accuracy, portability, scan speed, and digital reconstruction quality. Some of the leading brands, such as Dentsply Sirona, Align Technologies, 3Shape A/S, Carestream, Medit Corp offer innovative features that make it easy to capture detailed dental and soft tissue data. Although IOS is widely used in restorative cases such as crown and bridge manufacturing, its application in removable denture cases is still challenging. This is due to the dynamic variations in oral soft tissue anatomy and the need to produce a stable and comfortable denture base for the patient. One of the crucial procedures for making a partial denture is impression. It is important that the prosthesis can be properly designed for maximum retention, stability, support and aesthetics following appropriate insertion and removal directions.[3] Conventional anatomical and secondary impression procedures on the free end edentulous using alginate and elastomer are performed to obtain more accurate impression results because there is a difference in compressibility between the mucosa of the edentulous region and the existing dentition. However, these impression are prone to inaccuracies due to distortion, inappropriate water to powder ratio, and shrinkage of the impression material.[4]

In digital workflow, scanning intraoral is used to obtain digital models. Digital impression has several advantages, namely high impression quality, ease of reimpression, easy model visualization, time efficiency, reduce the number of patient visits, laboratory work, and increase patient comfort and has a cut-out rescan feature that allows operators not to repeat the scan from the beginning if the errors occur.[4] The quality of IOS scans can be measured in terms of accuracy. Accuracy is a key method in evidence-based research to assess the quality of IOS scans for clinical use. Studies show digital impression results have higher accuracy than conventional impression.[5]

According to ISO 5725-1, there are two factors that need to be considered when measuring the accuracy of IOS scans, namely trueness and precision. Trueness refers to the ability of the IOS to accurately capture the 3D shape of an object according to its original dimensions. Meanwhile, precision measures the consistency of the scan results when the IOS is used repeatedly under the same conditions.[6] There are several factors that affect the accuracy of scanning using IOS including intra oral factors, such as the extent of the edentulous and oral cavity's condition, the scanner, such as lighting, temperature, scanner head size, and software, operator, such as operator expertise, distance, angulation and scan strategy.[7]

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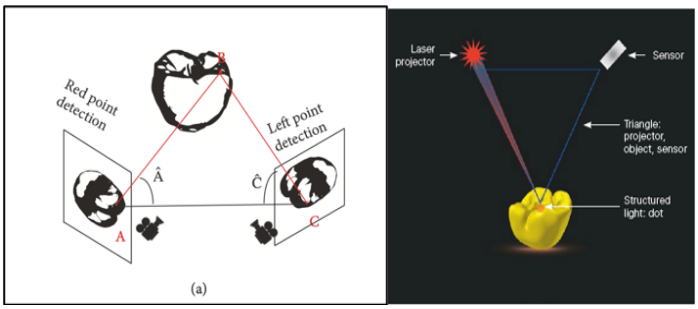

Figure 1. Triangulation: the distance BC is determined by the formula BC = AC × sin Â / (sin Â + Ĉ)

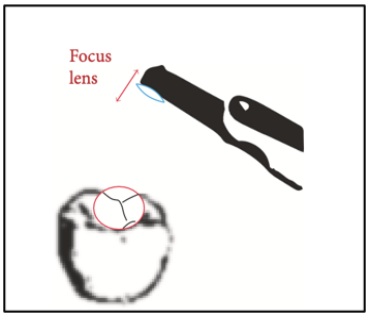

Figure 2. Confocal: The distance to the object is determined based on the focal distance

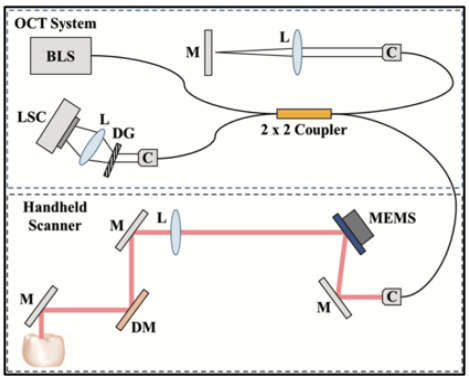

Figure 3. Schematic of OCT working principle

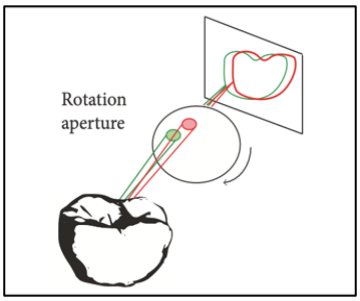

Figure 4. AWS requires a camera and an off-axis module that moves on a circular path around the optical axis. This module generates rotation at the points of focus of attention

Various conventional (manufacturer's) scan strategies have been recommended to produce accurate images in dentate arch. Scan strategies include scanning paths, sequences or combinations. A study by Chang I-Chang et al (2023) showed higher accuracy results in the Mucosa-Dental strategy but recommended the Tooth-Mucosa strategy using the TRIOS 3 Pod Scanner due to reduced leverage effect and more stable denture results.[2] A study by Gavounelis NA et al (2022) showed that a combination sequence of zigzag on the anterior and linear on the posterior produced the best accuracy compared to linear and zigzag only.[8] A study by Feng CW et al (2021) stated that linear and circular movements showed the highest trueness in maxillary impression.[1] To date, there is no recommended manufacturer's standard and few studies have discussed scan strategies in free end edentulous cases.

The purpose of this review is to discuss the IOS scan strategy on digital impression accuracy in free end edentulous.

Literature Study

Intraoral scanner (IOS)

An intraoral scanner (IOS) is a device used for direct optical impressions in dentistry. Just like other three-dimensional (3D) scanners, it projects a light source (such as a laser or structured light) onto the object to be scanned, in this case the jaw arch, including the tooth preparation and implant body scan (a cylinder mounted on the implant, used to transfer the 3D position of the implant).[9] Images of the dental and gingival tissues captured by the image sensor are then processed by the device.

Working principle of IOS

Here is how the IOS works in capturing the 3D geometry of an object:[10,11] Light projection: IOS uses a light source such as a laser or structured light, to illuminate. This light will then be projected onto objects, such as teeth and surrounding tissues; Image capture: the camera in the scanner captures the light reflected from the tooth surface and surrounding tissues. This image is captured in the form of a photo or video and contains information about the contours and shape of the object; Data Processing: the captured images are then processed by the scanner software. This software combines the images to form a three-dimensional model of the scanned area; Coordinate recording: each point on the surface of the object is recorded in the form of three-dimensional coordinates (x, y, and z). The x and y coordinates are obtained from the images, while the z coordinate is calculated based on the distance between the camera and the object; Storage and analysis: the resulting three-dimensional model can be saved in a digital format such as STL (Standard Testellation Language) or other formats.

IOS Technology

Triangulation is an IOS method based on the principle that the position of a point in a triangle (object) can be calculated if we know the position and angle of two viewpoints figure 1. These two

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Various IOS manufacturer scan strategiesvantage points can be obtained from two different detectors, one detector using a prism, or they can be captured at two different times.[12]

Confocal irradiation is a technique that uses focused images. This technology can detect areas of image sharpness to determine the distance to the object related to the focal length of the lens. Dental images can be composed by successively taking images at various focus and aperture values and from different angles around the object figure 2. The area of sharpness is highly dependent on the operator's skill which can affect the motion blur effect, and the technique also requires bulky optics which can make it difficult to implement in clinical practice.[12]

Optical Coherence Tomography; The working principle of IOS using Optical Coherence Tomography (OCT) is based on the utilization of coherent light waves to produce three-dimensional (3D) images of dental tissues and soft tissues in the mouth. The process works by sending out infrared light which is then reflected by the various layers of oral tissues figure 3. The reflected light waves are measured in time and intensity, and then used to build an accurate 3D reconstruction.[12]

Active Wavefront Sampling (AWS) a surface imaging technique that requires a camera and an off-axis aperture module. The module moves in a circular path around the optical axis and generates rotation at the point of focus (POI) figure 4. Information on distance and depth is then obtained and calculated based on the pattern generated from each point.[12]

Stereophotogrammetry estimates all coordinates (x, y, and z) only through algorithmic analysis of the image. Since this method relies on passive light projection and software instead of active projection and hardware, the cameras used are relatively small, easier to use, and cheaper to produce.[12]

Accordion Fringe Interferometry (AFI) uses acousto-optics for non-contract 3D imaging by projecting interference fringes (e.g. Moire patterns) onto objects for measuring distances. This involves projecting two gratings of identical frequencies that are superimposed to form an interference fringe pattern. The laser wavelengths between 300 nm and 500 nm limit the illumination to the surface of translucent objects.

Indications and Contraindications

In the field of prosthodontics, IOS can be used to perform digital impressions in the treatment and production of various types of dental restorations such as single crowns, endocrowns, onlays, inlays, veneers, fixed dentures, removable dentures, implant bridge posts and cores, temporary restorations, digital smile designs.

In the field of orthodontics, digital impressions can be used for diagnosis, treatment plans as well as making orthodontic aligners, special appliances, and retainers. Digital impressions are also useful for creating guides in implant surgery.

In general, contraindications to digital impression using IOS are patients who are unable to sit still in the dental unit, patients with limited mouth opening due to certain reasons, such as patients

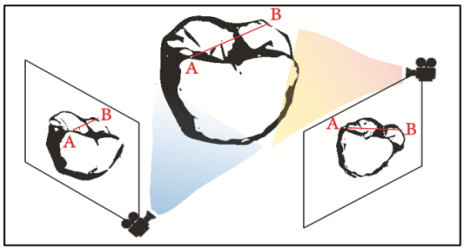

Figure 5. Stereophotogrammetry is a technology that generates files by analyzing multiple images using algorithms

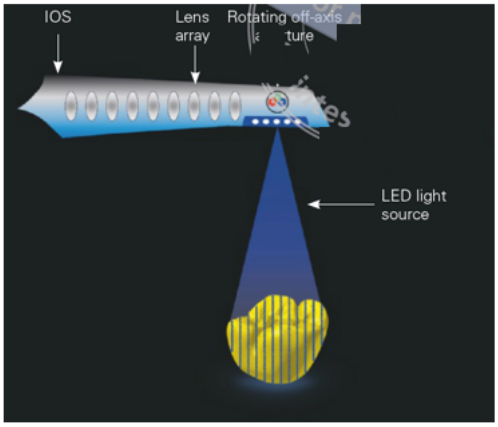

Figure 6. An intra-oral scanner with AFI technology

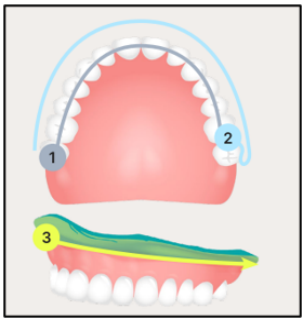

Figure 7. Scan strategy on upper jaw

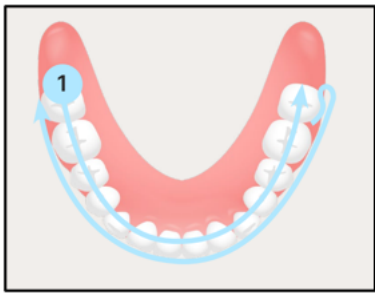

Figure 8. Scan strategy on lower jaw

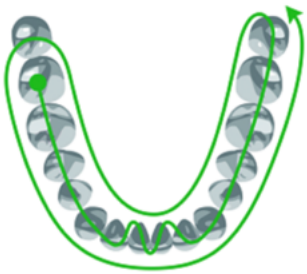

Figure 9. Scan strategy on upper jaw

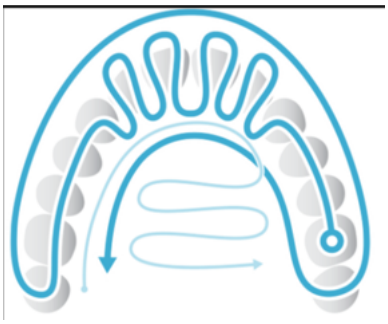

Figure 10. Scan strategy on lower jaw

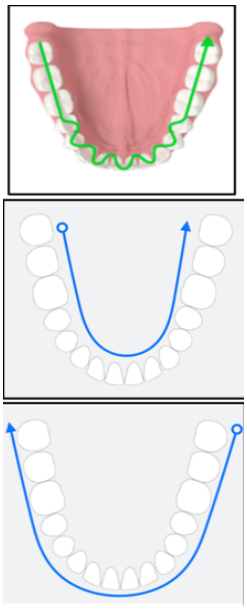

Figure 11. Scan strategy

with TMD disorders with limited opening, head scanners that are too large, tongue movement or using orthodontic devices. In addition, it is important to control bleeding before scanning in order to produce good images.[13,14]

Accuracy of IOS Digital Prints

Digital impression accuracy in dentistry can be assessed using the ISO 5725-1 standard, which specifies methods for measuring and evaluating the accuracy of measurement results. This standard defines two main concepts in measuring accuracy: trueness and precision. Trueness refers to how close the digital measurement results are to the true value of the object being scanned, while precision refers to the consistency of the measurement results when performed repeatedly under the same conditions.[6] In the context of dental digital impression, these two aspects are crucial to ensure that the three-dimensional model produced from intraoral scanning is accurate.

A systematic review examining the average accuracy of digital technologies, including intraoral scanners, found that the accuracy of jaw arch scans with laboratory scanners and IOS ranged from 17 to 378 µm. For prepared teeth, the minimum accuracy was 23 µm, while when the entire dental arch was scanned, the minimum accuracy was 60 µm. Scans of a single prepared tooth showed an accuracy between 20 and 40 µm, and scans of implants had an accuracy between 19 and 112 µm. Accuracy on partial and full edentulus ranged from 30-220 µm, while for fully edentulous dental arches, the accuracy ranged from 44-591 µm. The authors of the review concluded that current digital technology is accurate enough for certain applications, but scanning of the edentulous dental arch is still challenging.[15] Other researchers have also stated that this is due to tissue mobility and the lack of reference points in the dental arch edentulous.[14] Overall, accuracy results varied among various IOS systems.

Factors Affecting Scan Accuracy

Intraoral conditions; The state of the tooth to be scanned will affect the accuracy of the digital print. According to Alfaraj A (2024) IOS accuracy is influenced by the length of the edentulous area and the type of scanner used. Primescan AC shows a lower level of trueness compared to TRIOS 3 for most partial edentulous conditions, while both scanners have the same precision.[16] Intraoral conditions such as the presence of fluid or wetness will decrease the accuracy of digital impression. This is because the presence of wet dental and gingival tissues will cause uneven or distorted light reflection and interfere with the digital scanning sensor which causes disruption of the data captured by the sensor.[17]

Scanner; Another factor that can affect the accuracy of the IOS is related to the scanner. These are light, temperature, scanner head size, software. Environmental lighting conditions can affect intraoral scanner (IOS) accuracy, and the ideal conditions vary depending on the type of IOS used. In a study conducted by Revilla-Leon et al (2023) stated that various lighting conditions produce different results for each scanner. For the iTero Element (Align Technology) scanner , better accuracy was obtained under chair and room lighting. In contrast, the CEREC Omnicam (Densply Sirona) scanner obtained optimal accuracy in unlit conditions. Meanwhile, the TRIOS 3 (3Shape) scanner showed the highest accuracy under standard room lighting conditions.[16]

IOS comes in the market with various scanner head sizes. Scanners with smaller heads show much greater errors in terms of trueness and precision compared to larger scanner heads. This is because smaller scanner heads can be more easily moved around the oral cavity, allowing easier access to hard-to-reach areas. This can result in better accuracy in capturing complex details, although it may require more scans to cover the entire dental object.[4]

Operator factors play an important role in influencing the accuracy of digital impression results on teeth. Research by Revell et al. states that the skill and experience of the operator in using the IOS can affect the quality and accuracy of the results

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obtained. Inconsistent or less careful scanning techniques, such as too fast or unstable movements, can cause data deficiencies in digital models. In addition, the operator's understanding of how to optimize lighting, scanning angle and scan strategy is also crucial.

Scan strategy; During a scan, the clinician must place the object to be scanned in the center of the view finder and move the IOS scanner head along a specific path called the scan strategy.[8] These strategies include scanning paths, sequences, or combinations.[2] Medina et al (2018) and Pasos et al tested various IOS systems and found that the scan strategy affects IOS accuracy differently, depending on the data capture method.[18] Anh et al (2016) stated that the precision of the digital model depends on the starting point of the scan.[19] There are conventional scan strategies derived from the manufacturer's instructions as well as modified scan strategies.

Conventional Scan Strategy (Manufacturer)

Various scan strategies on toothed cases are suggested by the manufacturer depending on the brand and type of IOS technology used as follows:

Primescan (Dentsply)

Scan strategy maxilla; Begin the scan on the occlusal buccal surface of the molar and direct the scan to the entire dental arch; Tilt the scan approximately 60° buccally and guide the scanner around the entire dental arch. Continue the scan along the buccal border and loop the scan back across the entire dental arch to capture all border areas.

Scan strategy mandible; Start the scan at the last molar and scan its lingual surface; If scanning one arch, scan up to the opposite molar; If scanning one quadrant, scan up to the midline; Turn the scanner to the occlusal surface and scan back to the last molar; Rotate the scanner to the fascial surface and scan up to the location where you stopped on the previous implant; Fill in missing data in important areas such as margins or implant locations.

3S Trios

Scan strategy maxilla; Start by positioning the scanner on the occlusal surface of the molar tooth, wait for 3-5 clicks; Move the scanner towards the incisor, while capturing the occlusal surface; Continue the scanner slowly through the incisors and continue along the occlusal surface until it reaches the last molar tooth; Slowly rotate the scanner in a buccal direction by rotating it 60-90 degrees at the last molar and complete the buccal scan, taking note of areas where soft tissue may interfere with the scan results; Scan along the buccal side until you reach the last molar on the opposite side; Then, rotate the scan to the palatal direction and complete the scan on the palatal side.

Scan strategy mandible; Start by positioning the scanner on the occlusal surface of the molar tooth, wait for 3-5 clicks; Move the scanner towards the incisor, while capturing the occlusal surface; Continue the scanner slowly through the incisors and continue along the occlusal surface until it reaches the last molar tooth; Slowly rotate the scanner in a buccal direction by rotating it 60-90 degrees at the last molar and complete the buccal scan, taking note of areas where soft tissue may interfere with the scan results; Scan along the buccal side until you reach the last molar on the opposite side; Then, rotate the scan to the palatal direction and complete the scan on the palatal side.

Medit

Start the main scan on the occlusal surface from the last molar to the anterior teeth; When scanning the anterior teeth, ensure that the scan data is sufficient so that the anterior teeth appear green on the display layer; Scan the lingual side of the anterior teeth, tilt the scan tip for the incisal surface, and tilt again for the labial side scan; Complete the scan of the anterior tooth, then proceed to the occlusal surface until you reach the opposite molar tooth; On reaching the opposite molar, tilt the scan tip to the lingual side so that the lingual side of the tooth, lingual gingiva and occlusal surface are visible in the proportion of 1:1:1. Continue to the lingual side of the opposite molar until you return to the molar where you started the scan. Make sure to scan the anterior teeth from various angles.

Modified Scan Strategy

Some studies on modified scan strategies include scanning path, sequence or combination. Scanning path refers to the movement pattern of the scanner head and sequence refers to the sequence of steps or areas scanned. Research by Liu CT et al (2024) stated that the best accuracy was produced in the TQ scan strategy, which started from tooth 17 then went to quadrant II, then turned to tooth 21 through the palatal side and the scan continued to the buccal side of tooth 17. Next, the scan turned at tooth 21 from the buccal side to the occlusal surface of quadrant II, continued to tooth 27 back to the palatal surface, and returned to the palatal side of tooth 21. Then, the scan turned to the buccal side of quadrant II and ended at the buccal side of tooth 27.[21]

Chang et al (2023) stated that the recommended scanning strategy for the maxillary Kennedy Class I is the TR (Tooth-Ridge) strategy because it can reduce the seesaw effect and high RPD skeletal stabilization compared to the M (Manufacturer) and RT (Ridge-Tooth) strategies.[2] Chu K et al (2022) stated that the strategy of partially scanning the region of interest first in a continuous manner with the head scanner in a horizontal position at full jaw resulted in good accuracy. However, the authors do not recommend performing vertical rotation movements.[2] Gavounelis et al (2022) conducted a study with three different scan strategies namely linear, zigzag and combination (linear on posterior and zigzag on anterior). The results of this study stated that the best accuracy was obtained from the combination scan strategy. However, these three scan strategies are still within the acceptable accuracy range.[8] Diker B et al (2021) examined the scanning sequence in the partial edentulous, namely ScanR where this strategy starts from the right region and ScanL starting from the left region in the upper jaw. The results show the difference between the two because the deviation results will be smaller in the quadrant starting the scan.[23] According to Feng CW et al (2021), S-shaped and figure 8 movements are not recommended, while linear and circular movements show high accuracy. In the mandible, 8-shaped movements were also not recommended, while the other five movements (linear, circle, wave, S, AP) showed similar and lower deviations.[1]

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Discussion

The scan strategy is the specific path and movement that the IOS head scanner follows along the scanned object. Various in vitro studies have shown the influence of scanning strategy on data capture accuracy. In addition, the influence of scanning strategy on the accuracy of digital scanning is reported to vary depending on the IOS used. An inappropriate scanning strategy can lead to inaccuracies in the model, which in turn can affect the precision and comfort of the denture being produced. Most IOS manufacture recommends specific scan strategies for their systems, but these strategies are usually described for the dentate jaw arch. In general, the recommended scan strategy starts from the most posterior region. Different scanning strategies and techniques for scanning edentulous arches especially the free end are still very limited.

Some research on modified scan strategies include scanning path, sequence or combination. Scanning path refers to the movement pattern of the scanner head and sequence refers to the sequence of steps or areas scanned. Research by Chang et al (2023) stated that the recommended scanning strategy for maxillary Kennedy Cluster I is the TR (Tooth-Ridge) strategy because it can reduce the seesaw effect and high partial denture frame stabilization compared to the M (Manufacturer) and RT (Ridge-Teeth) strategies. This may be due to the fact that scans on teeth which have complex geometry shapes will be better for using complex best-fit algorithms compared to simple objects such as edentulous which are relatively flat and smooth will cause errors in alignment of scan data.[24]

Research by Liu CT et al (2024) stated that the best accuracy was produced in the TQ scan strategy, which started from tooth 17 then went to quadrant II, then turned to tooth 21 through the palatal side and scanning continued to the buccal side of tooth 17. Next, the scan turned at tooth 21 from the buccal side to the occlusal surface of quadrant II, continued to tooth 27 back to the palatal surface, and returned to the palatal side of tooth 21. Then, the scan turned to the buccal side of quadrant II and ended at the buccal side of tooth 27.[21]

This study is in line with previous research by Feng CW et al (2021) which states that undulating scanning movements will help IOS to capture tooth morphology better.[1] However, the results of this study obtained different results from the study by Oh et al (2022) who did not recommend performing vertical rotation on the IOS.[22]

Gavounelis et al (2022) conducted a study with three different scan strategies namely linear, zigzag and combination (linear on posterior and zigzag on anterior). The results of this study stated that the best accuracy was obtained from the combination scan strategy. However, these three scan strategies are still within the acceptable accuracy range.[8] This study is in line with research conducted by Zimmerman (2017) which states that the tendency of distortion is enlarged in the distal and anterior expansion due to the steep shape of the tooth morphology.[25] So that in the anterior scan a zigzag movement is carried out as in Feng CW et al (2021) which states that wavy movements will help IOS to capture tooth morphology better.[1]

Conclusion

Scan strategies including scanning path and sequence affect the accuracy of digital impression using IOS. Digital impression on Kennedy Class I, II requires a different scan strategy than Kennedy Class III and IV. Conventional scan strategies are not necessarily better than modified scan strategies.

References

1. Feng CW, Hung CC, Wang JC, Lan TH. Accuracy of different head movements of intraoral scanner in full arch of both maxilla and mandible. Applied Sciences (Switzerland). 2021 Sep 1;11(17).
2. Chang IC, Hung CC, Du JK, Liu C Te, Lai PL, Lan TH. Accuracy of intraoral scanning methods for maxillary Kennedy class I arch. J Dent Sci. 2023 Apr 1;18(2):747–53.
3. Carr AB, Brown DT. McCracken's Removable Partial Prosthodontics.13th ed. Missouri:Elsevier; 2016.
4. Hayama H, Fueki K, Wadachi J, Wakabayashi N. Trueness and precision of digital impressions obtained using an intraoral scanner with different head size in the partially edentulous mandible. J Prosthodont Res. 2018 Jul 1;62(3):347–52.
5. Abduo J, Elseyoufi M. Accuracy of intraoral scanners: A systematic review of influencing factors. Eur J Prosthodont Restor Dent. 2018;26(3):101-21.
6. Accuracy (trueness and precision) of measurement methods and results-Part 4: COPYRIGHT PROTECTED DOCUMENT [Internet]. 2020. Available from: https://standards.iteh.ai/catalog/standards/sist/d25f1a01-89b0-4b75-9ba6-
7. Alkadi L. A comprehensive review of factors that influence the accuracy of intraoral scanners. Diagnostics. 2023;13(3):1-10.
8. Gavounelis NA, Gogola CMC, Halazonetis DJ. The Effect of Scanning Strategy on Intraoral Scanner's Accuracy. Dent J (Basel). 2022 Jul 1;10(7).
9. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: A review of the current literature. BMC Oral Health. 2017 Dec 12;17(1).
10. Kihara H, Hatakeyama W, Komine F, Takafuji K, Takahashi T, Yokota J, dkk. Accuracy and practicality of intraoral scanner in dentistry: A literature review. Vol. 64, Journal of Prosthodontic Research. Elsevier Ltd; 2020. p. 109–13.
11. Hann-Min Hwang H, Chou CW, Chen YJ, Jane Yao CC, Hann-Min H, Jane CC. An Overview of Digital Intraoral Scanners: Past, Present and Future- From an Orthodontic Perspective. Taiwan J Orthod [Internet]. 2018;30(3).
12. Richert R, Goujat A, Venet L, Viguie G, Viennot S, Robinson P, dkk. Intraoral scanner technologies: a review to make a successful impression. J Healthc Eng. 2017;2017:1-9
13. Arthur, editor. Digital Dentistry: A step-by-step guide atlas. 1st ed. Oxford: John Wiley & Sons; 2022.
14. Jain P, Gupta M, editor. Clinical Applications Digitization in Dentistry. Cham: Springer;2021.
15. Bohner L, Gamba DD, Hanisch M, BS M, Tortamano Neto P, Laganá DC, dkk. Accuracy of digital technologies for the scanning of facial, skeletal, and intraoral tissues: a systematic review. J Prosthet Dent. 2019;121(2):246-51.
16. Alfaraj A, Khanlar LN, Lin WS, Zandinejad A. Exploring the impact of the extent of the partially edentulous area on the accuracy of two intraoral scanners. J Pros Dent 2024;131(1):163.e1-8.
17. Camcı H, Salmanpour F. Effect of saliva isolation and intraoral light levels on performance of intraoral scanners. Am J Orthod Dentofacial Orthop. 2020 Nov 1;158(5):759-66.
18. Medina-Sotomayor P, Pascual MA, Camps AI. Accuracy of four digital scanners according to scanning strategy in complete-arch impressions. PLoS One. 2018 Sep 1;13(9).
19. Anh JW, Park JM, Chun YS, Kim M, Kim M. A comparison of the precision of three-dimensional images acquired by 2 digital intraoral scanners: Effects of tooth irregularity and scanning direction. Korean J Orthod. 2016 Jan 1;46(1):3-12.
20. Lopes D de M, Nishyama R, Steagall W, Tamaki R, Tortamano Neto P. Impact of different scan strategies and implant angulation on impression accuracy of full arch multiple implant: an in vitro study. Brazilian Dent Sci. 2022 Jan 1;25(1).

DOI 10.46934/ijp.v6i1.295

21. Liu C Te, Chen JH, Du JK, Hung CC, Lan TH. Accuracy comparison of scan segmental sequential ranges with two intraoral scanners for maxilla and mandible. J Dent Sci. 2024 Jan 1;19(1):466–72.
22. Oh KC, Park JM, Moon HS. Effects of Scanning Strategy and Scanner Type on the Accuracy of Intraoral Scans: A New Approach for Assessing the Accuracy of Scanned Data. J Prosthodont. 2020 Jul 1;29(6):518–23.
23. Diker B, Tak Ö. Accuracy of Digital Impressions Obtained Using Six Intraoral Scanners in Partially Edentulous Dentitions and the Effect of Scanning Sequence. Int J Prosthodont. 2021 Jan;101–8.
24. Braian M, Wennerberg A. Trueness and precision of 5 intraoral scanners for scanning edentulous and dentate complete-arch mandibular casts: A comparative in vitro study. J Prosthet Dent. 2019 Aug 1;122(2):129-136.e2.
25. Zimmermann M, Koller C, Rumetsch M, Ender A, Mehl A. Präzision von Guided-Scanning-Verfahren bei digitalen Gesamtkieferabformungen in vivo. J Oro Ortho. 2017 Nov 1;78(6):466–71.

DOI 10.46934/ijp.v6i1.295