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RESEARCH AND EDUCATION

Accuracy of complete arch implant scans recorded by using intraoral and extraoral photogrammetry systems

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Extraoral photogrammetry (PG) systems provide a reliable digital procedure for acquiring 3-dimensional (3D) implant positions by recording extraoral images of intraoral optical markers positioned in the dental implants.[1–9] The PG software programs use these extraoral images to locate the 3D implant positions. Different studies have analyzed the accuracy of extraoral PG devices, reporting a mean trueness value ranging from 10 to 77 μm and a mean precision value from 2 to 203 μm.[1–8] However, the extraoral PG systems are unable to record all the information needed to design and fabricate an implant-supported prosthesis, such as soft tissue information, adjacent teeth, antagonist arch, and maxillomandibular relationship.[1–9]

ABSTRACT

Statement of problem. Extraoral photogrammetry (PG) systems provide a reliable method for recording implant positions; however, the accuracy of an intraoral PG system integrated into an intraoral scanner (IOS) system remains unknown.

Purpose. The purpose of this in vitro study was to compare the accuracy of complete arch implant scans captured by using 4 extraoral and 1 intraoral PG system.

Material and methods. An edentulous cast with 6 implant abutment analogs (MultiUnit Abutment Plus Replica) was digitized (T710). Five groups were created depending on the PG system used to capture complete arch implant scans: 4 extraoral PG systems, PIC (PIC System), Icam4D (Imetric), Grammee (BlueSkyBio), OxoFit (Oxo), and 1 intraoral PG device, Elite (Shining 3D) (n=30). In each group, the corresponding optical markers were placed on the implant abutment analogs of the reference cast, and 30 consecutive scans were recorded. Euclidean linear and angular measurements were obtained on the digitized reference cast and used to compare the discrepancies with the same measurements obtained on each experimental scan. One-way ANOVA and Tukey tests were used to analyze the trueness data. The Levene test was used to analyze precision values (α=.05).

Results. Significant linear trueness ($P<.001$) and precision ($P<.001$) discrepancies were found among the groups. PIC and Icam4D groups obtained significantly better linear trueness than the other PG systems, and PIC obtained the best linear precision. The linear discrepancies ranged from 17 to 30 μm. Significant angular trueness ($P<.001$) and precision ($P<.001$) differences were revealed among the groups. The Grammee obtained the best angular trueness, while PIC obtained the best angular precision. The angular discrepancies ranged from 0.17 to 0.34 degrees.

Conclusions. The PG system influenced the trueness and precision of complete arch implant scans. The intraoral PG obtained accuracy values similar to those of the 2 extraoral PGs (Grammee and OxoFit). The discrepancies measured among the systems may not be clinically significant. (J Prosthet Dent xxxx;xxx:xxx-xxx)

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Clinical Implications

The intraoral photogrammetry system has the potential to provide a reliable method for fabricating complete arch implant-supported prostheses.

As digital data acquisition technologies evolve, new solutions have been developed. Recently introduced intraoral scanner (IOS) system include a photogrammetry procedure for intraorally recording 3D implant positions. For this intraoral PG method, specific implant scan bodies are required. Additionally, as with any IOS device, this digital data acquisition method is also able to capture additional information, including soft tissue information, adjacent teeth, antagonist arch, and maxillomandibular relationship. Therefore, all the information needed to design and fabricate an implant-supported prosthesis can be recorded by using the same IOS system. However, the accuracy of this intraoral PG technology remains unknown.

The purpose of the present in vitro study was to compare the accuracy (trueness and precision) of complete arch implant scans recorded by using 4 extraoral (PIC system; PIC Dental, Icam4D; Imetric, Grammee; BlueSkyBio, OxoFit; Oxo) and 1 intraoral (Aoralscan Elite; Shining 3D) PG systems. The null hypotheses were that no significant difference would be found in the trueness and precision of the complete-arch implant scans captured by using the extraoral and intraoral PG systems tested.

MATERIAL AND METHODS

A maxillary stone cast with 6 implant abutment analogs (MultiUnit Abutment Plus Replica; Nobel Biocare) was obtained. The implant abutment analogs were located at the right and left canines, right and left first premolar molar, and right and left first molar. A new[9] 2-piece polyetheretherketone (PEEK)[10,11] implant scan body (ISB) (Scan Abutment Non Engaging, Ø4.8 mm, H10 mm; IPD) was tightened to 10 Ncm[11] on each implant abutment of the reference implant cast as per the manufacturer's instructions. Subsequently, the reference implant cast was digitized by using a calibrated laboratory scanner (T710; Medit) according to the manufacturer's recommendations. The manufacturer of the selected laboratory scanner reports a scanning accuracy of 4 μm as measured in accordance with the International Organization for Standardization (ISO) 12836 standard.[12] The reference standard tessellation language (STL) file was exported, and the ISBs were removed from the reference implant cast.

Table 1. Photogrammetry systems tested

Group	System; Manufacturer
PIC	PIC Dental, 1st generation; PIC System
Icam4D	Icam4D; Imetric
Grammee	Grammee; BlueSkyBio
OxoFit	OxoFit; Oxo
Elite	Aoralscan Elite; Shining 3D

The reference cast was positioned into a mannequin head (Adam Patient Simulator; KaVo). The ambient illumination condition at the mouth of the mannequin head was 1000 lux (Digital Light Meter LX1330B; Dr. Meter). Five groups were created depending on the PG system used to capture complete arch implant scans (Table 1): 4 extraoral PG systems, PIC (PIC System, 1st generation; PIC Dental), Icam4D (Icam4D; Imetric), Grammee (Grammee; BlueSkyBio), OxoFit (OxoFit, v.2.0.0; Oxo) groups; and 1 intraoral PG device, Elite (Aoralscan Elite; Shining 3D). A total of 30 consecutive PG scans per group were acquired (n=30), following the ISO 20896–1:2019 standard.[13,14]

In the PIC group, an optical marker (PIC Transfer, HC MUA Metal, Ø4.8 mm; PIC Dental) was hand tightened into each implant abutment of the reference cast according to the manufacturer's recommendations. The optical markers remained in the same position during all the digitizing procedures of this group. The code of each reference marker was introduced into the software program of the PG system, and the consecutive complete arch implant scans were captured by using the camera (PIC Camera; PIC Dental) with a scanning distance ranging from 25 to 30 cm[15] (Fig. 1). The implant located in the right first molar was selected as the implant reference by using the tools of the PG program.[16] After the acquisition of each specimen, the STL file was exported.

In the Icam4D group, an optical marker (IcamBodies MU, RP 1.4; Imetric) was hand tightened into each implant abutment of the reference cast as per the manufacturer's instructions. The optical markers

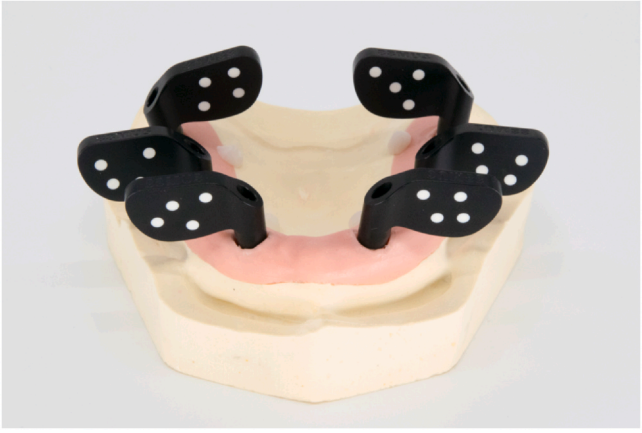

Figure 1. Reference cast with optical markers of PIC group.

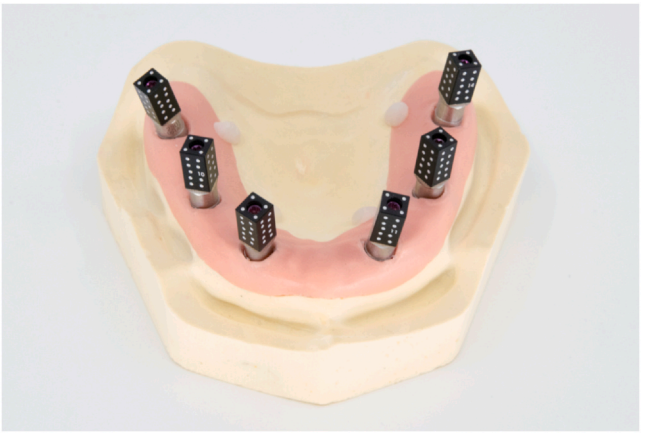

Figure 2. Reference cast with optical markers of Icam4D group.

remained in the same position during all the digitizing procedures of this group. Before each acquisition procedure, the PG device was calibrated by using the calibration plate according to the manufacturer's protocol. Complete arch implant scans were captured by using the capturing camera (Icam4D Camera, Generation 4; Imetric) with a scanning distance ranging from 25 to 30 cm according to the manufacturer's recommendations (Fig. 2). After the acquisition of each specimen, the STL file was exported.

In the Grammee group, an optical marker (Posts Grammee, Post Set 293; BlueSkyBio) was hand tightened into each implant abutment of the reference cast as per the manufacturer's instructions (Fig. 3). The optical markers remained in the same position during all the digitizing procedures of this group. Before each acquisition procedure, the PG device was calibrated by using the specific calibration plate according to the manufacturer's protocol. Complete arch implant scans were captured with a scanning distance of 7 cm according to the manufacturer's recommendations. After the acquisition of each specimen, the STL file was exported.

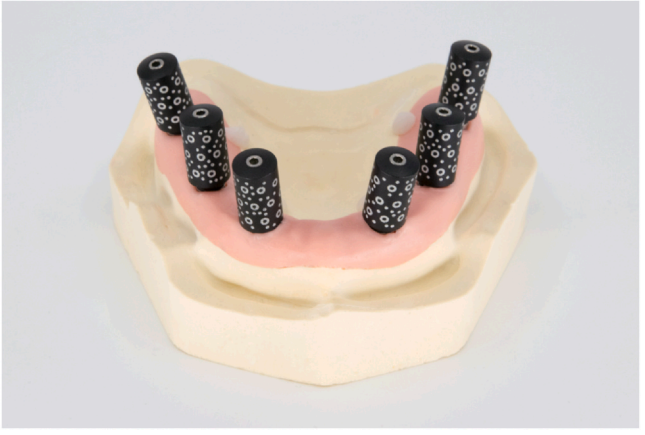

Figure 3. Reference cast with optical markers of Grammee group.

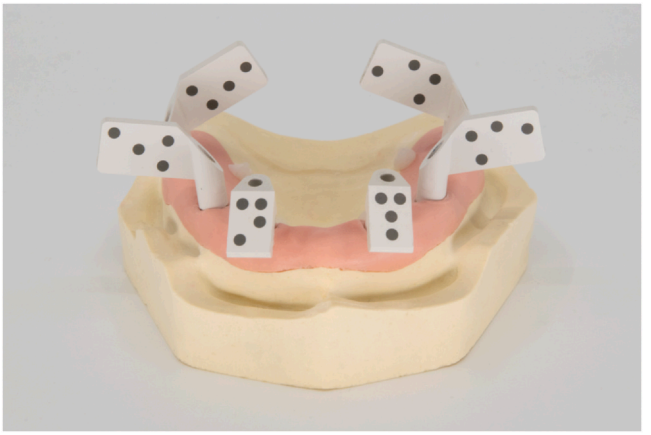

Figure 4. Reference cast with optical markers of OxoFit group. Flag 3 on right first molar implant, flag 8 on right first premolar implant, flag 5 on right canine implant, flag 7 on left canine implant, flag 4 on left first premolar implant, and flag 1 on left first molar implant.

In the OxoFit group, an optical marker (Posts, MUA RP; Oxo) was hand tightened into each implant abutment of the reference cast as per the manufacturer's instructions (Fig. 4). The optical markers remained in the same position during all the digitizing procedures of this group. The code of each reference marker was introduced into the software program of the PG system, and complete arch implant scans were captured with a scanning distance ranging from 20 to 25 cm according to the manufacturer's recommendations. After the acquisition of each specimen, the STL file was exported.

In the Elite group, a specific implant scan body (Elite Photogrammetry marker; Shining 3D) was hand tightened into each implant abutment of the reference cast as per the manufacturer's instructions. The implant scan bodies were oriented towards the center of the palate, and the implant scan bodies were not touching (Fig. 5). The IOS was calibrated before starting data collection and after every 10 scans by using the calibration devices

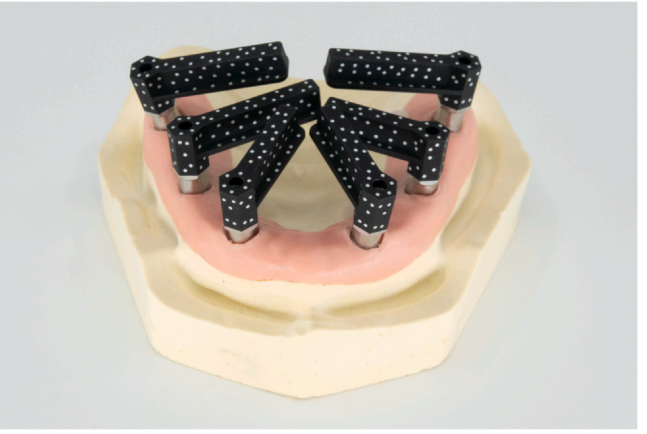

Figure 5. Reference cast with specific implant scan bodies of Elite group.

according to the calibration protocol endorsed by the manufacturer. After the acquisition of each specimen, the STL file was exported.

The manufacturer of the ISB (Scan Abutment Non Engaging, Ø4.8 mm, H10 mm; IPD) used to capture the virtual reference casts provided the corresponding CAD file. The reference STL file and the CAD file of the selected ISB were imported into a reverse engineering software program (Geomagic, Control X; 3D Systems). In the reference STL, the z plane was located at the most coronal surface of each ISB, followed by the location of the longitudinal axis of each ISB.[15–17] The z plane marked on each ISB was moved apically 10 mm, which corresponded to the height of the selected ISB, and the point located at the intersection between the z-plane and the longitudinal axis of each ISB was used to measure the Euclidean linear distances among the 6 ISBs.[15–17] Additionally, the longitudinal axes of the implant scan bodies were used to calculate the Euclidean angular distances among the ISBs.[15–17]

The same CAD procedures were completed on each experimental scan. First, each scan was imported in the same reverse engineering software program. Then, the z plane was located at the apical base of each implant abutment, followed by the longitudinal axis of each implant abutment. Similarly, as in the reference file, the point located at the intersection of the z-plane and the longitudinal axis of the implant abutment was used to measure the Euclidean linear distances among the 6 implant abutments.[15–17] Additionally, the longitudinal axes of the implant abutments were used to calculate the Euclidean angular distances among the ISBs.[15–17] The linear and angular measurements obtained in the reference file were used as a reference to calculate the scanning distortion with each experimental scan. Trueness was defined as the average linear and angular measurement discrepancies between the reference and experimental scans.[13,14] Precision was described as the linear and angular measurement variations for each group.[13,14]

The Q-Q plots indicated the normality of residuals in regression models while the variance across the groups was significantly unequal. Therefore, 1-way Welch analysis of variance (ANOVA) and the pairwise comparison Tukey tests were used to analyze the trueness data (α=.05). The Levene test and the pairwise comparison Wilcoxon rank sum test with continuity correction data was used to analyze the precision values (α=.05). All the statistical analysis was completed using a statistical software program (SAS, v.3.81, Enterprise Edition; SAS Institute Inc.).

RESULTS

The linear and angular mean ±SD discrepancies obtained among the groups tested are presented in Table 2.

Table 2. Descriptive statistics of overall linear and angular measurement discrepancies computed among groups tested

Group	Mean ±SD Linear Discrepancies (μm)	Mean ±SD Angular Discrepancies (Degrees)
PIC	17 ±4	0.34 ±0.01
Icam4D	18 ±6	0.29 ±0.05
Grammee	28 ±9	0.17 ±1.0
OxoFit	30 ±14	0.31 ±0.02
Elite	27 ±5	0.27 ±0.02

SD, standard deviation.

Regarding the analysis of the linear measurements, 1-way Welch ANOVA revealed significant trueness discrepancies among the groups tested (df=4, F=28.4, P<.001) (Fig. 6A). Additionally, the Tukey post hoc multiple pairwise comparison revealed significant trueness differences among the groups (P<.001). The PIC and Icam4D groups obtained significantly better linear trueness when compared with the other groups tested (Table 3). The mean linear discrepancies ranged from 17 to 30 μm among the groups tested. The Levene test revealed significant precision discrepancies among the groups tested (P<.001). Moreover, the pairwise comparison Wilcoxon rank sum test with continuity correction data revealed that the PIC and Grammee (P<.001), PIC and OxoFit (P<.001), PIC and Elite (P<.001), Icam4D and Grammee (P<.001), Icam4D and OxoFit (P=.001), and Icam4D and Elite (P<.001) groups were significantly different. Therefore, the PIC group obtained the best linear precision among the groups tested.

Regarding the analysis of the angular measurements, 1-way Welch ANOVA revealed statistically significant trueness differences among the groups tested (df=4, F=71.3, P<.001) (Fig. 6B). Additionally, the Tukey post hoc multiple pairwise comparison test revealed significant differences among the groups tested (P<.001). The Grammee group obtained the best angular trueness among the groups tested (Table 4). The mean angular discrepancies ranged from 0.17 to 0.34 degrees among the groups tested. Moreover, the pairwise comparison Wilcoxon rank sum test with continuity correction data revealed that all the groups tested were significantly different, except for the Icam4D and OxoFit groups (P>.999) and the Icam4D and Elite (P=.23) (Table 5). The PIC system obtained the best angular precision among the groups tested.

DISCUSSION

Based on the results of the present study, trueness and precision discrepancies were found among the extraoral and intraoral PG systems tested when recording complete arch implant scans. Therefore, the null hypothesis that no significant difference would be found in the trueness and precision of the complete-arch implant

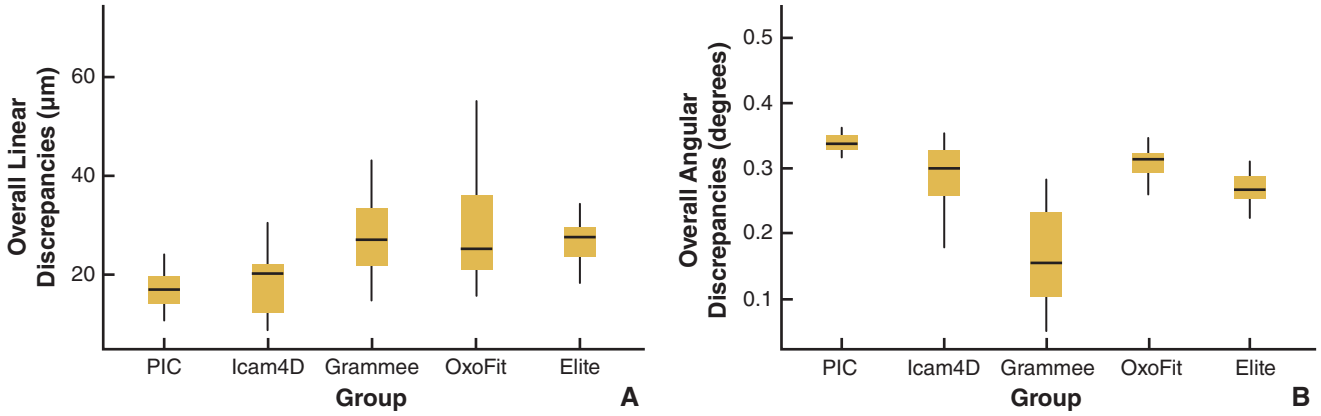

Figure 6. Overall discrepancies among groups tested. A, Linear measurements. B, Angular measurements.

Table 3. Results of Tukey post hoc multiple pairwise comparison test for overall linear discrepancies among groups tested

Group		PIC	Icam4D	Grammee	OxoFit	Elite
PIC	Mean difference	—	−0.754	−11.3	−13.33	−9.70
	P	—	.997	**<.001***	**<.001***	**<.001***
Icam4D	Mean difference	—	—	−10.6	−12.58	−8.94
	P	—	—	**<.001***	**<.001***	**<.001***
Grammee	Mean difference	—	—	—	−2.02	1.61
	P	—	—	—	.879	.942
OxoFit	Mean difference	—	—	—	—	3.63
	P	—	—	—	—	.436
Elite	Mean difference	—	—	—	—	—
	P	—	—	—	—	—

* Groups significantly different (*P*<.05)

Table 4. Results of Tukey post hoc multiple pairwise comparison test for overall angular discrepancies among groups tested

Group		PIC	Icam4D	Grammee	OxoFit	Elite
PIC	Mean difference	—	0.0477	0.170	0.0296	0.0692
	P	—	.003*	<.001*	.155	<.001*
Icam4D	Mean difference	—	—	0.122	−0.0181	0.0215
	P	—	—	<.001*	0.629	0.458
Grammee	Mean difference	—	—	—	−0.1403	−0.1006
	P	—	—	—	<.001*	<.001*
OxoFit	Mean difference	—	—	—	—	0.0396
	P	—	—	—	—	.022*
Elite	Mean difference	—	—	—	—	—
	P	—	—	—	—	—

* Groups significantly different (*P*<.05)

scans captured by using the extraoral and intraoral PG systems tested was rejected. The PIC and Icam4D systems demonstrated the best linear trueness, and the PIC revealed the best linear precision when compared with the other extraoral and intraoral PG systems tested. Additionally, the Grammee system obtained the best angular trueness, and the PIC had the best angular precision when compared with the other PG systems examined. However, for a complete arch implant scan, the linear discrepancy measured among the extraoral and intraoral photogrammetry systems tested ranged from 17 ±4 to 30 ±14 µm, and the angular discrepancy measured among the PG systems assessed varied from 0.17 ±1.0 to 0.34 ±0.01 degrees. Therefore, the impact of the discrepancies measured may be not clinically significant.

Table 5. Pairwise comparison Wilcoxon rank sum test with continuity correction data for angular precision discrepancies among groups tested

Group	PIC	Icam4D	Grammee	OxoFit
Icam4D	<.001*	—	—	—
Grammee	<.001*	<.001*	—	—
OxoFit	<.001*	>.999	<.001*	—
Elite	<.001*	.23	<.001*	<.001*

* Groups significantly different (*P*<.05)

Previous studies have analyzed the accuracy of 2 extraoral PG systems (PIC System; PIC Dental, Icam4D; Imetric).[1–8] A recent systematic review reported that the PIC system has a mean trueness ranging from 10 to 49 µm and a mean precision from 5 to 65 µm, while the iCam4D system has a mean trueness from 24 to 77 µm and a mean precision varying from 2 to 203 µm.[1] The

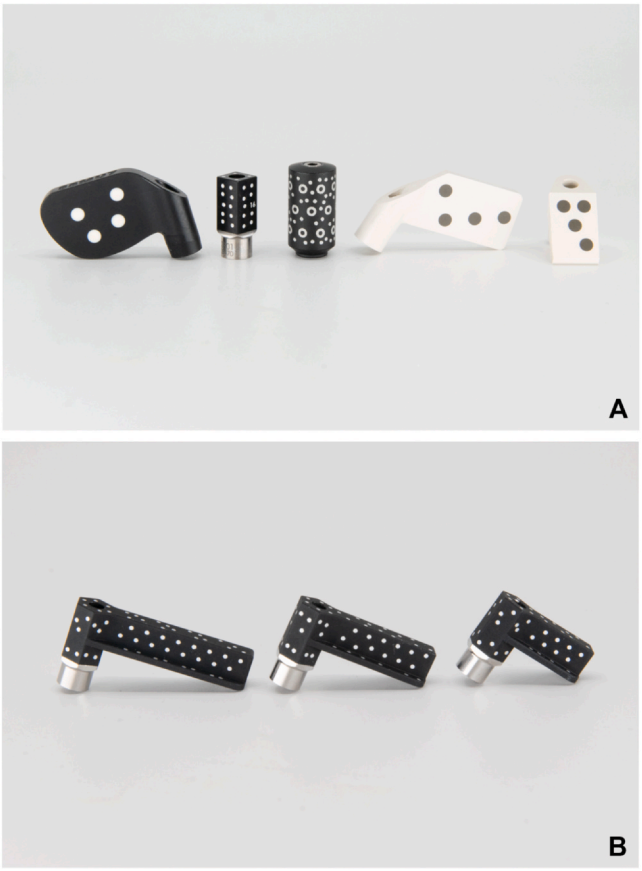

Figure 7. A, Markers of extraoral photogrammetry systems tested. B, Implant scan bodies of intraoral photogrammetry system.

results of the present investigation are in agreement with these results. However, the authors are unaware of a previous investigation that assessed the scanning accuracy of a recently introduced intraoral PG system (Aoralscan Elite; Shining 3D) and 2 relatively new extraoral PG devices (Grammee; BlueSkyBio, OxoFit; Oxo). Therefore, comparisons with previous investigations regarding the reported accuracy values of these 3 PG systems are not feasible.

The extraoral PGs tested had different functionality. One of the extraoral PGs assessed in the present investigation has not only the capacity to capture the 3D position of the implants (OxoFit) but also to record the mandibular motion of the patient (OxoJaw). However, the accuracy of this additional functionality of this extraoral PG system remains unknown. In addition, these extraoral PG systems only capture the 3D positions of the implant; therefore, an IOS is needed to record soft tissue information, adjacent teeth, antagonist arch, and maxillomandibular relationship.

Based on the results of the present investigation, the intraoral PG system was able to obtain accuracy values similar to those of 2 of the extraoral photogrammetry systems (Grammee and OxoFit) tested when recording complete arch implant scans. This IOS device obtained a mean linear discrepancy of 27 ±5 μm and a mean angular discrepancy of 0.27 ±0.02 degrees. Additionally, this IOS has functionalities similar to those of other IOS devices, providing a significant advantage when compared with the extraoral PG systems. However, the scanning accuracy of the recent incorporation of the latest version (Aoralscan Elite) of this IOS system (Shining 3D) for fabricating casts, dental devices, and dental restorations has not yet been reported. Studies are needed to further assess the accuracy of this IOS (Aoralscan Elite; Shining 3D) for different purposes.

The design of the optical markers varied among the extraoral and intraoral PG tested (Fig. 7). As the effect of the different optical marker design on the accuracy of the PG is unknown, studies are needed to further evaluate this parameter. However, the scanning accuracy is related to the hardware and software of the PG system, not only to 1 specific parameter. Additionally, the impact of the sterilization procedures and of the positioning torque of these optical markers on the accuracy of these PG systems needs to be analyzed.

Different techniques are available for obtaining the reference file from which scanning discrepancies are calculated, including a coordinate measurement machine,[2,4,8] industrial scanner,[9] and laboratory dental scanner.[3,5–7] The Euclidean measurement technique used in the present investigation to examine trueness and precision has been used previously.[3,5,10] Limitations of the present investigation included the in vitro conditions, reference file obtained by using a laboratory scanner, the limited implant abutment design and the single implant manufacturer analyzed, and the single clinical condition tested involving 6 dental implants in the maxillary arch. Additional in vitro and in vivo studies are suggested to assess the scanning accuracy of extraoral and intraoral PG systems for implant-supported prostheses.

CONCLUSIONS

Based on the results of the present in vitro study, the following conclusions were drawn:

1. The PG system influenced the trueness and precision of complete arch implant scans. The PIC and Icam4D systems demonstrated the best linear trueness, and the PIC revealed the best linear precision. Additionally, the Grammee system obtained the best angular trueness, and the PIC had the best angular precision.
2. The intraoral photogrammetry obtained accuracy values (linear and angular discrepancies) similar to those of 2 of the extraoral photogrammetry systems (Grammee and OxoFit) tested.

3. The mean linear discrepancies measured ranged from 17 to 30 μm and the mean angular discrepancies computed varied from 0.17 to 0.34 degrees among all the PG systems tested.

REFERENCES

1. Gómez-Polo M, Barmak AB, Ortega R, Rutkunas V, Kois JC, Revilla-León M. Accuracy, scanning time, and patient satisfaction of stereophotogrammetry systems for acquiring 3D dental implant positions: A systematic review. *J Prosthodont.* 2023;32:208–224.
2. Revilla-León M, Att W, Özcan M, Rubenstein J. Comparison of conventional, photogrammetry, and intraoral scanning accuracy of complete-arch implant impression procedures evaluated with a coordinate measuring machine. *J Prosthet Dent.* 2021;125:470–478.
3. Ma B, Yue X, Sun Y, Peng L, Geng W. Accuracy of photogrammetry, intraoral scanning, and conventional impression techniques for complete-arch implant rehabilitation: An in vitro comparative study. *BMC Oral Health.* 2021;21:636.
4. Revilla-León M, Rubenstein J, Methani MM, Piedra-Cascón W, Özcan M, Att W. Trueness and precision of complete-arch photogrammetry implant scanning assessed with a coordinate-measuring machine. *J Prosthet Dent.* 2023;129:160–165.
5. Tohme H, Lawand G, Chmielewska M, Makhzoume J. Comparison between stereophotogrammetric, digital, and conventional impression techniques in implant-supported fixed complete arch prostheses: An in vitro study. *J Prosthet Dent.* 2023;129:354–362.
6. Kosago P, Ungurawasaporn C, Kukiattrakoon B. Comparison of the accuracy between conventional and various digital implant impressions for an implant-supported mandibular complete arch-fixed prosthesis: An in vitro study. *J Prosthodont.* 2023;32:616–624.
7. Zhang YJ, Qian SJ, Lai HC, Shi JY. Accuracy of photogrammetric imaging versus conventional impressions for complete-arch implant-supported fixed dental prostheses: A comparative clinical study. *J Prosthet Dent.* 2023;130:212–218.
8. Sallorenzo A, Gómez-Polo M. Comparative study of the accuracy of an implant intraoral scanner and that of a conventional intraoral scanner for complete-arch fixed dental prostheses. *J Prosthet Dent.* 2022;128:1009–1016.
9. Arcuri L, Lio F, Campana V, et al. Influence of implant scanbody wear on the accuracy of digital impression for complete-arch: A randomized in vitro trial. *Materials ((Basel)).* 2022;15:927.
10. Shi X, Liu X, Liu S, Wang M, Liu F. Vertical deviation caused by tightening torque on implant scan body: An in vitro study. *Int J Prosthodont.* 2022;35:653–659.
11. Gómez-Polo M, Donmez MB, Çakmak G, Yilmaz B, Revilla-León M. Influence of implant scan body design (height, diameter, geometry, material, and retention system) on intraoral scanning accuracy: A systematic review. *J Prosthodont.* 2023;32:165–180.
12. International Organization for Standardization. ISO 12836:2015. Dentistry — Digitizing devices for CAD/CAM systems for indirect dental restorations — Test methods for assessing accuracy. ⟨https://www.iso.org/standard/68414.html⟩ Accessed 02–01-20.
13. International Organization for Standardization. ISO 5725–1:1994. Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions. ⟨https://www.iso.org/obp/ui/#iso:std:iso:5725:-1:ed-1:v1:en⟩ Accessed 02–01-20.
14. International Organization for Standardization. ISO 20896–1:2019. Dentistry — Digital impression devices — Part 1: Methods for assessing accuracy. ⟨https://www.iso.org/standard/69402.html⟩ Accessed 02–01-20.
15. Revilla-León M, Gómez-Polo M, Drone M, et al. Impact of scanning distance on the accuracy of a photogrammetry system. *J Dent.* 2024;142:104854.
16. Revilla-León M, Gómez-Polo M, Drone M, et al. Influence of implant reference on the scanning accuracy of complete arch implant scans captured by using a photogrammetry system. *J Prosthet Dent.* 2025;133:252–257.
17. Gómez-Polo M, Álvarez F, Ortega R, et al. Influence of the implant scan body bevel location, implant angulation and position on intraoral scanning accuracy: An in vitro study. *J Dent.* 2022;121:104122.

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