Received: 31 January 2023 | Revised: 30 May 2023 | Accepted: 31 May 2023
DOI: 10.1111/jerd.13070

RESEARCH ARTICLE

WILEY

Effect of different intraoral scanners and scanbody splinting on accuracy of scanning implant-supported full arch fixed prosthesis

Yasmine Ashraf BDS, MSc | Ahmad Abo El Fadl BDS, MSc, PhD | Amina Hamdy BDS, MSc, PhD | Kamal Ebeid BDS, MSc, Phd

Department of Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University, Cairo, Egypt

Correspondence
Kamal Ebeid, Faculty of Dentistry, Ain Shams University, Organization of African Unity Street, Heliopolis, Cairo, Egypt.
Email: kamal_ebeid@dent.asu.edu.eg

Abstract

Objective: This study evaluated the accuracy of different intraoral scanners (IOS) for scanning of implant-supported full arch fixed prosthesis with different implant angulations with and without scanbodies splinting.

Materials and Methods: Two maxillary models were designed and fabricated to receive an all-on-four implant retained. The models were divided into two groups according to the angulation of the posterior implant (Group 1; 30 and Group 2; 45). Each group was then divided into three subgroups according to the type of IOS used: Subgroup C; Primescan, subgroup T; Trios4, and subgroup M; Medit i600. Then each subgroup was divided into two divisions according to scanning technique; division S: splinted and division N: nonsplinted. Ten scans were made by each scanner for every division. Trueness and precision were analyzed using Geomagic controlX analysis software.

Results: Angulation had no significant effect on both the trueness ($p = 0.854$) and precision ($p = 0.347$). Splinting had a significant effect on trueness and precision ($p < 0.001$). Scanner type had a significant effect on trueness ($p < 0.001$) and precision ($p < 0.001$). There was no significant difference between trueness of Trios 4 (112.15 ± 12.85) and Primescan (106.75 ± 22.58). However, there was a significant difference when compared to trueness of Medit i600 (158.50 ± 27.65). For the precision results Cerec Primescan showed the highest precision (95.45 ± 33.21). There was a significant difference between the three scanners, precision of Trios4 (109.72 ± 19.24) and Medit i600 (121.21 ± 17.26).

Conclusion: Cerec Primescan has higher trueness and precision than Trios 4 and Medit i600 in full arch implants scanning. Splinting the scanbodies improve the accuracy of full arch implants scanning.

Clinical Significance: Cerec Primescan and 3Shape Trios 4 can be used for scanning of All-on-four implant supported prosthesis when scanbodies are splinted using a modular chain device.

KEYWORDS
all-on-4, dental implants, digital dentistry, fixed prosthodontics, implant scanbody

1 | INTRODUCTION

The “All-On-4” treatment modality was first introduced by Paulo Malo, using two straight and two angled multi-unit abutments to provide fully edentulous patients with an immediately loaded full arch restoration with the aid of only four implants.[1] This concept advocates for the placement of tilted distal implants in edentulous arches enabling the placement of longer implants which can improve anchorage in the bone resulting in an enhanced prosthetic support with a short cantilever arm.[2] The reported survival rates for the maxillary arch ranged from 93.9% to 100% after up to 13 years of follow-up and 91.7%–100% for the mandibular arch after up to 18 years of follow-up.[1,3]

Digital impressions can be acquired using intraoral scanners (IOS) directly from the patient's mouth[4,5] or by scanning the impressions or the gypsum casts using laboratory scanners.[6–8] Intraoral scanning was suggested as a substitute to the conventional impression to overcome its drawbacks and ensure patient satisfaction and comfort.[9–12] IOS have greatly developed since their first introduction in the 1980s.[13] Throughout the years, they have not only solidified their reputation in accurately scanning various preparation designs and tooth geometry,[14] but they have also established their reliability in shade determination.[15]

However, IOS presented errors in full arch scanning, due to their limited reference points and the absence of anatomic irregularities.[16,17] Moreover, three-dimensional visualization and mathematical interpretation of multiple scan bodies were indistinguishable by the IOS, which resulted in failure to obtain accurate digital impressions due to their identical geometry.[18,19] As the morphology of the area captured was mostly cylindrical, IOS interpreted the different scan bodies as only one.[20]

Numerous techniques to improve the accuracy of full arch scanning have been proposed in the literature [21]. First, studies suggested placing an artificial landmark over the edentulous area.[22] However, one limitation to this technique is the difficulty in fixing the landmark on soft tissue. Second, another technique is using a geometric device designed on a Computer-Aided Design (CAD) software, followed by 3D printing.[23,24] However, this technique provides an additional step which may impact timely completion of the workflow. Another technique is the connection of the implant scan bodies with the use of thermoplastic resin.[25] Finally, some studies suggested the alteration of the surface topography of the scanned bodies,[20] as well as the innovation of different shapes of devices that are cemented[26] or placed around the scan bodies.[27]

The term accuracy is defined as trueness and precision (ISO5725-1),[26,28,29] where trueness is determined by the conformity of the tested impression method against the original geometry, and precision is determined by the conformity of the tested impression within a test group.[30–32] IOS technologies,[33–37] the different scanning strategies,[38] calibration,[39] the surface characteristics and different substrate[40,41] and type and angulation of scanbody[42–45] all play an important role in determining the accuracy of digital impressions.

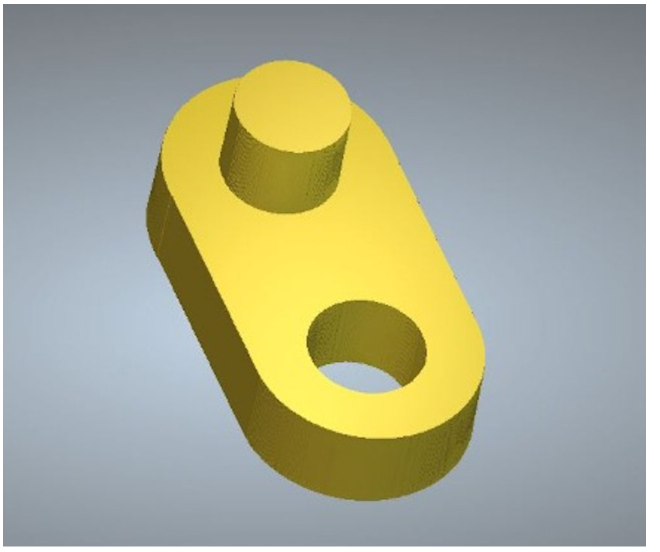

FIGURE 1 Design of 3D printed element in form of rectangle with dimensions of 15 mm × 5 mm having a knob on one side and a hole on the other side.

The purpose of this study was to assess the accuracy of digital impressions of four implants placed with two different distal implant angulations to restore full arch edentulous maxilla, scanned with three different intra-oral scanners utilizing an originally designed modular chain splinting device intended to avoid stitching difficulties and overlapping errors, while prioritizing the timely completion of workflow processes, on par with the recent shift in clinical practices.

The research hypotheses tested were that

1. There is a significant effect of the splinting using the modular chain device on the accuracy of the full arch scanning
2. There is a significant effect of the implant angulation on the accuracy of the full arch scanning.
3. There is a significant effect of the intraoral scanner type on the accuracy of the full arch scanning.

2 | MATERIALS AND METHODS

In this in-vitro study, two models were designed to receive all on four implant retained fixed dental prosthesis. These two models were divided into two groups according to posterior implant angulation (Group 1; 30° distal implant angulation, and group 2; 45° distal implant angulation). Each group was then divided into three subgroups according to the type of intraoral scanner used: subgroup C; Cerec Primescan (Densply Sirona, Bensheim, Germany), subgroup T; Trios 4 (3Shape, Copenhagen, Denmark), and subgroup M; Medit i600 (Medit, Seoul, Korea). Then each subgroup was divided into two divisions according to scanning technique; division S: splinted and division N: nonsplinted. Ten scans were made by each scanner for every division.

Implant planning for a maxillary fully edentulous arch was done using DDS pro software (Czestochowa, Poland). Virtual implant placement (Straumann NC bone level, Basel, Switzerland) was done using the software followed by digital attachment of the scan bodies. The files were then imported by Exocad software (Exocad GmbH, Darmstadt, Germany) to produce the models. The digital files were saved in stereolithography format (stl). The models were produced by three-dimensional (3D) printing technology using the printer Formlab form 3 (Boston, MA, USA) with 25-micron XY resolution and 250 mW laser power using a gray standard material.

Four scan bodies were inserted in each model (Cares NC mono-scanbody, Straumann, Basel, Switzerland) with diameter of 3.5 and 10 mm in height. Two anterior scan bodies were placed at the canines' positions with 0° horizontal angulation parallel to each other, and two scan bodies were placed in the posterior positions with 30° distal angulation in the first model and 45° in the second. Scan bodies were then screwed onto implant analogues (Straumann, Basel, Switzerland).

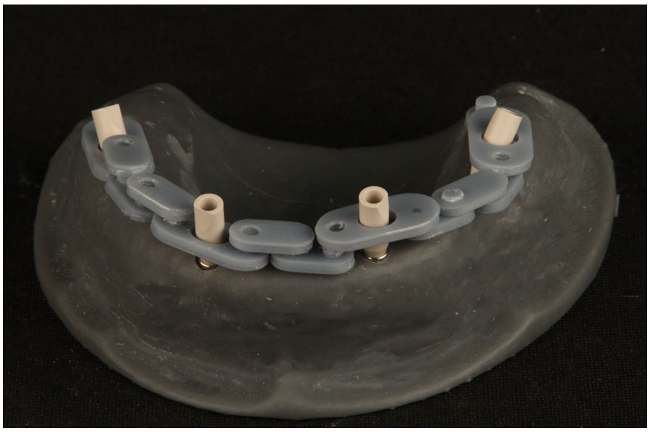

FIGURE 2 Printed model with scanbodies splinted using modular chain device.

The splinted scanning technique was achieved by fabricating two shapes of 3D printed elements using Accura resin (3DSystems, Rock Hill, SC, USA) in the form of rectangle with dimensions of 15 mm × 5 mm having a knob on one side and a hole on the other side (Figure 1). The other form of the element had a central hole to encircle the scanbody later. These elements were easy to be assembled to form a modular chain around the scanbodies having the same curvature of the edentulous ridge (Figure 2).

Intra oral scanning was done for all samples at 23 ± 1°C and 50 ± 5% relative humidity with the same experimented operator and in the same room, IOS calibration was performed after each division was scanned, as recommended by the manufacturer.

Data processing was done on cad software (Exocad GmbH) to align each scan body of the measured scan to the cad file of the library to allow for digital analogue matching, then accuracy measurement in terms of 3D surface discrepancies was performed after importing all data files to a reverse engineering software Geomagic control X (3D systems, NC, USA).

For trueness measurement, scans were superimposed to the reference stl file obtained from an industrial 3D scanner having structured blue light emitting diode (ATOS Core 200 5M, GOM GmbH, Braunschweig, Germany) Alignment was done using initial alignment then best fit alignment that uses an iterative closest point algorithm (ICP). 3D deviation along the scan bodies surfaces were only measured by resegmenting the reference file and merging only the assigned scan bodies. For the precision measurement, the scans of each division were superimposed on each other considering each scan as the reference stl. Trueness and precision were expressed in root mean square (RMS). When two scans were superimposed, the square of the phase difference between several points in 3-D space was

TABLE 1 Effect of scanner type on trueness and precision.

Measurement	Scanners	Mean ± SD (μm)	Mean difference (μm)	95% CI		*p* Value
				Lower	Upper	
Trueness	Cerec PrimeScan	106.75 ± 22.58	−5.40	−22.07	11.27	0.717
	3Shape Trios 4	112.15 ± 12.85				
	Cerec PrimeScan	106.75 ± 22.58	−51.75	−68.42	−35.08	<0.001*
	Medit i600	158.50 ± 27.65				
	3Shape Trios 4	112.15 ± 12.85	−46.35	−63.02	−29.68	<0.001*
	Medit i600	158.50 ± 27.65				
Precision	Cerec PrimeScan	95.45 ± 33.21	−14.27	−31.07	2.53	0.112
	3Shape Trios 4	109.72 ± 19.24				
	Cerec PrimeScan	95.45 ± 33.21	−25.76	−42.56	−8.96	0.002*
	Medit i600	121.21 ± 17.26				
	3Shape Trios 4	109.72 ± 19.24	−11.49	−28.29	5.31	0.237
	Medit i600	121.21 ± 17.26				

Abbreviations: 95% CI, 95% confidence interval for mean difference; SD, standard deviation.
*Significant ($p < 0.05$).

TABLE 2 Effect of splinting on trueness and precision.

Measurement	Splinting	Mean ± SD (μm)	Mean difference (μm)	95% CI Lower	95% CI Upper	*p* Value
Trueness	With GD	109.60 ± 22.28	−32.40	−46.63	−18.17	<0.001*
	Without GD	142.00 ± 31.94				
Precision	With GD	95.31 ± 25.15	−26.96	−37.57	−16.35	<0.001*
	Without GD	122.27 ± 19.64				

Abbreviations: 95% CI, 95% confidence interval for mean difference; SD, standard deviation.
*Significant (p < 0.05).

TABLE 3 Effect of angulation on trueness and precision.

Measurement	Angle	Mean ± SD (μm)	Mean difference (μm)	95% CI Lower	95% CI Upper	*p* Value
Trueness	30°	126.57 ± 33.92	1.53	−15.05	18.11	0.854
	45°	125.03 ± 30.12				
Precision	30°	111.72 ± 21.99	5.86	−6.47	18.18	0.347
	45°	105.86 ± 29.85				

Abbreviations: 95% CI, 95% confidence interval for mean difference; SD, standard deviation.

calculated (x-, y-, and z-axis). The sum of these squares was divided by the number of points, and RMS was calculated as the square root of this value.

Numerical data was represented as mean with 95% confidence interval and standard deviation (SD) values. Shapiro–Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity and were analyzed using three-way ANOVA followed by Tukey's post hoc test. The significance level was set at $p < 0.05$ within all tests. Statistical analysis was performed with SPSS software (SPSS v20, Chicago, IL).

3 | RESULTS

Regarding trueness, results of three-way ANOVA showed that both the type of scanner and splinting had a significant effect ($p < 0.001$), while the effect of implant angulation as well as different interactions were not statistically significant ($p > 0.05$). For scanner type, post hoc pairwise comparisons revealed no significant differences between Cerec Primescan (106.75 ± 22.58) and 3Shape Trios 4 (112.15 ± 12.85) ($p = 0.717$). However, both scanners showed significantly better trueness when compared to medit i600 (158.50 ± 27.65) ($p < 0.001$). As for splinting with geometric device, significantly better trueness was observed for splinted scans (109.60 ± 22.28) compared to nonsplinted scans (142.00 ± 31.94) ($p < 0.001$) (Tables 1–3).

Regarding precision, results of three-way ANOVA also showed scanner type and splinting to have a significant effect ($p < 0.001$), with the effects of implant angulation as well as different interactions' combinations to be not statistically significant ($p > 0.05$). Post hoc pairwise comparisons showed Cerec PrimeScan (95.45 ± 33.21) to have significantly better precision in comparison to medit i600 (121.21 ± 17.26) ($p = 0.002$), while they showed 3Shape Trios 4 (109.72 ± 19.24) scans to be not statistically different from those made with other scanners ($p > 0.05$). As for splinting with geometric device, significantly better precision was observed for splinted scans (95.31 ± 25.15) compared to nonsplinted scans (122.27 ± 19.64) ($p < 0.001$) (Tables 1–3).

4 | DISCUSSION

This study evaluated the effect of splinting, implant angulation, and type of IOS on the accuracy described in terms of trueness and precision of three IOS when scanning full arch maxilla restored with four implants under in-vitro conditions.

According to the results of this study, splinting of scan bodies improved the accuracy of IOS while the angulation did not seem to affect the accuracy of IOS. Moreover, the type of scanner affected the accuracy of scan obtained. Therefore, the first hypothesis was accepted, the second hypothesis was rejected as the difference in angulation showed insignificant results in terms of trueness and precision and the third hypothesis was accepted.

Intraoral scanning is a revolutionary innovation in dentistry. With the evolution of CAD/CAM technologies, a full digital workflow without the need of physical casts was claimed as an alternative solution of the conventional implant impression even though a lack of accuracy for complete-arch implant impression was reported.[11,12,33]

Inherent flaws may occur in the IOS software when processing the data during stitching of consecutive scanned frames.[25] In the current study, the models used resemble what actually occurs in the clinical environment regarding the number of implants and inter implant distances and angulation in order to produce IOS challenging scenario.[46] Optical scanning of homogenous soft tissues and implant surfaces without geometric variation results in a lot of scanning errors.[16,25]

Accuracy can be described in terms of both trueness and precision combined.[28,38] Trueness is defined as the proximity of agreement between a tested result and the true value while precision is defined as the proximity of agreement between measured quantity values obtained from multiple measurements of the same object under the same conditions. A high trueness indicates how close the scanned image to the actual image, while high precision indicates the predictability of the scan.[32,41]

Accuracy can be calculated when two scans are superimposed on each other using a reverse engineering software[20,26] by general arithmetic mean,[29] positive or negative deviations, absolute values[37] and root mean square.[6,14,29] In this study, RMS values were adopted because this may be a more reliable value because each data point is represented by both positive and negative values.[8] In the quantitative inspections if positive and negative values had equal distribution, the sum of these values will be close to zero.[37]

The results of the current study came in agreement with Iturrate et al.[23] whom reported an increase in accuracy of fully edentulous maxillary models impressions with four parallel pars simulating the intraoral scanbodies scanned with the aid of a bonded auxiliary geometry part (AGP). However, such technique requires an added step of impression for the fabrication of the AGP, also the difficulties in inserting such device in the presence of angulated implants.

Also the results were coinciding with Pozzi et al.,[26] whom concluded that complete-arch implant digital impression with splinted scan bodies showed an improvement in the overall accuracy. However, in this technique, although the splint was easily assembled, it needed flowable composite fixation which may result in a more complex procedure.

On the contrary, this was not in agreement with Mizumoto et al.,[21] whom evaluated the accuracy of different splinting techniques, and concluded that scan bodies splinting using floss led to significantly more distance deviation, this may be attributed to the difference in splinting techniques.

The result of the current study indicates a nonsignificant effect of angulation of the distal implant on the trueness and precision of the optical scan obtained from the full arch implant scanning. This was in agreement with Gimenez et al.,[45] whom conducted a study to evaluate the accuracy of implant impression with consideration of implant angulation and concluded that implant angulations do not have an effect on the final accuracy of the scan. Also, our results came in agreement with Alikhasi et al.[44] and Gonzalez et al.[36] whom also reported that accuracy was not affected by the implants angulation.

In contrast, the results were not in agreement with Ebeid et al.[7] study whom assessed the accuracy of five laboratory desktop scanners for scanning of implant-supported full arch fixed prosthesis, and reported that implant angle had a significant effect on the trueness, this can be attributed to the difference in scanners technologies between intraoral and extraoral scanners.

The third hypothesis was accepted, Cerec Primescan showed the least RMS in terms of trueness and precision, followed by Trios 4 then the Medit i600 which had the least trueness and precision. This can be attributed to the difference in the scanner image capturing technology in which Cerec Primescan and Trios 4 adapt parallel confocal microscopy capturing method while Medit i600 adapt active triangulation image capturing method. This was consistent with Revell et al.[4] whom reported also better trueness for the Cerec Primescan, Trios 4, and Trios 3 than Medit i500 in scanning complete full arch implants in an edentulous maxilla. Our results were also in agreement with Di Fiore et al.,[47] whom also reported better trueness for scanners adapting parallel confocal technology than scanners adapting active triangulation technology.

Although the results of this study can be promising and the scanners used in the study are the most recent, In vitro model cannot accurately simulate hard and soft-tissue interaction, thus the clinical reality may prove to be more challenging than conditions present in this study particularly during assembling the chain and for assessing its position when the arch is facing downwards.

5 | CONCLUSIONS

Within the limitation of this study, it was concluded that:

- The increase of distal angulation of posterior implant in full arch cases does not affect the scan accuracy.
- Splinting of implant scanbodies using the tested modular chain device influenced positively the accuracy of full arch intra-oral scanning.
- Cerec Primescan shows the highest trueness and precision among the tested scanners.

ACKNOWLEDGMENTS

The authors would like to thank the staff at the Center of innovative dental sciences (CIDS), Faculty of Dentistry, British University in Egypt.

CONFLICT OF INTEREST STATEMENT

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

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

1. Peñarrocha-Diago MA, Maestre-Ferrín L, Demarchi CL, Peñarrocha-Oltra D, Peñarrocha-Diago M. Immediate versus nonimmediate placement of implants for full-arch fixed restorations: a preliminary study. *J Oral Maxillofac Surg*. 2011;69:154-159.

2. Taruna M. Prosthodontic perspective to all-On-4® concept for dental implants. *J Clin Diagnostic Res*. 2014;8:16–19.
3. Korsch M, Walther W, Hannig M, Bartols A. Evaluation of the surgical and prosthetic success of all-on-4 restorations: a retrospective cohort study of provisional vs. definitive immediate restorations. *Int J Implant Dent*. 2021;7:48.
4. Revell G, Simon B, Mennito A, et al. Evaluation of complete-arch implant scanning with 5 different intraoral scanners in terms of trueness and operator experience. *J Prosthet Dent*. 2021;128:632-638.
5. Di Fiore A, Meneghello R, Graiff L, Savio G, et al. Full arch digital scanning systems performances for implant-supported fixed dental prostheses: a comparative study of 8 intraoral scanners. *J Prosthodont Res*. 2019;63:396-403.
6. Jeon JH, Hwang SS, Kim JH, Kim WC. Trueness and precision of scanning abutment impressions and stone models according to dental CAD/CAM evaluation standards. *J Adv Prosthodont*. 2018;10:10.
7. Ebeid K, Nouh I, Ashraf Y, Cesar PF. Accuracy of different laboratory scanners for scanning of implant-supported full arch fixed prosthesis. *J Esthet Restor Dent*. 2022;34:843-848.
8. Güth J-F, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. *Clin Oral Investig*. 2013;17:1201-1208.
9. Waldecker M, Rues S, Rammelsberg P, Bömicke W. Accuracy of complete-arch intraoral scans based on confocal microscopy versus optical triangulation: a comparative in vitro study. *J Prosthet Dent*. 2021;126:126-420.
10. Arcuri L, Pozzi A, Lio F, Rompen E, Zechner W, Nardi A. Influence of implant scanbody material, position and operator on the accuracy of digital impression for complete-arch: a randomized in vitro trial. *J Prosthodont Res*. 2020;64:128-136.
11. Joda T, Brägger U. Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial. *Clin Oral Implants Res*. 2016;27:e185-e189.
12. Wismeijer D, Joda T, Flügge T, et al. Group 5 ITI consensus report: digital technologies. *Clin Oral Implants Res*. 2018;29:436-442.
13. Natsubori R, Fukazawa S, Chiba T, Tanabe N, Kihara H, Kondo H. In vitro comparative analysis of scanning accuracy of intraoral and laboratory scanners in measuring the distance between multiple implants. *Int J Implant Dent*. 2022;8:18.
14. Ashraf Y, Sabet A, Hamdy A, Ebeid K. Influence of preparation type and tooth geometry on the accuracy of different intraoral scanners. *J Prosthodont*. 2020;29:800-804.
15. Ebeid K, Sabet A, El Sergany O, Della BA. Accuracy and repeatability of different intraoral instruments on shade determination compared to visual shade selection. *J Esthet Restor Dent*. 2022;34:988-993.
16. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. *BMC Oral Health*. 2017;17:17.
17. Digitizing implant position locators on master casts: comparison of a noncontact scanner and a contact-probe scanner. *J Prosthet Dent*. 2013;109:52.
18. Schmidt A, Billig J-W, Schlenz M, Wöstmann B. The influence of using different types of scan bodies on the transfer accuracy of implant position: an in vitro study. *Int J Prosthodont*. 2021;34:34-260.
19. Andriessen FS, Rijkens DR, Van Der Meer WJ, Wismeijer DW. Applicability and accuracy of an intraoral scanner for scanning multiple implants in edentulous mandibles: a pilot study. *J Prosthet Dent*. 2014;111:111-194.
20. Lawand G, Ismail Y, Revilla-león M, Tohme H. Effect of implant scan body geometric modifications on the trueness and scanning time of complete arch intraoral implant digital scans: an in vitro study. *J Prosthet Dent*. 2022.
21. Mizumoto RM, Yilmaz B, McGlumphy EA, Seidt J, et al. Accuracy of different digital scanning techniques and scan bodies for complete-arch implant-supported prostheses. *J Prosthet Dent*. 2020;123:96-104.
22. Kim JE, Amelya A, Shin Y, Shim JS. Accuracy of intraoral digital impressions using an artificial landmark. *J Prosthet Dent*. 2017;117:755-761.
23. Iturrate M, Eguiraun H, Etxaniz O, Solaberrieta E. Accuracy analysis of complete-arch digital scans in edentulous arches when using an auxiliary geometric device. *J Prosthet Dent*. 2019;121:447-454.
24. Masu R, Tanaka S, Sanda M, Miyoshi K, Baba K. Effect of assistive devices on the precision of digital impressions for implants placed in edentulous maxilla: an in vitro study. *Int J Implant Dent*. 2021;7:7.
25. Imburgia M, Kois J, Marino E, Lerner H, et al. Continuous scan strategy (CSS): a novel technique to improve the accuracy of intraoral digital impressions. *Eur J Prosthodont Restor Dent*. 2020;28:128–141.
26. Pozzi A, Arcuri L, Lio F, Papa A, Nardi A, Londono J. Accuracy of complete-arch digital implant impression with or without scanbody splinting: an in vitro study. *J Dent*. 2022;119:104072.
27. García-Martínez I, Zarauz C, Morejón B, Ferreiroa A, Pradíes G. Influence of customized over-scan body rings on the intraoral scanning effectiveness of a multiple implant edentulous mandibular model. *J Dent*. 2022;122:104095.
28. Mangano FG, Veronesi G, Hauschild U, Mijiritsk E, et al. Trueness and precision of four intraoral scanners in oral implantology: a comparative in vitro study. *PLoS One*. 2016;11:e0163107.
29. Jeong I-D, Kim W-C, Park J, Kim C-M, Kim JH. Ceramic molar crown reproducibility by digital workflow manufacturing: an in vitro study. *J Adv Prosthodont*. 2017;9:252-256.
30. Flügge T, van der Meer WJ, Gonzalez BG, Vach K, et al. The accuracy of different dental impression techniques for implant-supported dental prostheses: a systematic review and meta-analysis. *Clin Oral Implants Res*. 2018;29:374-392.
31. Hayama H, Fueki K, Wadachi J, Wakabayashi N. Trueness and precision of digital impressions obtained using an intraoral scanner with different head size in the partially edentulous mandible. *J Prosthodont Res*. 2018;62:62-352.
32. Emir F, Ayyıldız S. Evaluation of the trueness and precision of eight extraoral laboratory scanners with a complete-arch model: a three-dimensional analysis. *J Prosthodont Res*. 2019;63:434-439.
33. Diker B, Tak Ö. Accuracy of six intraoral scanners for scanning complete-arch and 4-unit fixed partial dentures: an in vitro study. *J Prosthet Dent*. 2022;128:187-194.
34. Kim RJY, Benic GI, Park JM. Trueness of ten intraoral scanners in determining the positions of simulated implant scan bodies. *Sci Rep*. 2021;11:11.
35. Albayrak B, Sukotjo C, Wee AG, Korkmaz İH, Bayındır F. Three-dimensional accuracy of conventional versus digital complete arch implant impressions. *J Prosthodont*. 2021;30:163-170.
36. Gimenez-Gonzalez B, Hassan B, Özcan M, Pradíes G. An in vitro study of factors influencing the performance of digital intraoral impressions operating on active wavefront sampling technology with multiple implants in the edentulous maxilla. *J Prosthodont*. 2017;26:650-655.
37. Patzelt SBM, Emmanouilidi A, Stampf S, Strub JR, Att W. Accuracy of full-arch scans using intraoral scanners. *Clin Oral Investig*. 2014;18:1687-1694.
38. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. *BMC Oral Health*. 2017;17:92.
39. Kim J, Park JM, Kim M, Heo SJ, Shin IH, Kim M. Comparison of experience curves between two 3-dimensional intraoral scanners. *J Prosthet Dent*. 2016;116:221-230.
40. Carbajal Mejía JB, Wakabayashi K, Nakamura T, Yatani H. Influence of abutment tooth geometry on the accuracy of conventional and digital methods of obtaining dental impressions. *J Prosthet Dent*. 2017;118:392-399.

41. Dutton E, Ludlow M, Mennito A, et al. The effect different substrates have on the trueness and precision of eight different intraoral scanners. *J Esthet Restor Dent*. 2020;32:204-218.
42. Çakmak G, Yilmaz H, Treviño Santos A, Kökat AM, Yilmaz B. Effect of scanner type and scan body location on the accuracy of mandibular complete-arch digital implant scans: an in vitro study. *J Prosthodont*. 2022;31:419-426.
43. Tomita Y, Uechi J, Konno M, Sasamoto S, et al. Accuracy of digital models generated by conventional impression/plaster-model methods and intraoral scanning. *Dent Mater J*. 2018;37:628-633.
44. Alikhasi M, Siadat H, Nasirpour A, Hasanzade M. Three-dimensional accuracy of digital impression versus conventional method: effect of implant angulation and connection type. *Int J Dent*. 2018;4:2018.
45. Giménez B, Özcan M, Martínez-Rus F, Pradíes G. Accuracy of a digital impression system based on parallel confocal laser technology for implants with consideration of operator experience and implant angulation and depth. *Int J Oral Maxillofac Implants*. 2014;29:853-862.
46. Mangano F, Mangano C, Margiani B, Admakin O, et al. Combining intraoral and face scans for the design and fabrication of computer-assisted design/computer-assisted manufacturing (CAD/CAM) polyether-ether-ketone (PEEK) implant-supported bars for maxillary overdentures. *Scanning*. 2019;2019:1-14.
47. Di A, Meneghello R, Graiff L, Savio G, et al. Full arch digital scanning systems performances for implant-supported fixed dental prostheses: a comparative study of 8 intraoral scanners. *J Prosthodont Res*. 2019;63:2-9.

How to cite this article: Ashraf Y, Abo El Fadl A, Hamdy A, Ebeid K. Effect of different intraoral scanners and scanbody splinting on accuracy of scanning implant-supported full arch fixed prosthesis. *J Esthet Restor Dent*. 2023;35(8):1257-1263. doi:10.1111/jerd.13070