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REVIEW ARTICLE

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A guide for maximizing the accuracy of intraoral digital scans. Part 1: Operator factors

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Abstract

Objectives: To describe the factors related to the operator skills and decisions that influence the scanning accuracy of intraoral scanners (IOSs). A new classification for these factors is proposed to facilitate dental professionals' decision making when using IOSs and maximize the accuracy and reliability of intraoral digital scans.

Overview: Each IOS system is limited by the hardware and software characteristics of the selected device. The operator decisions that can influence the accuracy of IOSs include the scanning technology and system selection, scanning head size, calibration, scanning distance, exposure of the IOS to ambient temperature changes, ambient humidity, ambient lighting conditions, operator experience, scanning pattern, extension of the scan, cutting off, rescanning, and overlapping procedures.

Conclusions: The knowledge and understanding of the operator factors that impact scanning accuracy of IOSs is a fundamental element for maximizing the accuracy of IOSs and for successfully integrating IOSs in daily practices.

Clinical Significance: Operator skills and clinical decisions significantly impact intraoral scanning accuracy. Dental professionals must know and understand these influencing operator factors for maximizing the accuracy of IOSs.

KEYWORDS
accuracy, digital impressions, digital scans, esthetic dentistry, influencing factor, intraoral scanners, operator factors

1 | INTRODUCTION

Facially driven treatment planning procedures are a fundamental step to achieve esthetic rehabilitations.[1–3] When using a digital workflow, the 3-dimensional (3D) virtual patient can be created by integrating facial and intraoral digital scans, with or without incorporating cone beam computed tomography (CBCT) information.[4–8] Obtaining accurate intraoral digital scans is critical for acquiring accurate virtual patient representations and, consequently, improving the reliability of the clinical procedure. The more accurate the digitizing methods, the higher the accuracy of the virtual patient.[5,8,9]

Intraoral scanners (IOSs) are increasingly implemented in dental practices (Figure 1).[10] Regardless of the type of imaging technology employed by an IOS, all cameras require the projection of light that is recorded as individual images or video and compiled by the software after recognition of the points of interest (POI).[11] The multiple sets of points (or point clouds) generated through the optical sensors are subsequently registered (aligned with respect to each other) and are converted into a surface model represented as a triangle mesh.[11,12] Therefore, a mesh in a 3D scan refers to the way the surfaces are represented in the software via computer graphics. A mesh is a collection of vertices and triangles and includes information on how the vertices make up the triangles, and how the triangles are connected to

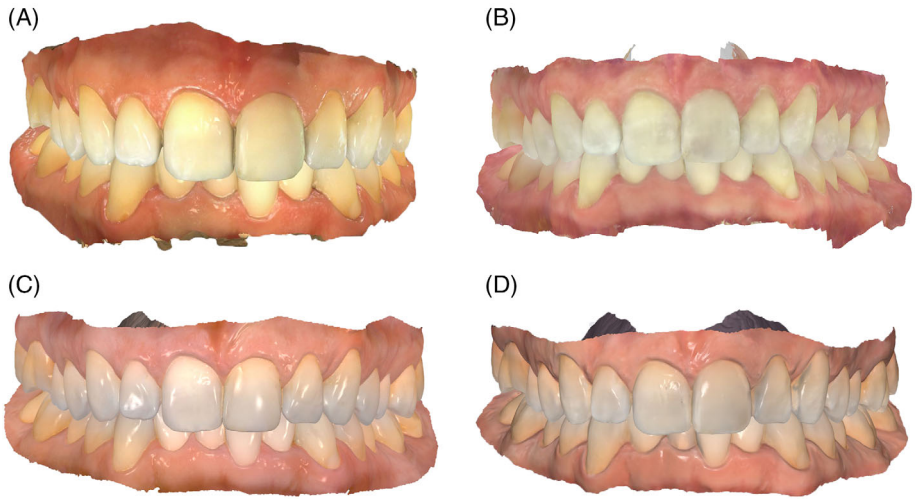

FIGURE 1 Esthetic intraoral digital scan visualizations in varying IOS software programs obtained in the same patient by using different IOSs. (A) Primescan; Dentsply Sirona. (B) iTero Element 5D; Align technologies. (C) Trios 4; 3Shape A/S. (D) i700 wireless; Medit. IOS, intraoral scanner.

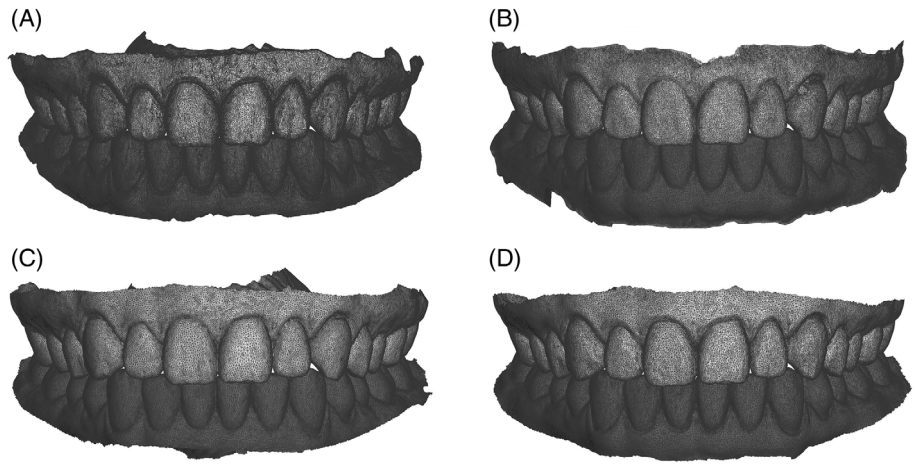

FIGURE 2 Representative mesh visualization of intraoral digital scans obtained in the same patient by using different IOSs. (A) Primescan; Dentsply Sirona. (B) iTero Element 5D; Align technologies. (C) Trios 4; 3Shape A/S. (D) i700 wireless; Medit. IOS, intraoral scanner.

each other (Figure 2).[12] Mesh density and quality discrepancies are present among the different IOSs.[13,14] Additionally, the algorithms employed by the IOS software programs can generate files of varying mesh densities. Higher density meshes usually produce more accurate analysis results or more surface detail reproduction.[12]

Accuracy is often the most important factor when assessing the quality of IOSs. Intraoral scanning accuracy is defined by trueness and precision.[15] Trueness measures how close the intraoral digital scan is to the real dimensions of the digitized intraoral tissues, while precision measures the reproducibility, or output consistency, of the intraoral digital scan obtained by using the same IOS system under the same scanning conditions.[15] Dental professionals should select IOS devices with high trueness and high precision values.

Multiple factors have been identified in the dental literature that can decrease the scanning accuracy of IOSs. Understanding and recognizing these influencing factors will increase the predictability and reliability of dental treatments completed by using digital workflows. These factors are related to either the operator or the patient. The objective of this first part of the manuscript is to describe a new classification of the factors related to the operator skills and decisions that significantly influence the scanning accuracy of IOSs systems. The goal of this classification is to simplify the understanding of the IOSs functionality, maximize the accuracy of the IOSs systems, and facilitate the integration of digital workflows in daily dental practices.

The operator factors are the dental professional skills and decisions that influence the scanning accuracy of IOSs (Figure 3). These operator factors include IOS technology and system selection, scanning head size, calibration, scanning distance, exposure of the IOS to ambient temperature changes, ambient humidity, ambient lighting conditions, operator experience, scanning pattern, extension of the scan, and cutting off, rescanning, and overlapping procedures.

1.1 | IOS TECHNOLOGY AND SYSTEM

The dental professional's first decision is to select an IOS system. There are multiple scanning technologies and IOSs systems available in the market (Table 1).[11] Each IOS system has the limitations determined by the hardware and software characteristics of the selected device. Different selection criteria have been described

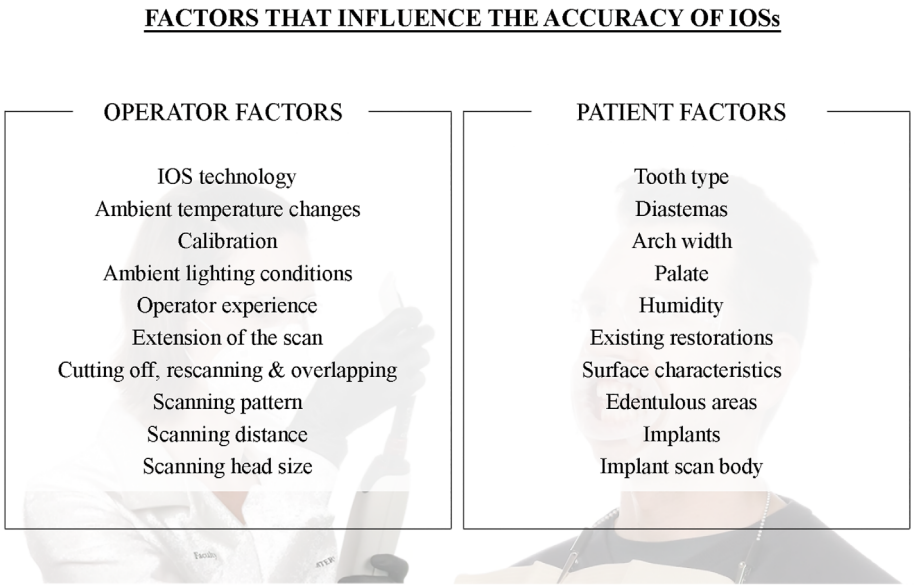

FIGURE 3 Factors related to the operator and patient that influence the scanning accuracy of IOSs systems. IOS, intraoral scanner.

TABLE 1 Available intraoral scanner systems

Manufacturer	Latest IOS
3Shape A/S	Trios 5
Align technologies	iTero Element 5D
Biotech Dental	WOW
Carestream	CS 3800
Condor	Condor IOS
Dental wings	Virtuo Vivo
Denterprise	QuickScan IOS
Dentsply Sirona	PrimeScan
Densys	Mia 3D IOS
E4D	Nevo
Eighteeth	Helios 600
GC America	Aadva IOS 200
Heron	Heron IOS
Intelliscan	Intelliscan IOS
Kavo	Kavo Xpro
Medit	I700 wireless
MyRay	3Di IOS
NewTom	NewTom IOS
Launca	Launca DL 206
Ormco	Lythos
Planmeca	Emerald S, PlanScan
Runyes	Runyes IOS
Seikowave health solutions	E-Vox
Shinning 3D	AoralScan
Suresmile	Oralscanner
Vatech	EZScan
Viz	Viz 3D IOS

Abbreviation: IOS, intraoral scanner.

for choosing an IOS including initial cost, monthly subscriptions expenses, scanning speed, wand size, ease of use, presence of a caries detection feature, software capabilities, wireless option, and manufacturer's support. However, dental professionals might want to balance these variables with the scanning accuracy of the IOS device which provides the reliability of the IOS system and, consequently, impacts the outcome of the manufacturing workflow of dental restorations.

Multiple studies have analyzed the accuracy of IOSs using in-vitro or clinical condition settings. However, research approaches should be distinguished between both methodologies. In laboratory studies, the ground truth or the reference model used to calculate accuracy values is known.[16–36] This means that the dimensions of the reference model are obtained by using the most accurate methods available today such as coordinate measurement machine (CMM) or an industrial scanner. On the other hand, in clinical conditions, the ground truth or the real dimensions of the patient's intraoral tissues being digitized are not known, and the reference model is obtained by using conventional techniques such as diagnostic stone casts.[16–36]

Variations in research methodologies among published studies compromises data comparison which makes it difficult to come to a clear conclusion. For in vitro conditions, the International Organization for Standardization (ISO) provides measurement method standards aiming to solve this issue within the last update completed in 2019 (ISO 20896-1:2019). However, the standardization of measurement methods in clinical settings is still needed.

Scanning accuracy discrepancies have been reported in the dental literature among the different scanning technologies and systems available based on the different clinical applications.[16–36] Independent of the scanning technology and IOSs system, IOSs provide a reliable digital impression alternative for acquiring virtual diagnostic casts with similar accuracy when compared with conventional impression

methods.[16–21,31] Clinical studies have evaluated the accuracy of IOSs for acquiring complete-arch intraoral digital scans, reporting a trueness mean value ranging from 73 to 433 μm and a precision mean value ranging from 80 to 199 μm.[16,19–21]

Complete digital workflows for fabricating tooth- and implant-supported crowns and short span fixed dental prostheses obtain similar marginal and internal discrepancies compared with conventional methods.[21–35] The challenge today remains to incorporate IOSs into complete digital workflows for fabricating complete dentures[29] and Kennedy Class I and II removable partial dentures.[30] Published studies have shown that intraoral digital scans can accurately digitized edentulous areas with firm attached tissue and mucosa, but capturing areas with mobile tissue by using an IOS is challenging, regardless of the scanning technology and system elected.[29,30,36–40] Therefore, for fabricating complete dentures or Kennedy Class I and II removable partial dentures, digitizing conventional impressions by using IOSs have been recommended.[29,30,36–40]

Similarly, complete-arch scans by using IOSs for fabricating complete-arch tooth- and implant-supported rehabilitations have shown contradictory results in the literature regarding reliability and accuracy.[31–35,41,42] Different techniques have been described to improve the scanning accuracy of complete-arch implant digital scans; however, due to the limited clinical data published, a systematic recommendation of complete-arch implant digital scans by using IOSs is difficult.[43–45]

Multiple published studies report discrepancies among the different IOSs depending on the clinical procedures tested.[17,28,41,46] Therefore, the selection of a specific IOS device would impact the accuracy of the intraoral digital scan for different clinical applications. Additionally, it is important to understand that not all available IOSs have been evaluated in those investigations. Therefore, the generalization of the studies' results should be done cautiously.

1.2 | SCANNING HEAD SIZE

Different scanning head sizes can be found among the various IOSs available in the market. Smaller head sizes are practical when acquiring intraoral digital scans with accessibility constraints such as patients with limited mouth opening. However, very few IOSs systems provide different scanning tip sizes for the same IOS device.

Limited studies have assessed the influence of scanning head sizes on the accuracy of intraoral digital scans.[47,48] These studies have reported higher intraoral scanning accuracy when employing larger scanning head sizes compared with smaller scanning head sizes.[47,48] This may be explained by the need to use a different scanning pattern when acquiring the intraoral digital scan due to the limited access or smaller scanning head, which might cause a different stitching process on the postprocessing procedures and result in a higher distortion. Additional studies are needed to further evaluate the impact of scanning head size on the scanning accuracy of different IOSs.

1.3 | IOS CALIBRATION

Except the iTero Element from Align Technologies and Trios 5 from 3Shape A/S IOSs that has integrated a self-calibration system,[12] all the IOSs require that the operator or dental professional calibrates the scanner. Additionally, a specific calibration device and protocol is provided by each IOS manufacturer (Figure 4). Although IOS software programs deliver alerts requiring the calibration of the system based on the time since the last calibration or the number of intraoral digital scans acquired since the latter calibration, dental professionals should probably include protocols in their practices to ensure daily IOS calibration before starting data collection procedures.[49]

1.4 | SCANNING DISTANCE

Scanning distance is the distance between the surface being scanned and the intraoral scanning tip, while scanning depth can be defined as the focal depth at which the scanner can capture reliable data. Recent studies have reported scanning accuracy discrepancies when the scanning distance is altered.[50,51] However, the optimal scanning distance and the focal depth of the scanner are determined by the hardware of the IOS selected. Each IOS manufacturer describes the optimal scanning distance for an appropriate handling of the system, as well as for optimizing the performance of the IOS. The understanding of the optimal scanning distance of the IOS selected will optimize the IOS performance and minimize the inadequate handling of the operator.

1.5 | AMBIENT TEMPERATURE CHANGES

Dental literature has recently identified ambient temperature changes as a variable that can influence intraoral scanning accuracy.[49] The exposure of an IOS to ambient temperature changes can easily occur in a dental practice, university, or dental institution between working and nonworking hours or even during the same day. These ambient temperature changes decalibrate the IOS and, subsequently, reduce its scanning accuracy.[49]

Revilla-León et al[49] assessed the influence of ambient temperature changes within the recommended operating ambient temperature ranges (15–30°C) on the accuracy of an IOS (Trios 4; 3Shape A/S). Results demonstrated that ambient temperature changes had a detrimental effect on the scanning accuracy of the IOS tested. In order to solve this problem, IOSs should probably be calibrated before starting each workday.

1.6 | AMBIENT HUMIDITY

Ambient humidity has been also identified as a factor that can decrease intraoral scanning accuracy.[52] In a laboratory study, Park et al[52] assessed the influence of varying simulated intraoral conditions on the scanning accuracy of two IOSs (Trios 3 from 3Spahe A/S and CS 3500 from Carestream). The authors attempted to replicate intraoral conditions by using a custom simulator in which ambient temperature, humidity, and lighting

FIGURE 4 (A) Examples of calibration devices provided by IOS's manufacturers for calibrating their systems. (B) Representative calibration protocol for an IOS (PrimeScan; Dentsply Sirona). IOS, intraoral scanner.

settings were controlled.[52] Two groups were created based on the conditions tested: group 1 (temperature ranged from 18–22°C, 40% humidity, and 262–272 -lux of ambient illumination) and group 2 (temperature ranged from 29–31°C, 100% humidity, and 173–197 -lux of ambient illumination).[52] No significant difference was found between the simulated intraoral conditions tested.[52] Further studies are still needed to determine if ambient humidity can impact intraoral scanning accuracy. Authors recommend calibrating IOSs to minimize the effect of ambient humidify on the IOS performance, except for iTero element from Align Technologies and Trios 5 from 3Shape A/S devices that has a self-calibration system.

1.7 | AMBIENT LIGHTING CONDITIONS

Ambient lighting conditions, or the intensity of the ambient light of the room in which the intraoral digital scan is acquired, has a significant impact on the scanning accuracy of IOSs in dentate patients (Figure 5).[13,20,53–57] Dental literature has revealed that the recommended lighting condition depends on the IOS selected (Table 2).[13,53–57] A luxmeter positioned at the patient's mouth is suggested for measuring the ambient light intensity at which the intraoral digital scan would be acquired (Figure 6).[13,20,54–56]

Although there is no universal optimal lighting condition that can maximize the accuracy of all IOSs, the majority of the IOSs perform better under 1000 lux ambient illumination conditions, known as room lighting conditions.[13,20,53–57] Achieving this ambient lighting condition requires turning off the dental chair light while leaving the room ceiling light on. It is important to understand that each room or operatory might have different ambient lighting intensities; therefore, the employment of a luxmeter to standardize ambient lighting conditions is recommended.

A recent publication has assessed the influence of five different ambient lighting conditions on the accuracy of seven IOSs when

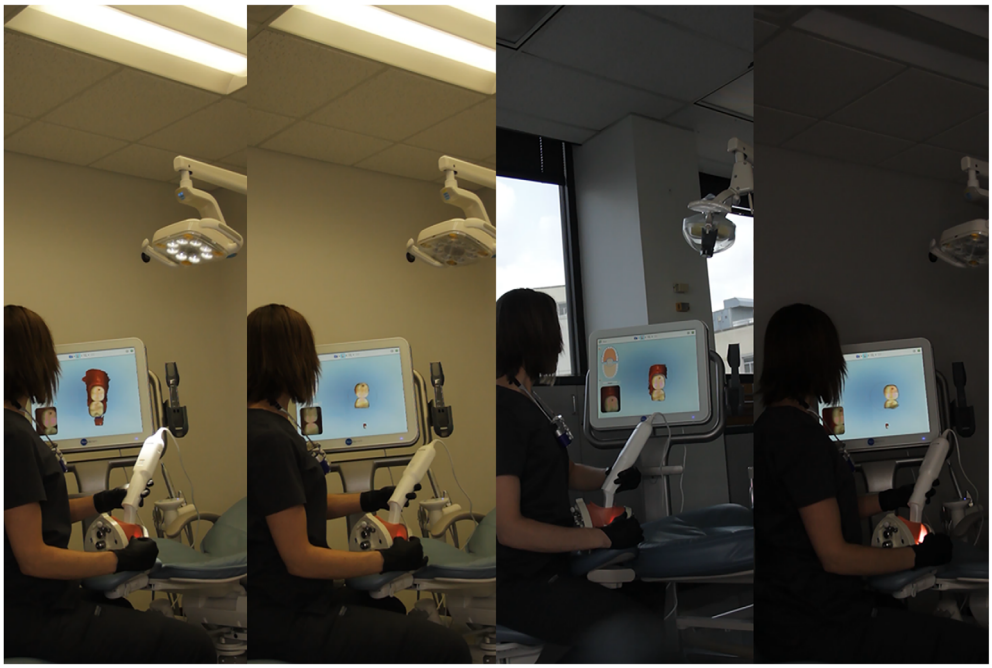

FIGURE 5 Varying ambient lighting conditions including chair light, ceiling light, natural window light, or no light

digitizing implant scan bodies.[58] Based on the results of this study, the optimal ambient lighting conditions for an IOS might be different when scanning teeth or implant scan bodies. Further studies are needed to assess the influence of ambient lighting conditions on the scanning accuracy of the various IOSs under different clinical conditions.

1.8 | OPERATOR EXPERIENCE

The previous handling experience of the operator acquiring intraoral digital scans has been identified as a factor that can impact the scanning accuracy of IOSs, where the greater the operator experience, the higher the accuracy of the intraoral digital scan.[59–62] However, this relationship seems to be stronger when using older generations of IOSs.[61] Additionally, operator experience reduces scanning time, improving the efficiency of the digital procedure.[59]

Undoubtedly, dental professionals require a learning period to effectively use IOSs while basic intraoral scanning concepts are learned. In 2021, a survey-based study performed by the Council of Scientific Affairs of the American Dental Association (ADA) revealed that 82% of the dental professionals surveyed received their IOS training by the manufacturer of the IOS purchased and 52% learned by doing.[10] As the technology matures and more studies are published, the data-related scanning accuracy of IOSs and its influencing factors are better described and identified. This scientific based advancement might accelerate the implementation of systematic teaching approaches in private and public educational dental institutions, but it may also provide the user with criteria to discern and evolve in the ocean of digital information, in which evidence-based learning will be more accreditive than anecdotal learning based on others' experience.

1.9 | SCANNING PATTERN

The scanning pattern or digitizing sequence performed when acquiring an intraoral digital scan significantly influenced the scanning accuracy of IOSs.[58,63–72] Therefore, if the scanning pattern is changed, the accuracy of the intraoral digital scan varies.[58,63–72] Generally, it is recommended to follow the scanning pattern recommended by the manufacturer of the IOS selected.

For acquiring intraoral digital scans in completely dentate patients, the scanning pattern is clearly described by the manufacturer of the IOS. For obtaining intraoral implant scans, the digitalization of the implant scan body is a fundamental procedure.[71] Dental literature has reported individualized scanning patterns for acquiring intraoral implant scans[73]; however, the literature assessing the optimal scanning pattern for capturing intraoral implant digital scans is scarce.[71] Similarly, few IOS manufacturers provide the recommended scanning protocol for extraorally digitizing complete dentures by using the IOS. Additionally, limited studies have assessed the influence on scanning accuracy of the scanning pattern for extraorally digitizing maxillary and mandibular complete dentures.[56]

In a clinical study, authors assessed the influence of the scanning pattern when digitizing the palate on the accuracy of the maxillary intraoral digital scan acquired by using an IOS (Trios 3 from 3Shape A/S).[72] Scanning accuracy discrepancies were observed between the two scanning patterns tested.[72]

Additionally, the scanning wand can be positioned with different orientations for acquiring the same scanning pattern. Oh et al[68] evaluated the influence of the rotation of the IOSs on their accuracy when performing complete-arch scans. Authors obtained better performance when the scanner head was positioned in a horizontal orientation throughout the scan when compared with rotations of scanner in a vertical direction.[68]

TABLE 2 Recommended ambient lighting condition based on the IOS system selected for acquiring intraoral digital scans.

Intraoral scanner; Manufacturer	Optimal ambient lighting conditions in dentate conditions	Optimal ambient lighting conditions digitizing implant scan bodies
Adva; GC America	1000 or 5000 Lux[39]	NA
CS 3600; Carestream	5000 Lux[39]	500 Lux[41]
CS 3700; Carestream	NA	100 Lux[41]
Emerald; Planmeca	Very inconsistent[39]	
i500; Medit	1000 Lux[40]	1000 Lux[41]
iTero Element; Align technologies	1000 Lux[34]	NA
iTero Element 5D; Align technologies	NA	100 Lux[41]
Omnicam; Dentsply Sirona	0 Lux[34] or 100 Lux[39]	NA
PrimeScan: Dentsply Sirona	NA	10,000 Lux[41]
Trios 3; 3Shape A/S	1000 Lux[34]	100 Lux[41]
Trios 4; 3Shape A/S	1000 Lux[34]	NA

Abbreviations: IOS, intraoral scanner; NA, not available.

FIGURE 6 Ambient light intensity should be measured at the patient's mouth by using a luxmeter.

1.10 | EXTENSION OF THE SCAN

Dental professionals should also decide the extension or length of the intraoral digital scan (i.e., half-arch or complete-arch scan) when manufacturing single restorations or short span rehabilitations. The extension of the intraoral digital scan can impact the accuracy of IOSs.[19,20,42,74,75] Previous studies have reported higher accuracy on half-arch scans when compared with complete-arch scans, which can justify the use of half-arch intraoral digital scans when manufacturing tooth- and implant-supported crowns and short span fixed dental prostheses.[19,20,42,74,75]

In an in-vitro study, authors compared the scanning accuracy of half- and complete-arch scans obtained by two IOSs.[74] Significant scanning accuracy discrepancies were reported based on the extension of the scan. For the Trios 3 IOS, in complete-arch scans a mean trueness ± precision value of 46.92 ± 20.79 μm was described, while for the half-arch scans a mean trueness ± precision value of 22.29 ± 14.12 μm was computed.[74] Similarly for the Primescan IOS, a mean trueness ± precision value of 28.73 ± 15.79 μm was measured for complete arch scans, while in the half-arch scans a mean trueness ± precision value of 18.91 ± 7.94 μm was computed.[74]

In a clinical study, Revilla-León et al[13] compared the scanning accuracy of half- and complete-arch scans obtained by an IOS (Trios 3). Authors reported higher accuracy on half-arch intraoral digital scans, when compared with complete-arch scans.[13] Kernen et al[19] evaluated the intraoral scanning accuracy of half- and complete-arch scans obtained in patients by using three different IOSs (True Definition, Trios 3, and Omnicam). For half-arch intraoral digital scans, authors reported a median trueness ± precision value of 47 ± 31 μm for the True Definition, 38 ± 23 μm for the Trios 2, and 45 ± 43 μm for the Omnicam. For complete-arch intraoral digital scans, results revealed a median trueness ± precision value of 433 ± 153 μm for the True Definition, 147 ± 80 μm for the Trios 2, and 198 ± 198 μm for the Omnicam.

1.11 | CUTTING-OFF, RESCANING, AND OVERLAPPING METHODS

Cutting off and rescanning procedures have been identified in the dental literature as factors that can decrease intraoral scanning accuracy.[76–79] Previous laboratory and clinical studies have demonstrated that rescanning mesh holes significantly decreases the accuracy of intraoral digital scans.[76–79] Furthermore, the higher the number and diameter of the mesh holes rescanned, the lower the accuracy.[78] To maximize the accuracy of the IOS selected when acquiring intraoral digital scans, it is recommended to obtain the scan without leaving mesh holes or missing information, so the operator does not have to rescan those areas.

TABLE 3 Summary of the operator factors that can impact the accuracy of intraoral scanners.

Factor	Description	Literature findings
IOS technology	Different IOS technologies: Active wavefront sampling, triangulation technique, confocal imaging method, and stereophotogrammetry	Scanning accuracy discrepancies have been reported in the dental literature among the different scanning technologies and systems available based on the different clinical applications.[16–36] Clinical studies have evaluated the accuracy of IOSs for acquiring complete-arch intraoral digital scans, reporting a trueness mean value ranging from 73 to 433 μm and a precision mean value ranging from 80 to 199 μm.[16,19–21]
Scanning head size	Dimensions of the scanning head of the IOS	Higher intraoral scanning accuracy have been reported when employing larger scanning head sizes compared with smaller scanning head sizes.[47,48]
Calibration	Calibration of the IOS	Except the iTero IOSs that has integrated a self-calibration system,[12] all the IOSs require that the operator or dental professional calibrates the scanner. Authors recommend calibrating the scanner daily.
Scanning distance	Scanning distance is the distance between the surface being scanned and the intraoral scanning tip	Scanning accuracy discrepancies have been reported when altering the optimal scanning distance which is based on the IOS hardware.[50,51]
Ambient temperature changes	Fluctuation of ambient temperature of the room where the IOS is located	Ambient temperature changes reduce the accuracy of IOSs.[49] In order to solve this uncalibration problem, IOS calibration is recommended daily
Ambient humidity	Humidity of the ambient	Ambient humidity has been also identified as a factor that can decrease intraoral scanning accuracy.[52] In order to solve this problem, IOS calibration is recommended daily
Ambient lighting conditions	Light intensity of the ambient lighting measured at the patient's mouth	Ambient lighting conditions have a significant impact on the scanning accuracy of IOSs.[13,20,53–57] The optimal lighting conditions reported is provided in Table 2.
Operator experience	Operator previous IOS handling time	The greater the operator experience, the higher the accuracy of the intraoral digital scan.[59–62] This relationship seems to be stronger when using older generations of IOSs.[61] Operator experience reduces scanning time, improving the efficiency of the digital procedure.[59]
Scanning pattern	Scanning path used to acquire an intraoral digital scan	Scanning pattern influences the accuracy of intraoral digital scans.[58,63–72] Generally, it is recommended to follow the scanning pattern recommended by the manufacturer of the IOS selected.
Extension of the scan	Length of the intraoral digital scan: half or complete-arch scans	The extension of the intraoral digital scan impacts the accuracy of IOSs.[19,20,42,74,75] Overall, half-arch scans have higher scanning accuracy than complete-arch scans.[19,20,42,74,75]
Cutting-off, rescanning, and overlapping	Rescanning mesh holes with or without allowing overlapping (further modification of the pre-existing scan)	Cutting off and rescanning procedures decrease intraoral scanning accuracy.[76–79] Authors recommend obtaining the scan without leaving mesh holes or missing information, so the operator does not have to rescan those areas.

Abbreviation: IOS, intraoral scanner.

When cutting-off and rescanning procedures are selected, some IOS software programs provide the capability to block any changes to the existing prescan and prevent overlapping, so that the mesh hole is rescanned to capture information, but the existing prescan is not further modified. In a clinical study, Revilla-León et al[77] obtained lower accuracy on the intraoral digital scans obtained using cutting off and rescanning procedures when overlapping was allowed. Therefore, cutting-off and rescanning procedures should be completed without allowing further modification of the preexisting intraoral digital scan to maximize scanning accuracy.[77]

In a recent study published in 2022, authors demonstrated that the impact of the cutting off and rescanning procedures on scanning accuracy varied depending on the IOS tested.[79] Two different IOS from the same manufacturer, Omnicam and Primescan systems, were assessed. The Primescan system was found to be more negatively impacted by these cutting off and rescanning procedures that its predecessor IOS device tested.[79] However, the studies analyzing the influence of cutting off and rescanning procedures are scarce. Studies are needed to further assess the impact of those scanning procedures on the accuracy of virtual casts, as well as its influence on the fit of the definitive restorations.

Recommended digital workflows for fabricating tooth- and implant-supported restorations include cutting off and rescanning procedures. First, a prescan is obtained which normally incorporates the interim restoration. Then the operator intentionally creates a mesh hole into the existing prescan in the interim restoration area. Finally, the mesh hole is rescanned to capture a tooth preparation or an implant scan body.

2 | CONCLUSIONS

Operator skills and decisions significantly influence intraoral scanning accuracy (Table 3). These influencing operator factors include scanning technology and system selection, scanning head size, calibration, scanning distance, exposure of the IOS to ambient temperature changes, ambient humidity, ambient lighting conditions, operator experience, scanning pattern, extension of the scan, and the use of cutting off, rescanning, and overlapping procedures. Dental professionals must know and understand these operator factors for maximizing the accuracy of IOSs and successfully integrating digital workflows in daily practices.

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