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RESEARCH AND EDUCATION

Complete arch digital implant scan accuracy with screw-retained or snap-on scan bodies: A comparative in vitro study

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ABSTRACT

Statement of problem. Different scan body types have been reported to influence intraoral scanning accuracy. Stiff implant connections allow the use of snap-on scan bodies. However, data on the influence of scan body retention type are lacking.

Purpose. The purpose of this in vitro study was to assess and compare the accuracy of complete arch digital scanning with that of screw-retained or snap-on scan bodies.

Material and methods. An edentulous mandibular master model with 4 conical connection analogs was digitized with an extraoral optical scanner to achieve a reference file. Seventy-six test scans were obtained with an intraoral scanner: 38 using screw-retained and 38 using snap-on scan bodies. The resulting 76 test files were aligned to the reference file with a best fit algorithm. Linear (ΔX, ΔY and ΔZ- axis), and angular deviations (ΔANGLE) were evaluated for each implant position (n=304). Three-dimensional (3D) deviation was calculated for each position according to the Euclidean distance (ΔEUC). Descriptive analysis and multivariable analysis were stratified considering scan body type and implant position (α=.05).

Results. Considering ΔEUC, scan body type showed no significant difference (P=.097), while implant position was statistically significant (P<.001), with the left second premolar as the most critical and the right lateral incisor the most accurate. Considering ΔANGLE, the snap-on scan bodies were significantly better (P=.033). The implant position also resulted in statistically significant differences (P<.001) with the left second premolar being the most critical and the right lateral incisor as the most accurate.

Conclusions. Snap-on scan bodies showed comparable 3D and higher angular accuracy compared with screw-retained scan bodies. Tilted posterior implants were the least accurate and resulted in more critical positions, especially the most distal position to be recorded. (J Prosthet Dent 2025;134:774-781)

The implant-supported prosthesis production workflow is composed of several steps that could influence the definitive fit of the prosthesis on the implants. Impression making is a crucial step that could be affected by impression technique and material, implant position, angulation, and depth.[1–3] The main impression techniques have been the closed (transfer), the open (direct), and the splinted, while the main impression materials have been polyether and polyvinyl siloxane.[3] The introduction of intraoral scanners (IOSs) has revolutionized implant dentistry, increased patient compliance, and simplified the recording of the workflow.[4–6] Even though the conventional

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Clinical Implications

Snap-on scan bodies can simplify the digital scanning procedure, avoiding the screwing and unscrewing of the recording components, facilitating the provision of complete arch implant-supported prostheses, without reducing overall scanning accuracy.

open-tray splinted impression technique is still considered the standard, recent clinical evidence has shown that IOSs have accuracy comparable with that of conventional implant impressions.[7–14]

Nevertheless, the IOS workflow could be influenced by factors related to the patient (anatomic features, interimplant distance, and implant number and position) and to the operator (IOS technology, wand size, calibration protocol, ambient light, temperature and humidity, operator experience, scanning strategy, and scan body characteristics).[15–30] Implants with a steep conical connection could be supplied for the traditional and digital workflow with implant impression transfers and implant scan bodies without a fixing screw. A snap-on scan body can be attached to the implant only with finger pressure, without a screw. Screw-retained scan bodies could require a dedicated extractor after the removal of the screw to allow removal of the scan body because the internal taper connection design most likely keeps the implant-abutment assembly from disengaging.[31] The use of snap-on scan bodies could facilitate the prosthetic steps, avoiding the use of an extractor, but its reliability in terms of accuracy requires validation. The authors are unaware of scientific evidence comparing the implant position transfer accuracy of screw-retained and snap-on scan bodies. The digital workflow allows a direct comparison of the accuracy of the test scans obtained with the investigated scan body types with respect to a selected reference scan.[32,33] Accuracy has been defined by trueness and precision according to the International Organization for Standardization (ISO)5725–1 standard[34]; trueness has been defined as the conformity of measurements to actual values, and precision the repeatability of the measurements.[35,36]

The objectives of this in vitro study were to assess and compare the accuracy of complete arch conical connection implant intraoral scanning executed with screw-retained and snap-on scan bodies and to assess the effect of implant position. The null hypotheses were that no significant difference would be found in the 3-dimensional (3D) and angular accuracy of the digital scan obtained with the 2 tested scan body types and that no significant difference would be found in the 3D and angular accuracy of the 4 implant positions.

MATERIAL AND METHODS

An edentulous mandibular polymethyl methacrylate (PMMA) milled model with a removable soft tissue frame was produced. Four implant analogs (In-Kone; Global D) were embedded at the positions of the right second premolar (30 degrees distal angulation, 2.5 mm depth), right lateral incisor (0 degrees angulation, 1 mm depth), left lateral incisor (0 degrees angulation, 2.5 mm depth) and left second premolar (17 degrees distal angulation, 1 mm depth) (Fig. 1). The implants had a steep, 8-degree, conical connection and hexagonal interlocking (Fig. 2).

A desk scanner with 2.5 megapixel camera (Optor Performance; Open Tech 3D srl) was used to obtain a standard tessellation language (STL) file containing the digital positions of the 4 implants to be used as a reference for the accuracy measurements. The scanner had been certified with a 4-μm trueness and 2-μm precision according to the 12836 standard.[36] Before scanning, an automated scanner calibration protocol was used.

A pen-grip powder-free confocal microscope IOS (TRIOS 4; 3Shape A/S) with a software program (3Shape Unite, v1.4.7.5; 3Shape A/S) was used to obtain 76 STL files containing the digital positions of the 4 implants to be superimposed and compared with the reference file. The device had been calibrated for color and 3D before use. One experienced operator (L.T.), blinded to the study aims, performed all test scans, 38 using screw-retained scan bodies and 38 with snap-on scan bodies. Both scan body types were made from anodized titanium (In-Kone; Global D), the screw-retained scan bodies with a cave structure as a hole for a fixing screw and the snap-on scan bodies built as solid structure to be just pushed into the implant connection without a screw. Both scan body types engaged the internal hexagon of the implant connection (Fig. 3). Before each test scan, a second operator (L.A.) secured the screw-retained scan bodies with a 10-Ncm torque or

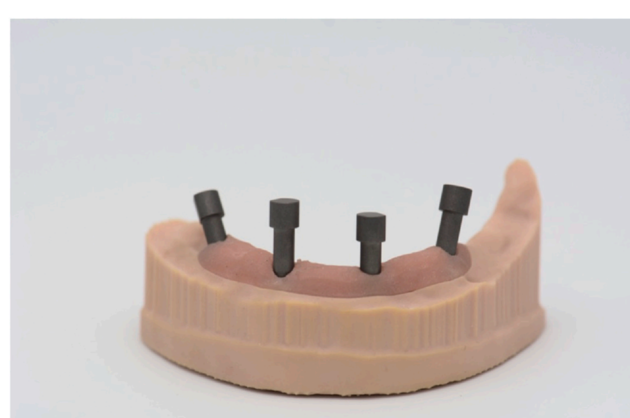

Figure 1. Mandibular model with 4 snap-on scan bodies.

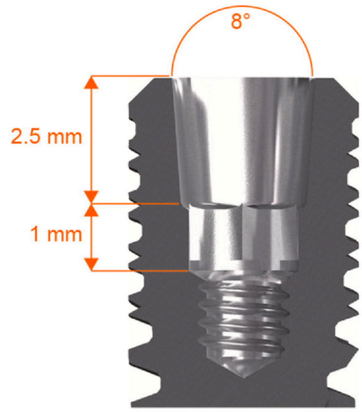

Figure 2. Implant connection specifics.

Figure 3. Screw-retained scan body (left) and snap-on scan body (right).

pushed the snap-on scan bodies into the implant connections and visually checked the seating with magnifying loupes (Eyezoom 5X; Orascoptic). At the end of each test scan, the second operator removed the snap-on scan bodies and the screw-retained scan bodies with a dedicated extractor (In-Kone; Global D) by hand after removing the fixing screw. The 2 scan body types (screw-retained scan bodies and snap-on scan bodies) were alternated according to a binary randomized sequence. All test scans followed the same scan strategy, starting from the right second premolar implant and heading to the left second premolar with 5 minutes between each scan.

Each of the 76 test files was superimposed to the reference file with a 0.01-mm tolerance best-fit alignment using a dedicated software program (MeshMixer; Autodesk Inc). Digital analog geometries of test and reference files were visualized as cylinders. The resulting 76 aligned files were imported into a metrology software program (Hyper Cad S; Open Mind Technologies AG) to calculate the linear (ΔX, ΔY, and ΔZ) and angular deviation (ΔANGLE) of each implant position (n=304) (Fig. 4). X, Y, and Z coordinates defined the lateral,

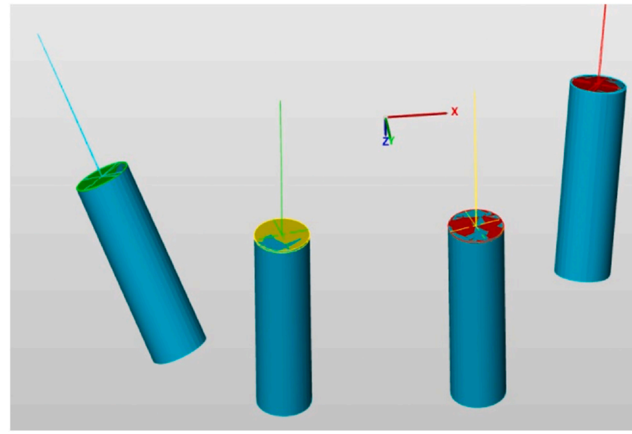

Figure 4. Linear and angular deviation assessment.

longitudinal, and vertical axis, with negative values showing deviations directed towards left, backward, and upward. Deviation measurements were executed at the center of the upper base of each digital analog, and linear deviations were used to calculate 3D deviation in terms of Euclidean distance (ΔEUC).

Assuming Euclidean distance as the primary endpoint and a significance level of.05, n=304 was the sample size needed to ensure a test power of 0.90 for a minimum expected difference of 15 µm (standard deviation 40 µm). Sample size determination was based on the *t* test. Mean, standard deviation, and minimum and maximum values were used to summarize continuous variables. Empirical distributions were described by histograms and Kernel density estimates.

Multivariable analysis was based on the ANOVA model. Two models were fitted assuming ΔEUC and ΔANGLE as response variables. In both models, the main effects of scan body type and implant position were evaluated together with their 2-way interaction. Least squares means were computed for each effect, and all pairwise differences were tested using the Tukey correction for multiplicity. Normality assumption was assessed by residual analysis. All analyses were undertaken using statistical software programs (R version 4.4; The R Project for Statistical Computing, SAS software program version 9.4; SAS Institute).

RESULTS

Deviations among the 76 test and the reference scan were calculated for each implant position for a total of 304 observations. Descriptive analysis of the deviations (mean, standard deviations, and range) stratified per scan body type (snap-on scan bodies and screw-retained scan bodies) are reported in Table 1, and the relative empirical distributions in Figure 5. Screw-retained scan bodies and snap-on scan bodies had mean ΔEUC

Table 1. Descriptive analysis stratified for scan body type

	Snap-on Scan Bodies			Screw-retained Scan Bodies		
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
ΔY (µm)	15.3	46.9	(−101.7, 130.5)	19.8	50.8	(−129.2, 164.5)
ΔX (µm)	9.6	57.7	(−231.2, 210.2)	19.1	19.2	(−154.9, 285,6)
ΔZ (µm)	19.2	75.0	(−200.1, 166.6)	23.3	75.1	(−141.1, 170.0)
ΔEUC (µm)	99.9	42.5	(198.0, 296,7)	107.6	40.8	(14.8, 308.0)
ΔANGLE (degrees)	0.35	0.23	(0.02, 1.45)	0.41	0.23	(0.04, 0.99)

deviations of 107.6 and 99.9 µm with extreme deviations up to 308.0 and 296.7 µm. The standard deviation was 42.9 µm for snap-on scan bodies and 40.8 µm for screw-retained scan bodies.

Considering ΔANGLE, screw-retained scan bodies and snap-on scan bodies had mean deviations of 0.41 and 0.35 degrees, with extreme deviations up to 0.99 and 1.45 degrees. The standard deviation was the same for both scan body types (0.23). ΔANGLE empirical distribution stratified per scan body type is presented in Figure 6.

Multivariable analysis of variance (ANOVA) considered ΔEUC and ΔANGLE as response variables. Estimated effects of scan body type (snap-on scan bodies and screw-retained scan bodies) and implant position (left second premolar [30 degrees distal angulation, 2.5 mm depth], left lateral incisor [0 degrees angulation, 1 mm depth], right lateral incisor [0 degrees angulation, 2.5 mm depth] and right second premolar [17 degrees distal angulation, 1 mm depth]) were calculated and are reported in Tables 2 and 3.

When ΔEUC was considered as response variable, implant position was a statistically significant variable ($P<.001$), while scan body type was not significant ($P=.097$). Posterior implant positions were significantly more critical compared with the right lateral incisor (error difference of −17.1 and −26.1 µm) and the left lateral incisor (error difference of −12.7 and −21.7 µm) ($P<.05$). The difference between the 2 anterior positions was not significant ($P>.05$) (Table 2). No significant interaction was found between scan body type and implant position ($P=.075$).

When ΔANGLE was considered as a response variable, scan body type and implant position showed a significant effect ($P=.033$ and $P<.001$). Screw-retained scan bodies performed significantly worse, with an error increase of 0.05 degrees. The right second premolar and left second premolar were the most critical positions,

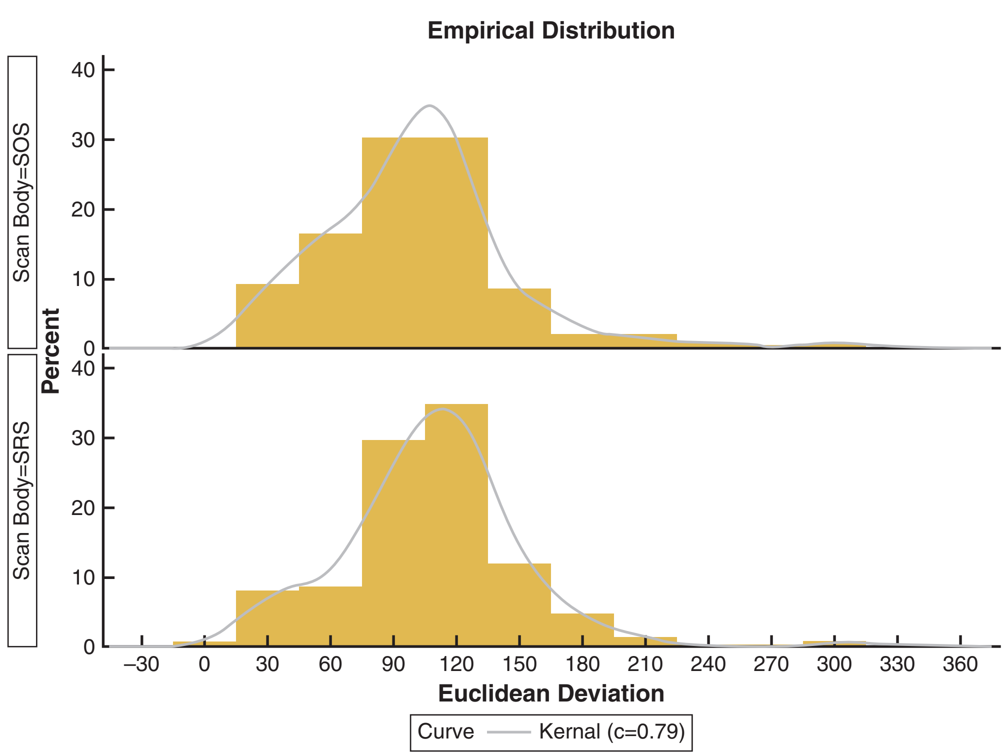

Figure 5. ΔEUC empirical distribution stratified for scan body type.

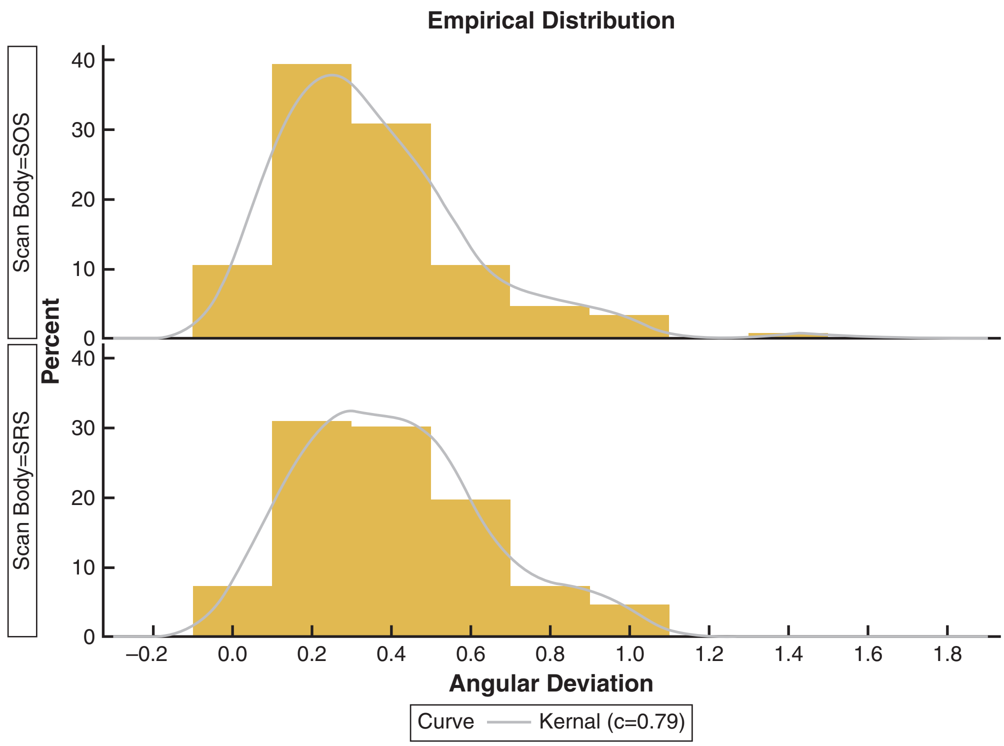

Figure 6. ΔANGLE empirical distribution stratified for scan body type.

Table 2. Multivariable analysis considering ΔEUC

Source of Variation	Mean Square (μm)	F Statistic	*P*
Scan body	4.5	2.76	.097
Position	10.8	6.56	<.001
Contrast	Estimated difference (μm)	Simultaneous 95% confidence limits	*P*
Snap-on scan bodies vs Screw-retained scan bodies	7.7	(−1.4, 16.9)	.097
Right lateral incisor vs Left lateral incisor	−4.4	(−21.4, 12.6)	.909
Right lateral incisor vs Left second premolar	−26.1	(−43.1, 9.1)	<.001
Right lateral incisor vs Right second premolar	−17.1	(−34.1, 0.1)	.048
Left lateral incisor vs Left second premolar	−21.7	(−38.7, 4.7)	.006
Left lateral incisor vs Right second premolar	−12.8	(−29.7, 4.2)	.216
vs Right second premolar	9.0	(−8.01, 26.0)	.523

with a significant error difference of −0.17 and −0.26 degrees compared with the right lateral incisor (Table 3). Also, the left second premolar performed worse compared with the left lateral incisor and right second premolar. Interaction between scan body type and implant position was not significant (*P*=.633). In both models, no evidence was found of departures from normality.

Table 3. Multivariable analysis considering ΔANGLE

Source of Variation	Mean Square (degrees)	F Statistic	*P*
Scan body	0.20	4.58	.033
Position	0.97	22.00	<.001
Contrast	Estimated difference (degrees)	Simultaneous 95% confidence limits	*P*
Snap-on scan bodies vs Screw-retained scan bodies	0.05	(0.00, 0.10)	.033
Right lateral incisor vs Left lateral incisor	−0.08	(−0.17, 0.00)	.065
Right lateral incisor vs Left second premolar	−0.26	(−0.35, −0.17)	<.001
Right lateral incisor vs Right second premolar	−0.17	(−0.25, −0.08)	<.001
Left lateral incisor vs Left second premolar	−0.18	(−0.27, −0.09)	<.001
Left lateral incisor vs Right second premolar	−0.08	(−0.17, 0.00)	.072
Left second premolar vs Right second premolar	0.10	(0.01, 0.18)	.026

DISCUSSION

This in vitro study assessed and compared the accuracy of 2 scan body types (snap-on scan bodies and screw-retained scan bodies) for complete arch IOS implant impressions. Accuracy outcomes were 3D (ΔEUC) and angular deviations (ΔANGLE). The null hypotheses that no significant difference would be found in the 3-dimensional (3D) and angular accuracy of the digital scan obtained with the 2 tested scan body types and that no significant difference would be found in the 3D and angular accuracy of the 4 implant positions were partially rejected because the snap-on scan bodies performed better than the screw-retained scan bodies in terms of angular deviations (*P*=.033); considering 3D deviation, no significant difference was found (*P*=.097). The authors are unaware of scientific evidence comparing digital scan recording components with and without a fixing screw, so no comparison reference is available. This was mainly because of the singular characteristics of the analyzed implant connection with an 8-degree steep inclined plane with hexagonal interlocking that allows the use of snap-on recording components. From the results, it appears that the use of snap-on scan bodies for complete arch digital implant scans could be as accurate as of the screw-retained scan bodies according to 3D deviation and even more accurate considering angular deviation. From a clinical point of view the use of snap-on scan bodies could simplify and accelerate the prosthetic procedure. When using screw-retained scan bodies, after fixing screw removal, the use of a dedicated extractor is necessary to detach the activated connection between the implant and the scan body. This procedure could be critical for both the patient and the clinician, especially when dealing with multiple implants. Nevertheless, the seating of the screw-retained scan bodies could be controlled and standardized with the fixing screw torque, while snap-on scan body seating relies only on the operator's perception of finger pressure.

Concerning the implant positions, a significant effect was found both on 3D (*P*<.001) and angular deviation (*P*<.001), with posterior implants experiencing higher deviations. The implant position effect requires a proper evaluation considering not only the location along the arch, that is the scanning order effect, but also the implant position in space, angulation, and depth.

Considering the scanning order, increased errors have been associated with a longer span, especially in the last part of the scan because of the stitching process at the base of most IOS systems, necessary to overlap consecutively acquired 3D images according to a best fit algorithm.[11,13,15–17,19,21–23] The results of the present study confirmed this trend, with the last implant position scanned (left second premolar) being the least accurate. Interimplant distance was not analyzed as a potential variable in the present study as the implants were planned and placed in the model with the same interimplant distance.

Considering implant angulation and depth, in the present study, posterior implants had 2 levels of angulation (right second premolar 30 degrees; left second premolar 17 degrees), while anterior implants were placed parallel to each other with a 1.5 depth difference. Although the right second premolar was the first position to be scanned, it was significantly less accurate than the anterior implants, attributed to the distal angulation of 30 degrees and depth of 2.5 mm. Nevertheless, the accuracy of the right second premolar was higher than of the left second premolar, suggesting that the scanning order could be more detrimental to IOS accuracy than the implant inclination and depth. Despite the 1.5-mm depth difference, anterior implants did not differ significantly in accuracy, suggesting that slight depth difference alone may not be crucial to IOS accuracy.

Gómez-Polo et al[22] reported similar results from an in vitro study, concluding that parallel implant positions showed higher accuracy than angled positions. The results were also confirmed by a recent in vivo study by the same group that reported implant angulation and scan body height as variables that significantly affected scanning accuracy.[29] Another recent in vitro study[30] reported no significant effect of angulation up to 18 degrees on IOS accuracy; nevertheless angled groups showed higher deviations than parallel ones. The angulation of the implant could negatively affect the accuracy, as part of the scan body could be difficult to reach with the IOS wand and to record properly. For this reason, deficiency in the scanned image of the scan body could be critical in the scan body shape alignment to the computer-aided design (CAD) library and lead to a drop in the accuracy of the implant position transfer.[18] The same issue could be noticed when dealing with deep implants that were reported to lead to the reduced amount of scan body visibility available for the CAD library superimposition.[28]

Results from the descriptive analysis showed the highest mean deviations on the Z-axis (vertical) for the investigated scan body types. The high deviation values found on the vertical axis could be attributed to the steep implant connection that could make it difficult to control the recording components seating repeatably. The X-axis (lateral) had the lowest mean and standard deviation. However, deviations of the extreme abutments were the highest, reaching 285 μm. This could be attributed to the collapse of the mandibular arch, already noticed by other studies, with the last implant of the arch frequently showing a great deviation towards the medial and leading to a contraction of the jaw curvature.[24,33] The 3-dimensional deviation of the 2 scan body types was similar, but a higher mean angular deviation of screw-retained scan bodies was noticed.

The study design with one experienced operator, one IOS and one implant type limits the generalization of the results. The snap-on scan body is currently only available for 2 implant manufacturers, another limitation on generalization. Nevertheless, the trend in designing more stable internal implant connections could lead to the spread of this type of scan body by simplifying the recording workflow.

The accuracy results stratified for implant position along the arch could be influenced by the scanning order and simultaneously by the depth and inclination of the implant, making it difficult to determine the effect of the scanning order and implant position on accuracy. Furthermore, the choice of best fit alignment to superimpose the test and reference scan could distribute the recorded deviations to all the implant positions. Despite this limitation, the best fit alignment remains the most used superimposition method.[14,20,24,27]

Future research should analyze the physical combination between snap-on scan bodies and screw-retained scan bodies with the implant connection and correlate it with the accuracy analysis. The seating of snap-on scan bodies requires investigation when different operators are involved because measuring the match of the recording components with screw-retained scan bodies using a dynamometer is not possible. Scan body base wear has also been reported to be a variable correlated with IOS accuracy, with studies required on the wear pattern of the 2 scan body types after repeated use and their effect on accuracy.[20] In vivo studies are also encouraged to confirm the obtained results and to test the patient compliance according to the scan body type used.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. Snap-on scan bodies showed comparable 3D and higher angular accuracy compared with screw-retained scan bodies.
2. Tilted posterior implants positions were less accurate compared with the straight anterior positions.
3. The last position scanned along the arch was the least accurate.

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