

RESEARCH AND EDUCATION

## Accuracy of surgical guides from 2 different desktop 3D printers for computed tomography-guided surgery



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The use of computed tomography (CT)-guided surgery for the installation of dental implants involves cone beam computed tomography (CBCT), intraoral digital scan, planning, design, and fabrication of the surgical guide. In each step of the workflow and in the surgical procedure, errors may influence the overall accuracy.<sup>1-8</sup> Such errors can be the alignment of CBCT and the acquired digital scan, errors during CBCT image acquisition, inexact tolerance, or imprecise mounting of the guide sleeve.<sup>1,9,10</sup> Furthermore, the level of accuracy is affected by the intraoral support of the surgical guide with respect to bone, mucosa, or teeth. The surgical workflow (fully guided, pilot guide, freehand dental implant placement) and single or multiple dental implant surgical guides will affect accuracy.<sup>2,11-15</sup> As the accuracy of the treatment protocol is essential to prevent damage to surrounding structures, each step in the process needs to be carefully executed.<sup>12</sup> Regarding the fabrication of the surgical guide, one can distinguish between 2 fabrication methods: additive manufacturing and the use of mechanical positioning devices.<sup>16</sup>

### ABSTRACT

**Statement of problem.** Different factors influence the degree of deviation in dental implant position after computed tomography-guided surgery. The surgical guide-manufacturing process with desktop 3D printers is such a factor, but its accuracy has not been fully evaluated.

**Purpose.** The purpose of this in vitro study was to evaluate the deviation in final dental implant position after the use of surgical guides fabricated from 2 different desktop 3D printers using a digital workflow.

**Material and methods.** Twenty 3D-printed resin models were prepared with missing maxillary premolar. After preoperative planning, 10 surgical guides were produced with a stereolithography printer and 10 with a digital light-processing (DLP) printer. A guided surgery was performed; 20 dental implants (3.8×12 mm) were installed, and a digital scan of the dental implants was made. Deviations between the planned and final position of the dental implants were evaluated for both the groups.

**Results.** A statistically significant difference between stereolithography and DLP were found for deviation at entry point ( $P=.023$ ) and the vertical implant position ( $P=.009$ ). Overall lower deviations were found for the guides from the DLP printer, with the exception of deviation in horizontal implant position.

**Conclusions.** The tested desktop 3D printers were able to produce surgical guides with similar deviations with regard to the final dental implant position, but the DLP printer proved more accurate concerning deviations at entry point and vertical implant position. (*J Prosthet Dent* 2019;121:498-503)

With a trend toward the greater use of digital technology in implant dentistry<sup>17</sup> and the increased range of desktop 3D printers and scanners for intraoral use, accuracy must be properly defined. Accuracy consists of trueness and precision as defined in ISO 5725-1.<sup>18</sup> Trueness describes how measurements deviate from the actual object measured, and precision describes how close a series of measurements of the same object are to each other. For CT-guided surgery, accuracy is also

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## Clinical Implications

Digital techniques can be used for postoperative verification of computed tomography–guided surgeries. With careful control of the manufacturing process, desktop 3D printers are a suitable option for fabricating surgical guides.

defined as the deviation between the dental implant position in the planning and postoperative position.<sup>10</sup>

Along with the increased methods of surgical guide manufacturing, evaluating the accuracy of the procedures is important. A recent study evaluating the accuracy of 3D-printed surgical guides produced with a desktop 3D printer concluded that producing surgical guides of high quality was possible.<sup>19</sup> However, different desktop 3D printers and surgical guide materials may affect the overall accuracy of the procedure and may need to be further investigated. Both stereolithography (SLA) and digital light processing (DLP) are used in dentistry. SLA printers create shapes layer by layer using ultraviolet laser light to solidify a liquid photopolymerizing resin, an additive manufacturing process. The DLP printer operates in a similar way, except that it uses projector technology for photopolymerization and has significantly faster print times. However, the resolution may be reduced, depending on the quality of the projector and the material used.

The accuracy of guided surgery is frequently defined as the deviation between the position of the dental implant postoperatively and the planned position. A common procedure for this involves a postoperative CBCT examination of the patient.<sup>4</sup> The use of digital scans and dental implant scan bodies has been evaluated and demonstrated to be a valid alternative to conventional impressions and in registering the dental implant position.<sup>20–28</sup> A mean trueness of  $50.2 \pm 2.5 \mu\text{m}$  and a mean precision of  $24.5 \pm 3.7 \mu\text{m}$  for the TRIOS 3 (3Shape) scanner for digital scans of a partially edentulous maxilla have been reported.<sup>21</sup> Using digital scans to acquire the final implant position may eliminate the need for a postoperative CBCT examination.<sup>29</sup> This method has been recommended for the evaluation of guided surgery.<sup>30</sup>

The purpose of this in vitro study was to evaluate the degree of deviation in the final dental implant position after the use of surgical guides fabricated from 2 different desktop 3D printers using a digital workflow. The null hypothesis was that no difference would be found in the 2 groups with different surgical guides.

## MATERIAL AND METHODS

A digital scan (TRIOS 3; 3Shape) of a maxillary typodont was used to create a 3D model. The model was then digitally manipulated in a 3D sculpting–based computer-

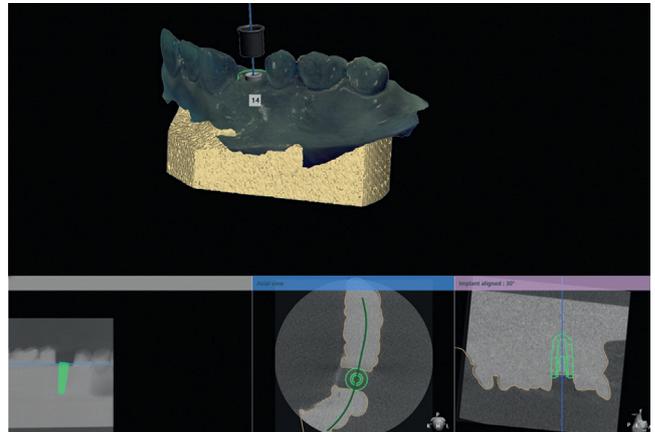
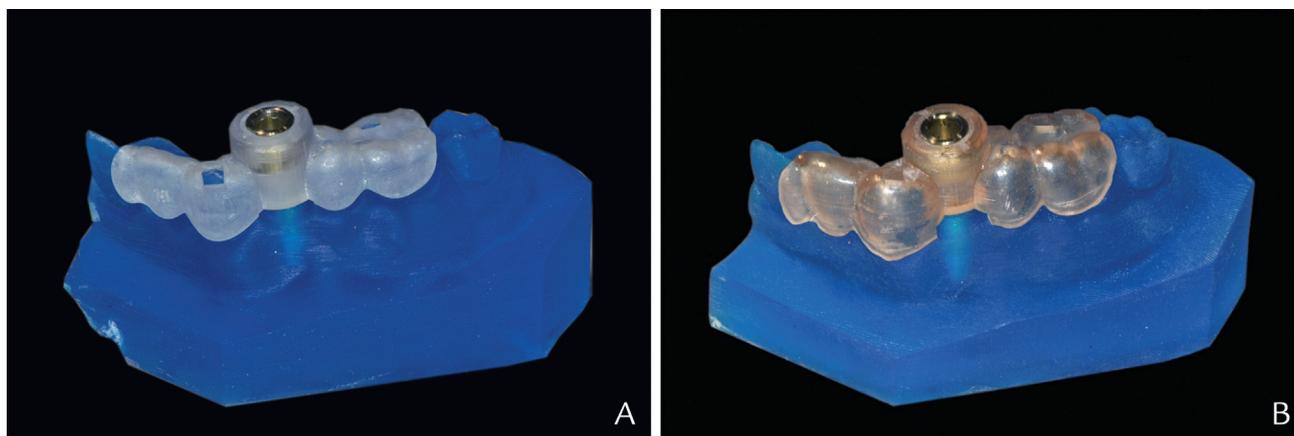


Figure 1. Guided surgery planning.

assisted design (CAD) software program (Meshmixer 3.2; Autodesk) as follows: the first premolar on the left side was removed, and the space was flattened and cropped to a half dental arch. Using an SLA printer (Form 2; Formlabs) 20 surgical models were fabricated (Tough Resin V4; Formlabs). The models were numbered 1 through 20 and divided into 2 groups, namely SLA and DLP. Each model was digitally scanned (TRIOS 3; 3Shape) and radiographed with a CBCT machine (ProMax 3D; Planmeca). All CBCTs were performed with the same characteristics: voxel size of 0.2 mm, exposure factors were 60 kV and 8.0 mA; and exposure time was 4.065 seconds. A series of axially sliced image data were obtained and exported to digital imaging and communications in medicine (DICOM) format and numbered according to corresponding model. Digital scans and DICOM files were imported into a CT-guided surgery software program (Implant Studio; 3Shape) for planning and surgery guide design.

For each situation, a dental implant (Tapered Internal; BioHorizons), 12 mm in length and 3.8 mm in diameter, was selected, resulting in the same drilling protocol. In the guided surgery software, the dental implants were virtually positioned 1 mm above the model surface as seen in Figure 1. In the DLP group, 10 surgical guides were fabricated from a photopolymer resin (E-Guide; EnvisionTEC) using a DLP printer (Vida; EnvisionTEC) as seen in Figure 2A. Guide thickness was 1.4 mm, offset from teeth to guide was 0.02 mm, and offset from sleeve to guide was 0.01 mm, according to manufacturing recommendations. In the SLA group, 10 surgical guides were fabricated from a different photopolymer resin (Dental SG Resin; Formlabs) using an SLA printer (Form 2; Formlabs) as seen in Figure 2B. Guide thickness was 2 mm, offset from teeth to guide was 0.06 mm, and offset from sleeve to guide was 0.05 mm, according to manufacturing recommendations. The surgical guides were positioned, printed, and then processed according



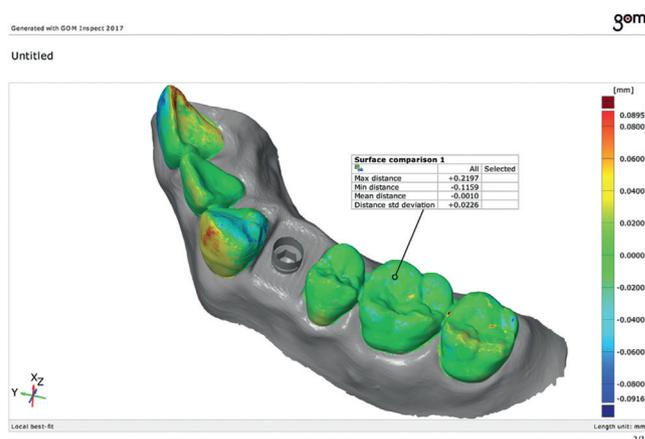
**Figure 2.** A, Surgical guide DLP (Vida 3D printer and E-guide material). B, Surgery guide SLA (Form two 3D printer and Dental SG Resin material). DLP, digital light processing; SLA, stereolithography.

to the manufacturers' guidelines. Master cylinder sleeves (Master Sleeve; BioHorizons) were then incorporated into the surgical guides. The two 3D printers were calibrated before guide fabrication.

A visual inspection was performed to evaluate the correct seating of the surgical guides on their respective surgical model. All 20 dental implants were installed using a guided surgery kit (BioHorizons) by 1 operator (B.G.), following the drill protocol and the implant manufacturer's instruction for fully guided surgery. The implant driver and a torque wrench (BioHorizons) were used to reach the indicated stop position and adjust the implant hexagon to correspond with the indication marking on the surgical guide.

After implant placement, scan bodies (PEEK Scan Abutments; BioHorizons) were attached onto each dental implant, and the models were digitally scanned (TRIOS 3; 3Shape). The digital scans and the guided surgery planning were separately imported into a dental design software program (Dental Designer; 3Shape), from which standard tessellation language data sets were exported with incorporated geometric dental implant structures. Corresponding data sets of the planned and final dental implant position were then imported into a 3D data measurement analysis software program (GOM Inspect 2017, build 2017-09-14; GOM Metrology). To make the superimposition more precise, irrelevant areas beyond the field of interest were not selected for alignment after the primary alignment between the data sets.

Alignments were performed using a best-fit algorithm based on the selected surfaces of the neighboring teeth.<sup>23</sup> Color-coded deviation maps were generated to show the difference between 2 aligned data sets as seen in Figure 3, in addition to the mean deviation. To identify the central entry point and apex of the dental implant, fitting elements were applied to key geometric surfaces of the dental implant using the Gaussian best-fit approach. The following parameters were calculated: deviation at

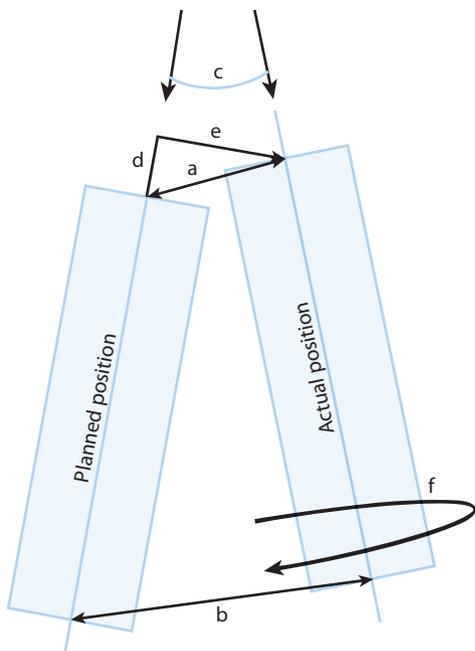


**Figure 3.** Alignment of data sets, color-coded deviations maps, and mean deviation.

entry point, measured at the center of the implant (in mm); deviation at apex, measured at the center of the implant apex (in mm); angular deviation (in degrees); deviation in vertical implant position, measured at the center of the implant (in mm); deviation in horizontal implant position, measured at the center of the implant (in mm); and rotational deviation of the implant hexagon (in degrees).<sup>2</sup> The parameters are illustrated in Figure 4. The software calculated the distance between the measuring points on the x, y, and z axes and the Euclidian distance ( $d_{xyz}$ ) (Fig. 5) using the following equation:

$$d_{xyz} = \sqrt{(x_{ref} - x_{test})^2 + (y_{ref} - y_{test})^2 + (z_{ref} - z_{test})^2}.$$

Statistical analysis was performed using a statistical software program (IBM SPSS Statistics, v22; IBM Corp). The data were tabulated, and from these measurements, median, mean, minimum, maximum, and standard deviations (SDs) were calculated. The



**Figure 4.** Deviation measurements: Deviation at entry point (a); deviation at apex (b); angular deviation (c); deviation in vertical implant position (d); deviation in horizontal implant position (e); rotational deviation of implant hexagon (f).

Mann-Whitney *U* test was used to analyze the 2 independent groups ( $\alpha=.05$ ).

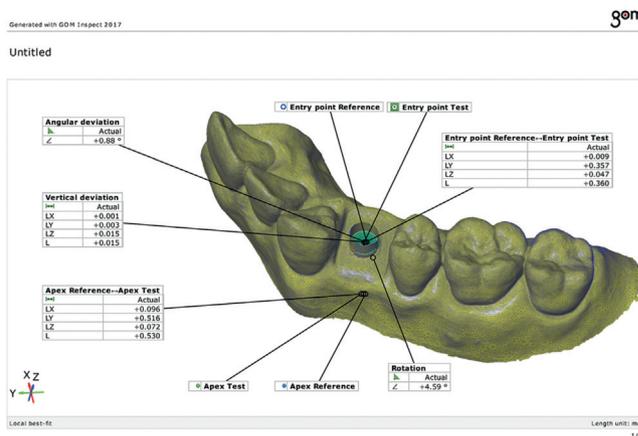
**RESULTS**

A total of 20 dental implants were placed with no unexpected occurrences during surgical guide fabrication or fixture installation. The mean  $\pm$ SDs for the deviation between the points used for the best-fit alignment of the 2 data sets were  $18.8 \pm 4.0 \mu\text{m}$  for DLP and  $18.9 \pm 4.3 \mu\text{m}$  for SLA ( $P=.739$ ). In the DLP group, the lowest mean deviation was found for vertical implant position ( $0.16 \pm 0.11 \text{ mm}$ ) and for the SLA group in horizontal implant position ( $0.16 \pm 0.11 \text{ mm}$ ). The SLA group had the highest mean deviation at the apex ( $0.49 \pm 0.17 \text{ mm}$ ). For the DLP group, the deviation at the apex was  $0.34 \pm 0.14 \text{ mm}$ . Statistically significant differences were found for deviation at the entry point ( $P=.023$ ) and for vertical implant position ( $P=.009$ ). A summary of the statistical analysis for deviations in dental implant position between the DLP and SLA groups is presented in Table 1.

**DISCUSSION**

The null hypothesis was partially rejected because significant differences were found in the final dental implant position between the guides fabricated from the 2 tested desktop 3D printers.

A digital scan of a dental implant with an intraoral scan body is commonly used in the fabrication of



**Figure 5.** Inspection variables software output.

implant-supported crowns and has been investigated.<sup>22,24,25</sup> This procedure, in conjunction with data from the guided surgery software, can be used to extract data sets with the intended and postoperative dental implant positions. Cristache and Gurbanescu<sup>29</sup> used a similar method to compare the data sets from the surgical planning with post insertion digital scan data sets. In the past, a second CBCT examination of the patient was necessary to identify the postoperative implant position, exposing the patient to additional radiation. Use of intraoral scan bodies reduces radiographic exposure and is in accordance with recommendations of a recent systematic review.<sup>30</sup>

No significant difference in deviation was found between the 2 groups for the alignment of planned and final data sets. Best-fit alignment has been commonly used to align data sets and can be used in studies to evaluate the accuracy of digital scans. Ender et al<sup>26</sup> reported on the precision of repeated quadrant dental arch silicone impressions ( $18.8 \pm 7.1 \mu\text{m}$ ) and the TRIOS 3 (3Shape) scanner ( $26.1 \pm 3.8 \mu\text{m}$ ). Full-arch best-fit alignment might, however, generate systematic errors because of the deviation between 2 large data distances.<sup>20,27</sup> The precision and trueness of the intraoral scanner used in the present study have been evaluated.<sup>21,27,28</sup>

In the present study, the DLP and SLA groups presented a low degree of deviation between the planned and postoperative dental implant positions. The findings fall within the mean system error of 1.2 mm for the horizontal and 0.5 mm for the vertical direction established by the European Association for Osseointegration consensus in 2012.<sup>15</sup> For in vitro studies, lower deviations are to be expected, as reported in a recent systematic review with a mean horizontal coronal deviation of  $1.10 \pm 0.09 \text{ mm}$  for clinical studies and  $0.77 \pm 0.15 \text{ mm}$  for in vitro studies.<sup>3</sup> These results do not consider the number of dental implants or type of guide support.

**Table 1.** Deviation difference (Mann-Whitney *U* test)

Variable	DLP		SLA		U Value	P
	Median	Mean ±SD (min-max)	Median	Mean ±SD (min-max)		
Deviation at entry point (mm)	0.28	0.27 ±0.08 (0.15-0.36)	0.38	0.39 ±0.01 (0.21-0.63)	20	.023*
Deviation at apex (mm)	0.36	0.34 ±0.14 (0.10-0.53)	0.53	0.49 ±0.17 (0.23-0.77)	25	.063
Angular deviation (degrees)	0.86	0.99 ±0.57 (0.27-1.90)	1.29	1.25 ±0.49 (0.52-1.98)	35	.280
Deviation in vertical implant position (mm)	0.12	0.16 ±0.11 (0.02-0.33)	0.34	0.34 ±0.18 (0.09-0.58)	16	.009*
Deviation in horizontal implant position (mm)	0.16	0.17 ±0.09 (0.07-0.36)	0.16	0.16 ±0.11 (0.02-0.33)	48	.912
Rotational deviation (degrees)	3.06	3.66 ±1.89 (0.98-7.64)	3.66	4.68 ±4.14 (0.53-14.59)	50	1.000

DLP, digital light processing; SD, standard deviation; SLA, stereolithography. For vertical deviation, positive values represent more coronal position of implant. \*Statistically significant,  $P < .05$ .

Lower deviations are to be expected for single dental implants tooth-supported guides,<sup>13</sup> but a variation in deviation does occur.<sup>4-8</sup> In the present study, the deviations could in part be explained by the tolerance between the guide tools, length of dental implant, and distance between guide sleeve and implant site.<sup>10</sup> The high SD for rotational deviation, indicating data with a wide spread, was to be expected as the hexagon position was visually aligned during installation. Further improvement of guided surgery tools may help reduce such deviations.

A statistically significant difference was found between the DLP and SLA for deviation at the entry point ( $P=.023$ ) and in vertical implant position ( $P=.009$ ), with a lower mean deviation in the DLP group. However, for all deviations values, with the exception of horizontal deviation, the mean results favored the DLP group. An explanation for the statistically significant differences could be that the larger offset values needed for the master cylinder sleeve and between guide and teeth for the SLA printer used could have influenced the mounting of the sleeve and the seating of the surgery guide on the model. Also, the surgery guides from the SLA printer needed to undergo a longer postpolymerization process than the DLP guides because of a lower degree of photopolymerization during 3D printing. Handling during the postpolymerization process may have caused minor distortions leading to improper seating of the guide. Factors related to the manufacturing of surgical guides including incorporation of the master sleeve, 3D printer resolution, surface finish of the material, machine reproducibility, offset values, postprocessing, and calibration of a 3D printer can affect the definitive implant position. Further research is recommended before any conclusions can be drawn. With the increased accessibility of desktop 3D printers and the possibility for more in-office production of surgical guides, validation of the workflow is important. The use of a digital scan to confirm the postoperative dental implant position as described in the present and another study<sup>29</sup> could easily be incorporated into guided surgery software and would greatly help in the quality control of the procedure. The authors are unaware of any CT-guided surgery software that has implemented this feature.

Clinical accuracy may be affected by different variables. This study did not account for saliva, soft tissue, patient movement, or humidity in the oral environment. Also, the material used for the surgical models does not have the same physical properties as bone, enamel, and soft tissue, meaning that seating of the guide and implant insertion may be different in a clinical setting. An additional limitation was that no reference objects were incorporated into the model design. Such objects would have helped in the alignment of the 2 data sets and the following measurements.<sup>19,20,27</sup> The use of a high-accuracy industrial scanner would also further minimize errors from the scanning procedure. These types of objects and scanners are not present in a clinical setting where the procedure would be more consistent with the present one.

## CONCLUSIONS

Within the limitation of this in vitro study, the following conclusions were drawn:

1. The tested desktop 3D printers proved capable of producing surgical guides with similar deviations to definitive implant position.
2. The DLP printer proved more accurate concerning deviations at the entry point and vertical implant position.

## REFERENCES

1. Widmann G, Bale RJ. Accuracy in computer-aided implant surgery—a review. *Int J Oral Maxillofac Implants* 2006;21:305-13.
2. Tahmaseb A, Wismeijer D, Coucke W, Derksen W. Computer technology applications in surgical implant dentistry: a systematic review. *Int J Oral Maxillofac Implants* 2014;29:25-42.
3. Bover-Ramos F, Viña-Almunia J, Cervera-Ballester J, Peñarrocha-Diogo M, García-Mira B. Accuracy of implant placement with computer-guided surgery: a systematic review and meta-analysis comparing cadaver, clinical, and in vitro studies. *Int J Oral Maxillofac Implants* 2018;33:101-15.
4. Farley NE, Kennedy K, McGlumphy EA, Clelland NL. Split-mouth comparison of the accuracy of computer-generated and conventional surgical guides. *Int J Oral Maxillofac Implants* 2013;28:563-72.
5. Edelmann AR, Hosseini B, Byrd WC, Preisser JS, Tyndall DA, Nguyen T, et al. Exploring effectiveness of computer-aided planning in implant positioning for a single immediate implant placement. *J Oral Implantol* 2016;42:233-9.
6. Fürhauser R, Mailath-Pokorny G, Haas R, Busenlechner D, Watzek G, Pommer B. Esthetics of flapless single-tooth implants in the anterior maxilla using guided surgery: association of three-dimensional accuracy and pink esthetic score. *Clin Implant Dent Relat Res* 2017;17:427-33.

7. Ersoy AE, Turkyilmaz I, Ozan O, McGlumphy EA. Reliability of implant placement with stereolithographic surgical guides generated from computed tomography: clinical data from 94 implants. *J Periodontol* 2008;79:1339-45.
8. Behneke A, Burwinkel M, Behneke N. Factors influencing transfer accuracy of cone beam CT-derived template-based implant placement. *Clin Oral Implants Res* 2012;23:416-23.
9. Widmann G, Fischer B, Berggren JPM, Dennhardt A, Schullian P, Reto B, et al. Cone beam computed tomography vs multislice computed tomography in computer-aided design/computer-assisted manufacture guided implant surgery based on three-dimensional optical scanning and stereolithographic guides: does image modality matter? *Int J Oral Maxillofac Implants* 2016;31:527-33.
10. Van Assche N, Quirynen M. Tolerance within a surgical guide. *Clin Oral Implants Res* 2010;21:455-8.
11. Vercruyssen M, Hultin M, Van Assche N, Svensson K, Naert I, Quirynen M. Guided surgery: accuracy and efficacy. *Periodontol* 2000 2014;66:228-46.
12. D'haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. *Clin Implant Dent Relat Res* 2012;14:321-35.
13. Pozzi A, Polizzi G, Moy PK. Guided surgery with tooth-supported templates for single missing teeth: a critical review. *Eur J Oral Implantol* 2016;9:135-53.
14. D'haese J, Ackhurst J, Wismeijer D, De Bruyn H, Tahmaseb A. Current state of the art of computer-guided implant surgery. *Periodontol* 2000 2017;73:121-33.
15. Sicilia A, Botticelli D, Working group 3. Computer-guided implant therapy and soft- and hard-tissue aspects. The third EAO consensus conference 2012. *Clin Oral Implants Res* 2012;23:157-61.
16. Vercruyssen M, Fortin T, Widmann G, Jacobs R, Quirynen M. Different techniques of static/dynamic guided implant surgery: modalities and indications. *Periodontol* 2000 2014;66:214-27.
17. Buser D, Sennerby L, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress, current trends and open questions. *Periodontol* 2000 2017;73:7-21.
18. International Organization of Standardization. ISO 5725-1:1994. Accuracy (trueness and precision) of measurement methods and results-Part 1: general principles and definitions. Geneva: International Organization of Standardization; 1994. Available at: <https://www.iso.org/standard/11833.html>.
19. Neumeister A, Schulz L, Glodecki C. Investigations on the accuracy of 3D-printed drill guides for dental implantology. *Int J Comput Dent* 2017;20:35-51.
20. Kuhr F, Schmidt A, Rehmann P, Wöstmann B. A new method for assessing the accuracy of full arch impressions in patients. *J Dent* 2016;55:68-74.
21. 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.
22. Mangano FG, Veronesi G, Hauschild U, Mijiritsky E, Mangano C. Trueness and precision of four intraoral scanners in oral implantology: a comparative in vitro study. *PLoS One* 2016;11:e0163107.
23. Rhee Y-K, Huh Y-H, Cho L-R, Park C-J. Comparison of intraoral scanning and conventional impression techniques using 3-dimensional superimposition. *J Adv Prosthodont* 2015;7:460-7.
24. Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U. Digital versus conventional impressions in fixed prosthodontics: a review. *J Prosthodont* 2018;27:35-41.
25. Papaspyridakos P, Gallucci GO, Chen C-J, Hanssen S, Naert I, Vandenberghe B. Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. *Clin Oral Implants Res* 2016;27:465-72.
26. Ender A, Zimmermann M, Attin T, Mehl A. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. *Clin Oral Investig* 2016;20:1495-504.
27. Muallah J, Wesemann C, Nowak R, Robben J, Mah J, Pospiech P, et al. Accuracy of full-arch scans using intraoral and extraoral scanners: an in vitro study using a new method of evaluation. *Int J Comput Dent* 2017;20:151-64.
28. Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, et al. Evaluation of the accuracy of 7 digital scanners: an in vitro analysis based on 3-dimensional comparisons. *J Prosthet Dent* 2017;118:36-42.
29. Cristache CM, Gurbanescu S. Accuracy evaluation of a stereolithographic surgical template for dental implant insertion using 3D superimposition protocol. *Int J Dent* 2017;2017:4292081.
30. Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. *Int J Oral Maxillofac Implants* 2014;29:55-77.

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