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A guide for maximizing the accuracy of intraoral digital scans: Part 2—Patient factors

Marta Revilla-León DDS, MSD, PhD[1,2,3] | Dean E. Kois DMD, MSD[4,5] | John C. Kois DMD, MSD[4,5,6]

[1]Department of Restorative Dentistry, School of Dentistry, University of Washington, Seattle, Washington, USA
[2]Research and Digital Dentistry, Kois Center, Seattle, Washington, USA
[3]Department of Prosthodontics, Tufts University, Boston, Massachusetts, USA
[4]Kois Center, Seattle, Washington, USA
[5]Private Practice, Seattle, Washington, USA
[6]Department of Restorative Dentistry, University of Washington, Seattle, Washington, USA

Correspondence
Marta Revilla-León, Kois Center, 1001 Fairview Ave N # 2200, Seattle, WA 98109, USA.
Email: marta.revilla.leon@gmail.com

Abstract

Objectives: To describe the factors related to patient intraoral conditions that impact the scanning accuracy of intraoral scanners (IOSs). A new classification for these influencing factors is proposed to facilitate dental professionals' decision-making and maximize the accuracy and reliability of intraoral digital scans.

Overview: Variables related to intraoral conditions of the patient that can influence the scanning accuracy of IOSs include tooth type, presence of interdental spaces, arch width variations, palate characteristics, wetness, existing restorations, characteristics of the surface being digitized, edentulous areas, interimplant distance, position, angulation, and depth of existing implants, and implant scan body selection.

Conclusions: The knowledge and understanding of the patient's intraoral conditions that can impact the scanning accuracy of IOSs is a fundamental element for maximizing the accuracy of IOSs.

Clinical Significance: The patient's intraoral conditions, or patient factors, can significantly impact intraoral scanning accuracy. Dental professionals must know and understand these influencing patient factors to maximize the accuracy of IOSs.

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

1 | INTRODUCTION

Intraoral scanners (IOSs) are being used more frequently in dental practices.[1] The identification of the different variables that can impact intraoral scanning accuracy is a fundamental element for optimizing the accuracy of IOSs and successfully implement IOSs in dental practices. The gross accuracy of IOSs can be reduced by inadequate skills and handling decisions from the operator, as well as by patient intraoral conditions.

Multiple factors have been identified in the dental literature that can decrease 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 influencing factors are related to either the operator or the patient and can significantly impact the outcome of the intraoral scan. However, these influencing factors have not been previously classified as being either patient or operator elements that are present when acquiring an intraoral digital scan and that can significantly impact the outcome of the intraoral scan. The objective of this manuscript is to describe a new classification of the factors related to the patient's intraoral conditions 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.

Patient factors are defined as the patient's intraoral conditions that influence the scanning accuracy of IOSs (Figure 1). These patient factors include tooth type, presence of interdental spaces, arch width variations, palate characteristics, wetness, existing restorations,

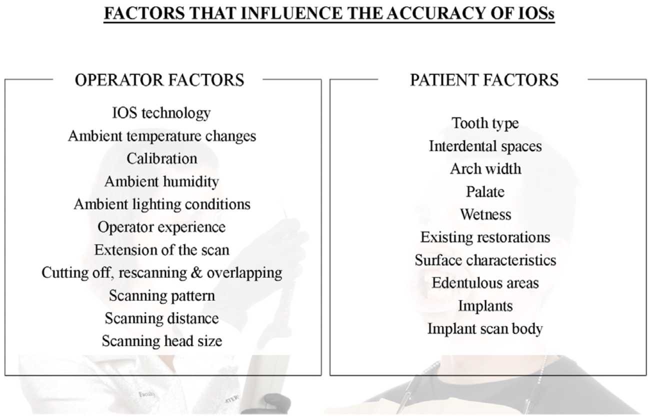

FIGURE 1 Factors related to the operator and patient that influence the scanning accuracy of IOSs systems. IOS, intraoral scanner

characteristics of the surface being digitized, edentulous areas, interimplant distance, the position, angulation, and depth of existing implants, and implant scan body selection. Although the intraoral conditions of the patient cannot be altered by the clinician, the systematic analysis of the patient's intraoral characteristics and the identification of the factors that can impact the accuracy of the intraoral digital scan would enhance the predictability and reliability of the digital procedure (Table 1).

2 | PATIENT FACTORS

2.1 | Tooth type

Tooth type has been recently identified as a factor that can influence intraoral scanning accuracy.[2] In an in vitro study, Son and Lee[2] evaluated the influence of the tooth type on the scanning accuracy of five different IOSs: CS 3500 and CS 3600 from Carestream, Trios 2 and Trios 3 from 3Shape A/S, and i500 from Medit. The results demonstrated scanning accuracy discrepancies among different tooth types: maxillary central and lateral incisor, canine, first and second premolar, and first and second molar.[2] Furthermore, for all the IOSs assessed, the more posterior the tooth, the lower the scanning accuracy computed.[2] This could be explained by the more complex anatomy of the posterior teeth compared with the anterior dentition, which might represent a more challenging geometry to digitize with IOSs. Moreover, all of the IOSs evaluated, except the i500 system, showed a horizontal displacement in the buccal direction as the scan moved posteriorly. In the i500 device, lateral displacements were shown in the lingual direction.[2] Additional laboratory and clinical studies are needed to further analyze the relationship between tooth type and the accuracy of IOSs.

2.2 | Interdental spaces

Publications in the dental literature assessing the influence of interdental space are uncommon.[3–9] In a laboratory study, the influence of 0-, 1-, 3-, and 5-mm of interdental space between the mandibular anterior teeth on the scanning accuracy of two IOSs (1st generation of the iTero system from Align Technology and the Trios 2 from 3Shape A/S) was measured.[3] Higher scanning discrepancies were obtained in the iTero system compared with the Trios 2 device, which might be explained by the generation discrepancies between the systems. For the Trios 2, when digitizing the mandibular cast without any interdental space, a mean trueness ± precision value of 32.32 ± 4.97 μm was reported; but when digitizing the cast with 5 mm of interdental space between the anterior teeth, a mean trueness ± precision value of 52.47 ± 16.83 μm was measured.[3] Therefore, a mean trueness discrepancy of 10 μm was computed between the best and worst values obtained.

Huang et al.[4] evaluated the effect of the distance between a tooth preparation and the adjacent teeth (1, 1.5, 2, 2.5, 3, and 3.5 mm) on the scanning accuracy of an IOS (CS 3600 from Carestream). For distances greater than 3.5 mm between the tooth preparation and the adjacent tooth, the scanning accuracy of the IOS tested was not affected.[4] When the distance between the abutment and the adjacent teeth was less than 3 mm, errors in the IOS evaluated differed depending on the direction of the scan with respect to the tooth preparation (buccal, lingual, mesial, and distal).[4] Furthermore, scan errors involving the margin scan area of the tooth preparation decreased as the distance between the tooth preparation and the adjacent teeth increased.[4]

Son et al.[5] study revealed that interproximal distance between the tooth preparation and adjacent tooth affected the scanning accuracy of an IOS (Primescan from Dentsply Sirona). Furthermore, as the interproximal distance increased, the trueness and precision values of the acquired scan increased, and the maximum positive deviation significantly decreased.[5]

Kim et al.[6] evaluated the influence of the presence of an adjacent tooth on the scanning accuracy of three IOSs (Primescan from Dentsply Sirona, Trios 3 from 3Shape A/S, and i500 from Medit) for a Class II inlay preparation. The presence of the adjacent tooth negatively affected the accuracy of all the IOSs assessed. The mean trueness and precision mean values decreased, and the maximum positive deviations increased compared to scans with no adjacent tooth.[6] Additionally, the absence of adjacent teeth increased the scanning accessibility.[6] The IOS software algorithm interpolates missing or uncertain data, which tends to smooth the surfaces and line angles in the scanned image and often leads to artificial bulges in the margins, which are presented as positive deviations.[6,7] Ferrari et al.[7] reported that artificial bulges on the margin and bridges between the preparation and adjacent teeth were frequently observed when the horizontal clearance was less than 0.5 mm.

The presence of diastemas or reduced space between tooth preparations and adjacent teeth creates difficult IOS accessibility, limits the scanning angle, and data acquisition procedures which can result in reduced scanning accuracy.[3–9] Further studies are required to assess the influence of varying space dimensions and locations on the scanning accuracy of the various available IOSs.

TABLE 1 Summary of the patient factors that can impact the accuracy of intraoral scanners

Factor	Description	Literature findings
Tooth type	Tooth type: maxillary central and lateral incisor, canine, first and second premolar, and first and second molar	Literature demonstrates scanning accuracy discrepancies among different tooth types.[2] Furthermore, the more posterior the tooth, the lower the intraoral scanning accuracy measured.[2]
Interdental spaces	Diastemas Space between a tooth preparation and the adjacent tooth	The presence of diastemas and/or reduced space between tooth preparations and adjacent teeth restrict IOS accessibility, limit the scanning angle, and difficult data acquisition procedures which can result in reduced scanning accuracy.[3–9]
Arch width	Arch width or intermolar distance	In general, the higher the intermolar width, the lower the intraoral scanning accuracy.[7,10,12]
Palate	Addition or not of the palate in the maxillary intraoral digital scan	Higher accuracy values have been reported when the palate is not included in the maxillary intraoral digital scan.[12]
Wetness	The presence of humidity on the intraoral tissues being digitized	Wetness difficult the digitizing procedure reducing intraoral scanning accuracy.[15,16]
Existing restorations	Presence of restorations on the teeth being scanned	Scanning accuracy discrepancies have been reported depending on the restorative materials being digitized, including material type, translucency, and surface finishing.[17–20]
Surface characteristics	Tooth preparation geometry including location of the pulpal and gingival floors, as well as position of the tooth preparation finish line	The characteristics of the surface being digitized can significantly reduce intraoral scanning accuracy.[8,9,26–35] Additionally, these discrepancies are different depending on the IOS technology and system selected.[8,9,26–35] • In general, the higher the complexity of a tooth preparation, the lower the scanning accuracy.[8,9,24,27,28] Sharp angles and uneven or rough surfaces are difficult to reproduce by using IOSs.[8,9,26–35] • Digitizing tooth preparations for full coverage restorations have demonstrated higher scanning accuracy values than scanning intra-coronal tooth preparations.[8,26,29] • The higher the occlusal convergence angle of the tooth preparation for a full coverage restoration, the higher the scanning accuracy values.[29] Similarly, the higher the divergence angle in intra-coronal tooth preparations, the higher the scanning accuracy values described.[29] • The most challenging area to acquire accurate tooth preparation geometric data is the axiogingival line angle.[30] • The higher the depth of the pulpal and gingival floors of a tooth preparation, the higher the discrepancy or lower scanning accuracy values.[33,35] • The more apically located the finish line of the tooth preparation, the more challenging to digitize and the lower the scanning accuracy values.[25,28,31]
Edentulous areas	Edentulous areas or spaces with missing teeth	Edentulous spaces present limited anatomical landmarks representing challenging surfaces for being digitized by using an IOS.[36–40] Different studies have revealed that IOSs can reproduce firm and attached mucosa with the same accuracy as conventional impression methods; however, registering mobile tissues are difficult independently of the IOS technology and system selected.[36–40]
Implants	Interimplant distance Implant position, angulation, and depth	Inconsistencies are present in the literature regarding the influence of interimplant distance, implant position in the dental arch, and implant angulation and depth on intraoral scanning accuracy.[36–47] • In general, scanning discrepancies increases as interimplant distance increases.[46,47] • The implant positioned in the dental arch at the end of the intraoral digital scan obtains significantly higher distortion than the contralateral implant.[45] • Contradictory results have been reported regarding the influence of implant angulation on intraoral scanning accuracy.[36–45] Some studies concluded that implant angulation decreased the scanning accuracy of IOSs,[36,39,41,42,45] while other studies have shown that implant angulation had no effect on intraoral scanning accuracy.[37] • Contradictory results have been reported regarding the influence of implant depth on the accuracy of IOSs. Overall, accuracy decreases as the implant depth increases.[39,40]
Implant scan body	Implant scan body design, geometry, and material	The restricted published data does not support a systematic recommendation for selecting an implant scan body design involving single or multiple implants.[53–60] Furthermore, there may be no implant scan body design that optimally performs for all the different IOSs available.[53–60]

Abbreviation: IOS, intraoral scanner.

2.3 | Arch width

Dental arch width variation has been identified as an intraoral patient condition that can impact intraoral scanning accuracy.[8,10–12] In 2020, an in vitro study measured the influence of different volumetric dimensions of maxillary casts on the scanning accuracy of three IOSs (CS 3600 from Carestream, Trios 3 from 3Shape A/S, and i500 from Medit).[10] The intermolar width tested ranged from 38.45 to 71.09 mm.[10] Results revealed that the scanning accuracy of the IOSs tested varied depending on the volumetric dimensions of the complete arch assessed.[9] Except for the i500, the higher the intermolar width, the higher the scanning discrepancies measured.[7] In the i500 system, the narrowest and broadest intermolar widths tested obtained the highest scanning discrepancies.[10]

In a clinical study, Gan et al.[12] assessed the influence of arch width on the accuracy of maxillary intraoral digital scans. Trueness scanning discrepancies were not found with variations in arch width; however, the scanning precision of the intraoral digital scans decreased with increased arch width.[12] Further in vitro and in vivo investigations are required for assessing the influence of arch widths on the scanning accuracy of IOSs.

2.4 | Palate

Few investigations have assessed the influence of digitizing the palate on the accuracy of the maxillary intraoral digital scans in completely dentate patients,[12,13] as well as in complete-arch implant digital scans in edentulous patients.[14]

A clinical study evaluated the influence of digitizing the palate and the palatal vault height (low, medium, or high) on the accuracy of maxillary intraoral digital scans.[12] Results showed higher trueness and precision mean values when the palate was not included in the maxillary intraoral digital scan.[12] Although the discrepancies were not statistically significant, the higher the palatal vault height, the higher the scanning accuracy discrepancies obtained.[12]

In an in vitro investigation, the influence of digitizing the palate on the accuracy of maxillary complete-arch implant digital scans was assessed by using an IOS (Trios; 3Shape A/S).[14] The generation of the system tested was not provided in the manuscript and the typodont tested included four dental implant analogs.[14] Results showed that the accuracy of digital scans of edentulous maxillary arch with four implants when the palate was stitched compared with unstitched was similar.[14] However, only a single IOS and scanning pattern was tested. Additionally, the ambient lighting conditions under which the intraoral scans were obtained is unknown. Additional investigations are required to further understand the influence of digitizing the palate on the accuracy of maxillary intraoral implant digital scans in different clinical conditions.

2.5 | Wetness

The presence of humidity on the surface being digitized can reduce intraoral scanning accuracy.[15,16] The light reflected from the wet tooth surface is refracted by the effect of water on the surface, which can reduce the performance of the IOSs.[16]

In a laboratory study, authors evaluated the influence of liquid on the surface being digitized (dry, presence of saliva or ultra-pure water, and blow-dried with a three- way syringe) on the scanning accuracy of complete-arch intraoral digital scans captured by using two IOSs (Trios 3 from 3Shape A/S and Primescan from Dentsply Sirona).[16] Humidity present on the digitized surface reduced the scanning accuracy of the IOSs tested.[16] Blow-drying the teeth with a three-way syringe effectively reduced the negative effects of the humidity of the surface being digitized on the accuracy values of the intraoral scan.[16]

2.6 | Existing restorations

The presence of restorations on the teeth being scanned can reduce intraoral scanning accuracy.[17–20] The reflectiveness characteristic discrepancies among the different restorative materials significantly influences the scanning performance of IOSs.[16–19] Scanning accuracy discrepancies have been reported depending on the restorative materials being digitized, including material type, translucency, and surface finishing.

Dutton et al.[17] evaluated the influence of different restorative materials on the scanning accuracy of various IOSs. A typodont with different materials (enamel, dentin, blue build up composite resin, amalgam, composite resin, lithium disilicate, zirconia, and gold) was digitized with eight IOSs (Omnicam and Primescan from Dentsply Sirona, i500 from Medit, iTero Element and iTero Element 2 from Align technologies, Emerald and Emerald S from Plamenca, and Trios 3 from 3Shape A/S). Results revealed significant scanning accuracy discrepancies among the different restorative materials independent of the IOS system used.[17] Furthermore, the different IOS systems tested presented scanning performance variations among the different materials tested.

Revilla-León et al.[19] assessed the influence of different interim (conventional poly-methyl methacrylate (PMMA), conventional bis-acryl composite resin, milled PMMA, and additively manufactured bis-acryl-based polymer) and definitive (milled gold, zirconia, lithium disilicate, hybrid ceramic, and composite resin) materials with two surface finishing protocols (polished and glazed) on the accuracy of an IOS (Trios 4 from 3Shape A/S). The data obtained demonstrated that the type and surface finishing of the different restorative dental materials tested influenced the trueness and precision of the IOS assessed.[19] Furthermore, the lowest trueness values were obtained when scanning high noble metal specimens, while the highest trueness values were measured when scanning conventional and milled PMMA and additively manufactured bis-acryl-based polymer polished specimens. Except for zirconia crowns, higher trueness values were obtained with the polished specimens when compared with glazed dental crowns.[19]

Digitizing a translucent restorative material or acquiring an intraoral digital scan in a patient with multiple existing restorations might be challenging by using an IOS.[17–20] Intraoral scanner powder may reduce the reflectiveness of the restoration, facilitate the digitizing methods, and reduce the scanning time.[9,21–25] However, in order to maximize the digitizing method, a uniform and thin coat of intraoral scanning powder is suggested.[9,21–25]

2.7 | Surface characteristics

The characteristics of the surface being digitized that significantly influence intraoral scanning accuracy include tooth preparation geometry and tooth location, depth of the pulpal and gingival floors, and finish line location of the tooth preparation.[8,9,26–35] Additionally, these discrepancies measured among the different tooth preparation characteristics would be different depending on the IOS technology and system selected.[8,9,26–35]

Tooth preparation geometry is an important factor that can reduce intraoral scanning accuracy; therefore, clinicians should revise preparations carefully before acquiring an intraoral digital scan to reduce sharp angles and uneven or rough surfaces.[8,9,26–35] Kim et al.[27] studied the scanning accuracy of nine IOSs (Omnicam from Dentsply Sirona, CS 3500 from Carestream, E4D Dentist 1st generation from D4D Technologies, FastScan from IOS Technology, iTero 1st generation from Align technology, Trios 2 from 3Shape A/S, True Definition from 3M ESPE, Zfx IntraScan from Zfx GmbH, and PlanScan from Planmeca) for acquiring complete-arch intraoral digital scans with denture teeth having different tooth preparations. Results revealed accuracy variations on the qualitative features among IOSs tested in terms of polygon shapes, sharp edge reproducibility, and surface smoothness.[27]

Different studies have shown that the higher the complexity of a tooth preparation, the lower the scanning accuracy.[8,9,24,27,28] Furthermore, digitizing tooth preparations for full coverage restorations have demonstrated higher scanning accuracy values than scanning intra-coronal tooth preparations such as inlay preparations.[8,26,29] The higher the occlusal convergence angle of the tooth preparation for a full coverage restoration, the higher the scanning accuracy values reported.[29] Similarly, the higher the divergence angle in intra-coronal tooth preparations, the higher the scanning accuracy values described.[29]

Tooth preparations involving proximal surfaces are the most challenging to accurately scan by using an IOS.[8,24,30] Moreover, the visibility of undercut areas below the height of contour can be restricted and appeared as shadow regions which are difficult to accurately scan. Jin-Young Kim et al.[30] assessed the influence of varying intra-coronal tooth preparation geometries on the scanning trueness of six different IOSs (Omnicam from Dentsply Sirona, E4D from D4D Technologies, FastScan from IOS Technology, iTero from Align technology, Trios from 3Shape A/S, Zfx IntraScan from Zfx GmbH). The authors reported not only trueness discrepancies among the IOSs, and intra-coronal tooth preparation geometries tested, but also the scanning trueness was compromised when the tooth preparation presented a steep occlusal divergence and sharp line angles.[30] Additionally, for all the IOSs tested, the trueness decreased where two surfaces of the tooth preparation met. In particular, the most challenging area to acquire accurate geometric data was the axiogingival line angle.[30]

Tooth preparation location has been identified as a factor that can influence intraoral scanning accuracy, with posterior teeth obtaining lower scanning accuracy values compared with the anterior dentition.[9,34] Another preparation variable is the depth of the pulpal and gingival floors which can also reduce the accuracy of the digitizing procedure. The higher the depth of the pulpal and gingival floors of a tooth preparation, the higher the discrepancy or lower scanning accuracy values reported.[33,35]

The finish line location of a tooth preparation significantly affects the scanning accuracy values (Figure 2).[25,28,31] Therefore, the apico-coronal position of the tooth preparation finish line may impact the accuracy of the intraoral digital acquisition procedure. Gingival retraction is recommended to expose the tooth preparation finish line to facilitate the digitizing technique. A finish line located more gingivally is the harder to digitize and results in a larger number of scanning deficiencies.[25,28,31] Son et al.[31] assessed the influence of the location of the preparation finish line (supragingival, equigingival, and intracrevicular without and without using a retraction cord) on the scanning accuracy values of an IOS (i500 from Medit). The more apically located the finish line of the tooth preparation, the more challenging it was to accurately digitize, and the lower the scanning accuracy values obtained.[31] In particular, the lowest accuracy values were measured on margins at the equigingival and subgingival finish line locations.[31] Moreover, the use of a retraction cord on the intracrevicular finish line location improved the scanning accuracy mean values by a mean 63%.[31]

An important step when digitizing tooth preparations by using IOSs involves the determination in the scan of the tooth preparation (Figure 3). This step is a fundamental procedure to optimize the outcome of the intraoral digital scan. Based on the area selected, the IOS software program selectively reduces the mesh density of the scan, maintaining a high mesh density on the tooth preparation area and reducing the mesh density in the rest of the scan. This procedure reduces the weight of the intraoral digital scan file, facilitating the management of the file, and optimizing the efficiency of the system. In the best knowledge of the authors, there is no published study that evaluates this selective mesh reduction procedure on the accuracy of the definitive restoration.

2.8 | Edentulous spaces

Edentulous spaces or areas with missing teeth have been identified as a variable that can decrease intraoral scanning accuracy.[36–41] Edentulous spaces present limited anatomical landmarks representing challenging surfaces for being digitized by using an IOS.[36–40] Different studies have revealed that IOSs can reproduce firm and attached mucosa with the same accuracy as conventional impression methods; however, registering mobile tissues are difficult independently of the IOS technology and system selected.[36–40]

In an in vitro investigation, Waldecker et al. compared the scanning accuracy of partially and completely dentate maxillary typodonts captured by using three different IOSs (Omnicam and Primescan from Dentsply Sirona and Trios 4 from 3Shape A/S).[41] Results revealed that dental status affected scanning discrepancies, resulting in larger deviations in the partially edentulous maxilla compared with the completely dentate maxilla in all the IOSs tested.[41]

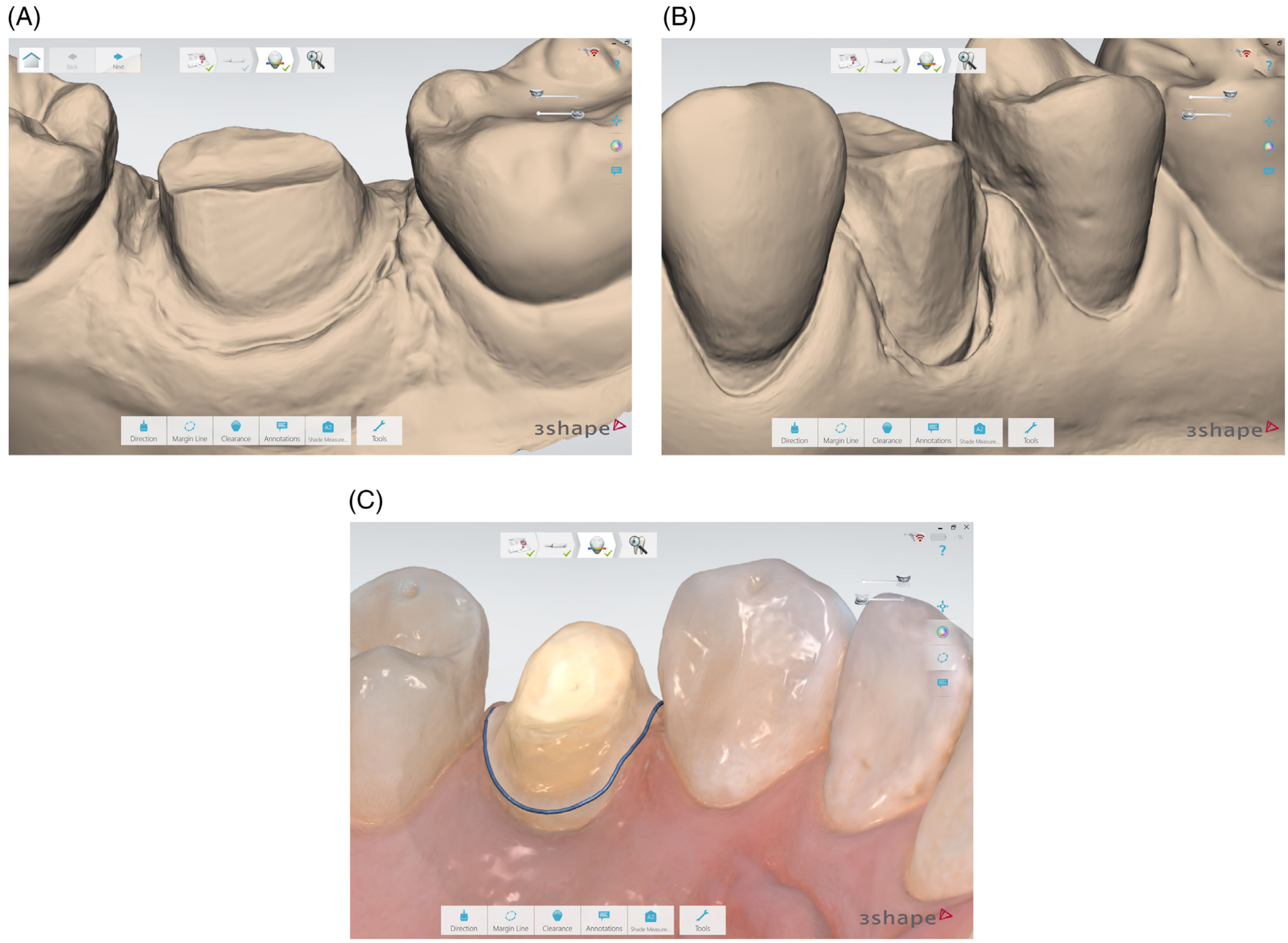

FIGURE 2 Intraoral digital scans that include a tooth preparation. (A) Inadequate finish line visibility of the tooth preparation. (B) Adequate digitalization of the finish line of the tooth preparation. (C) Finish line determination by using the tools of the IOS software program. IOS, intraoral scanner

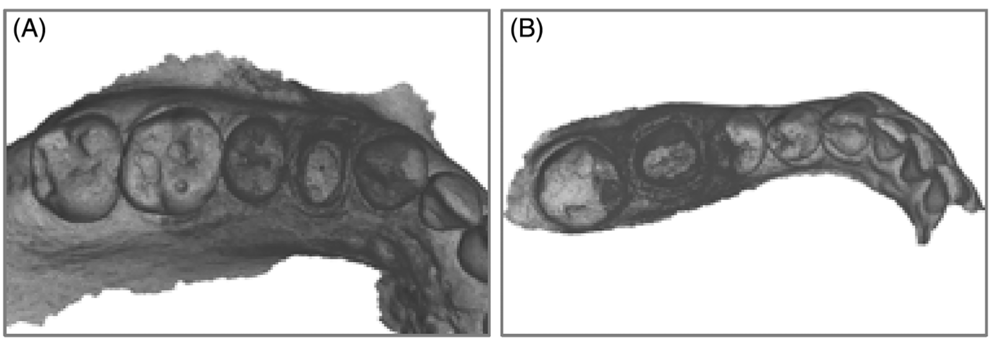

FIGURE 3 Representative intraoral digital scan with varying mesh density. Higher mesh density is located in the tooth preparation area. (A) Tooth preparation on a maxillary right first premolar. (B) Tooth preparation on a mandibular left first molar

2.9 | Interimplant distance, implant position, angulation, and depth

The distance between two adjacent implants, as well as implant position in the dental arch, implant angulation, and depth of the existing implants have been identified as variables that can decrease intraoral scanning accuracy.[41–52] However, inconsistencies are present in the dental literature regarding the influence of these variables on intraoral scanning accuracy.[41–52] Additional studies are needed to further assess the influence of implant related factors on scanning accuracy of IOSs. Photogrammetry systems provide a digital alternative to acquire the 3D position of the implants.[53–57]

A limited number of studies have analyzed the influence of the interimplant distance on intraoral scanning accuracy.[51,52] The results obtained by these studies were mainly consistent with the expectation that errors would increase as scanning distance or interimplant distance increased.[51,52]

Regarding implant position in the dental arch, Gómez-Polo et al.[50] assessed the influence of the implant angulation and implant position on the scanning accuracy of complete-arch implant scans captured by using an IOS (Trios 3 from 3Shape A/S). Results demonstrated that the implant positioned in the dental arch at the end of the intraoral digital scan obtained significantly higher distortion than the contralateral implant.[50]

Contradictory results have been reported regarding the influence of implant angulation and depth on intraoral scanning accuracy.[41–50] Some studies have reported that implant angulation decreased the accuracy of the digital scans compared to the conventional impressions, or that implant angulation decreased the scanning accuracy of IOSs.[41,44,46,47,50] However, other studies have shown that implant angulation had no effect on intraoral scanning accuracy.[42]

Implant depth is related to clinical implant scan body height.[43–45] Studies have analyzed the influence of the implant depth on intraoral scanning accuracy with contradictory results reported.[43–45] In an in vitro study, Laohverapanich et al.[43] evaluated the influence of the implant depth (3, 6, and 9 mm) on the scanning accuracy of four IOSs (Omnicam from Dentsply Sirona, Trios 3 from 3Shape A/S, True Definition from 3 M ESPE, and DWIO from Dental Wings) when obtaining a half-arch scan on a partially edentulous cast with 1 implant scan body. The best accuracy values were obtained when implants had up to 6-mm depth.[43] Similarly, Sequeira et al.[45] evaluated the influence of the implant depth (7, 6, 3, and 0 mm) on the accuracy of half-arch implant digital scans acquired by using an IOSs (CS3600 from Carestream). The cast selected had a single implant scan body. These results demonstrated that the accuracy values decreased as the depth increased.[45]

In a laboratory study, Gómez-Polo et al.[44] assessed the influence of the implant depth and implant angulation on the accuracy of complete-arch implant digital scans captured by using an IOS (Trios 3 from 3Shape A/S) and found that implant angulation and clinical scan body height influenced scanning accuracy.[44] When implants were parallel, no significant difference was computed between the different clinical implant scan body heights tested. However, in angulated implants, the shortest clinical implant scan body height resulted in the lowest scanning accuracy measured.[44]

2.10 | Implant scan bodies

Limited published data is available to determine the optimal implant scan body geometry and material for maximizing the scanning accuracy of intraoral digital scans involving single or multiple implants.[58–65] Different scan body designs have been tested aiming to simplify the digitizing procedures and to increase intraoral scanning accuracy.[48,64,65] However, the restricted clinical data does not support a systematic recommendation for selecting an implant scan body design. Furthermore, there may be no implant scan body design that optimally performs for all the different IOSs available.

Additional variables that should also be considered include implant scan body manufacturing tolerance,[66] implant scan body position distortion caused by tightening torque,[60,67] and one-piece PEEK implant scan body wear due to multiple reuses.[68–70] Due to the limited available data, it is difficult to establish protocols based on the number of times that an implant scan body can be sterilized and reused. Implant scan bodies with the implant interface fabricated in metal might be preferrable when compared with the one-piece PEEK implant scan bodies.[68–70] A cautious practice might include following the manufacturer's recommendation regarding the number of times that an implant scan body can be reused without affecting its performance, as well as the manufacturer's suggested torque when placing the implant scan bodies.

3 | CONCLUSIONS

The knowledge and understanding of patient intraoral conditions that can impact the scanning accuracy of IOSs is a fundamental element for maximizing the accuracy of IOSs. Although the intraoral conditions of the patient cannot be altered by the clinician, the systematic analysis of the patient's intraoral characteristics and the identification of the factors that can impact the outcome of the intraoral digital scan would enhance the predictability and reliability of the digital procedure.

DISCLOSURE

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

Research data not shared.

ORCID

Marta Revilla-León https://orcid.org/0000-0003-2854-1135

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