

RESEARCH AND EDUCATION

Accuracy of different definitive impression techniques with the all-on-4 protocol



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Immediate loading of implants with prosthetic restorations is frequently preferred for completely edentulous patients.¹ The main problems encountered in dental implant treatment are high cost and treatment time because of the advanced surgical procedures needed for patients with insufficient bone.^{2,3} The all-on-4 concept was introduced to address these problems for edentulous patients and those with failing dentition.^{2,3} In this technique, 4 implants with straight and angulated abutments are immediately loaded, and a fixed interim restoration is delivered on the day of surgery.⁴ However, passive fit of the prostheses with the all-on-4 technique is a key factor for success, and therefore, an accurate impression is essential. Implant-supported prostheses can be fabricated from conventional impressions or digital scans.

Conventional impressions can be made either directly (open tray) or indirectly (closed tray).⁵⁻¹² The closed-tray technique is an impression method that is performed by using a closed

ABSTRACT

Statement of problem. A nonpassive fit of implant-supported restorations can jeopardize the biological and mechanical success of the treatment. Data regarding the fit of different impression techniques for the all-on-4 protocol are limited.

Purpose. The purpose of this in vitro study was to digitally evaluate 4 different impression techniques used with the all-on-4 protocol, with distal multiunit analogs positioned in 4 different angulations.

Material and methods. Four maxillary definitive cast models with 4 multiunit analogs (T0 32202; NucleOSS) were fabricated according to the all-on-4 treatment protocol. In the anterior region, the analogs were positioned in a parallel direction, whereas in the posterior region, they were positioned in different angulations (0, 10, 20, and 30 degrees). One hundred and sixty models were obtained by using 4 different impression techniques (closed tray without plastic cap, closed tray with plastic cap, splinted open tray, sectioned resplinted open tray) (n=10) and polyvinyl siloxane impression material. Definitive casts and definitive duplicate casts were scanned using a modified laser scanner (Activity 880; Smart Optics Sensortechnik GmbH), and data were transferred to a software program (VRMesh Studio; Virtual Grid Inc). The definitive casts and definitive duplicate cast scans were digitally aligned. Angular and linear deviations in all axes (x, y, and z) of the analogs between definitive and duplicate casts were calculated and subjected to statistical analyses ($\alpha=.05$).

Results. Mean angular deviations were in the range of 0.03 to 0.16 degrees, and linear deviations were in the range of 0.10 to 0.75 mm. The increased angulation between impression copings caused higher linear and angular deviations when closed-tray impression techniques were used ($P<.05$).

Conclusions. Reduced linear and angular displacements were obtained from the open-tray impression techniques compared with the closed-tray impression techniques in the angulated groups. Angular and linear deviations increased with the increase in the angulation of the posterior analog. (*J Prosthet Dent* 2019;121:941-8)

impression tray and conical impression copings. The open-tray technique uses a custom tray with holes for the implant copings.¹³ Because the copings are unscrewed after the

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Clinical Implications

With the all-on-4 protocol, open-tray impression techniques can be recommended when 20 degrees or greater angulation exists between the impression copings. However, all impression techniques can be used when impression copings are parallel.

impression material has polymerized, the direct technique reduces the risk of the distortion inherent in the indirect technique which may occur in the impression material because of the angulations of implants.¹⁴ Furthermore, unlike with the indirect technique, eliminating the need for replacement of the copings into the impression reduces the risk of additional errors.¹⁵ However, the direct technique has some disadvantages in that it is technique sensitive and may cause a rotational motion during the coupling of analogs with corresponding copings.¹⁴

In the treatment protocols, especially in the all-on-4 concept in which implants are placed at an angle, it is difficult to achieve the desired angulation because there are only 2 angulation options (17 and 30 degrees) in multiunit abutments.⁴ Moreover, most of the implants have a hexagonal implant-abutment connection, and the rotational position of the angled distal implant is crucial because the divergency can be corrected only in 6 positions. Therefore, it is almost impossible to create absolute parallelism between the impression copings, which may affect the accuracy of the impression.⁴ Splinting or non-splinting, direct or indirect impression techniques, and angulations of inserted implants play important roles in the angular and positional accuracies of the definitive impression.^{11,12,16-20} The authors are unaware of studies valuating the accuracy of implants placed at different angulations in the posterior region with respect to the all-on-4 protocol by using different impression techniques. Therefore, the purpose of this study was to assess the accuracy and precision of the definitive cast by comparing the 4 impression techniques in the all-on-4 protocol. The null hypotheses were that increasing the angulation would not affect the dimensional accuracy of the impression and that different impression techniques would not affect the accuracy of the transfer of implants.

MATERIAL AND METHODS

A summary of the procedures is described in a flow-chart (Fig. 1). Four definitive casts were obtained by pouring a clear acrylic resin (Pegasus Plus Repair Acrylic; Davis Schottlander & Davis Ltd) into silicone matrixes (AG-3; Frasco GmbH), which simulated an edentulous maxillary arch. The definitive casts were scanned using a computer-aided design and computer-

aided manufacturer (CAD-CAM) scanner (in EOS X5; Dentsply Sirona) to obtain standard tessellation language (STL) data.

A special appliance was designed in accordance with STL data of the jaw model by using a 3D design program (Rhinoceros; McNeel Europe) and fabricated with metal holes for placing the multiunit analogs (T0 32202; NucleOSS) at 4 different angulations (parallel and 10, 20, and 30 degrees) (Fig. 2). A rotary instrument was used to open the multiunit analog sockets at different angulations with the guidance of the metal holes (Fig. 3). Sockets were prepared at the same dimensions with multiunit analogs, and then the analogs were fixed with resin into the control casts. In all definitive casts, anterior analogs were placed parallel to each other in the maxillary left and right lateral incisor regions. For the first definitive cast, posterior analogs were placed parallel to the long axis of the anterior analogs in the maxillary left and right, second premolar region. Posterior analogs were positioned in the second definitive cast at 10 degrees of distal angulation, in the third definitive cast at 20 degrees of distal angulation, and in the fourth definitive cast at 30 degrees of distal angulation to the long axis of the anterior analogs (Fig. 4). Three different points were defined on the definitive casts to use as reference points during the superimposition process (Fig. 5).

From each definitive cast, 160 custom impression trays were fabricated from light-polymerizing base plates (Plaque Photo; WP Dental). Three millimeter-high tissue stops were created by using a wax spacer (Set Up Wax; Cavex) to standardize the thickness of the impression material. The trays were divided into 2 groups, namely, open-tray and closed-tray impression techniques. For the open-tray technique, coronal parts of the impression trays were perforated to allow access to the impression coping screws. For the closed-tray technique, no perforation was made.

A total of 160 impressions were made with a mono-phase polyvinyl siloxane impression material (Hydrorise Maxi Monophase; Zhermack) by using 4 different impression techniques (closed tray, closed tray with plastic cap, splinted open tray, and sectioned resplinted open tray) from each definitive cast (n=10). The polyvinyl siloxane was mixed using an automatic device (Pentamix 2; 3M ESPE). Inner surfaces of the trays were coated with tray adhesive (Universal Tray Adhesive; Zhermack) and left to dry for 2 minutes according to the manufacturer's recommendations. The impression copings and analogs were tightened by the same clinician (O.H.) using a hand screwdriver to the first point when solid resistance is felt, ensuring that the impression copings and analogs were secured to simulate clinical situations. For all impression techniques, a medium-body impression material was injected around the impression copings. Impression trays were placed onto the models under finger pressure until

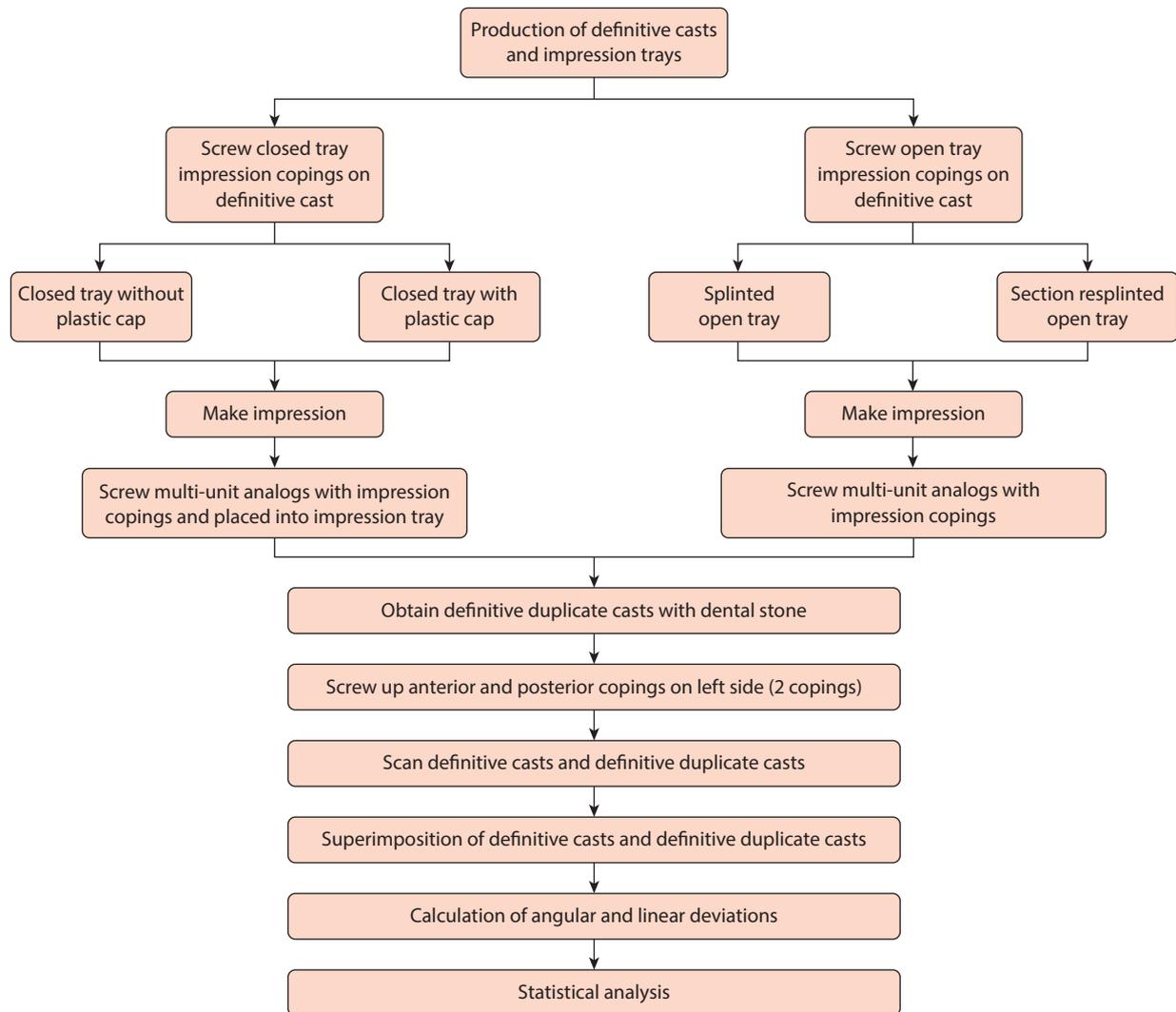


Figure 1. Flowchart of study design.

the guide stops being contacted, and the impression material was left to polymerize for 7 to 8 minutes in accordance with the manufacturer's recommendations. Thereafter, all trays were removed perpendicular to the occlusal plane. Special care was taken to maintain a similar path of removal to achieve standardization. A single clinician (O.H.) conducted all the procedures, and new components were used for impression procedures, which were performed according to the 4 impression techniques.

For the closed-tray technique and for the closed tray with plastic cap technique, closed-tray impression copings (T0 32607; NucleOSS) without plastic caps and closed-tray impression copings (T0 32900; NucleOSS) with plastic caps were screwed onto the analogs. An impression was made, and the impression tray was removed from the definitive cast. Multiunit analogs (T0 32202; NucleOSS) were connected to the impression copings and repositioned in their corresponding places

in the impression tray. For the splinted open-tray technique, open-tray copings (T0 32608; NucleOSS) were screwed onto the analogs on definitive casts and splinted by using dental floss and autopolymerizing acrylic resin (Pattern Resin LS; GC America Inc). Similar to the splinted open-tray technique, open-tray copings (T0 32608; NucleOSS) were also screwed onto the analogs and splinted in the sectioned respinted open-tray technique. As distinct from the splinted open-tray technique, the formed splint was cut after 17 minutes using the same rotary instrument (D203; Hager & Meisinger GmbH) to achieve the same thickness (1.2 mm) and respinted on the definitive cast. For both open-tray techniques, an impression was made, and after polymerizing, the impression tray was removed from the definitive cast by unscrewing the impression copings. Multiunit analogs were held in place using fingers while the screw was tightened with a hand screwdriver.

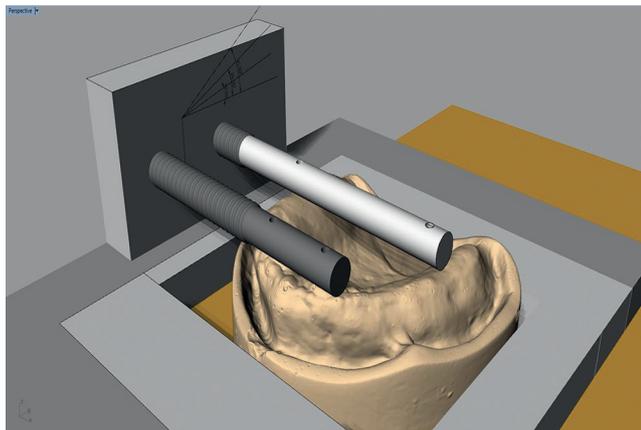


Figure 2. STL data of virtually designed appliance for insertion of multiunit analogs at 4 different angulations. STL, standard tessellation language.

Definitive duplicate casts were obtained from Type IV dental stone (Zhermack Elite Rock; Zhermack) in a single pour. After 1 hour for the setting of the dental stone, care was taken during the removal of models from impressions to minimize the risk of fracture or cracking.

The measurement procedures described by Kurtuluş-Yılmaz et al¹² were used. Right-side anterior and posterior impression copings were fixed by screwing to the corresponding analogs on the definitive and definitive duplicate casts. An optical scanner (Activity 880; Smart Optics Sensortechnik GmbH) with high accuracy (within 5 μm) was used to scan the definitive duplicate cast and the definitive cast. A single layer of scanning powder was applied by a single experienced clinician (H.O.) to the glossy surfaces of both the definitive cast and the definitive duplicate cast to achieve a minimum coating thickness ($43 \pm 14 \mu\text{m}$),²¹ thereby avoiding surface reflection. The scans of definitive duplicate casts were aligned with the main scan obtained from corresponding definitive casts to observe the superposition of anatomic markers using a 3D simulation software program (VRMesh Studio; Virtual Grid Inc) (Fig. 6). Two reference points were selected (using x, y, and z coordinates) on the long axis of copings on each definitive duplicate cast and definitive cast. These 2 points were selected at the center of the top and bottom of the impression copings and were used to convert the copings into cylinders. The linear differences between the center of the copings both on definitive and definitive duplicate casts for the bottom point (linear deviations in mm) and the angles observed between the long axes of the copings on definitive and definitive duplicate casts (angular deviations in degrees) were measured by Cartesian multiplication of the analytic coordinates of the points by the same observer (Fig. 7).^{12,22,23} The x-, y-, and z-coordinate values were provided by the 3D simulation

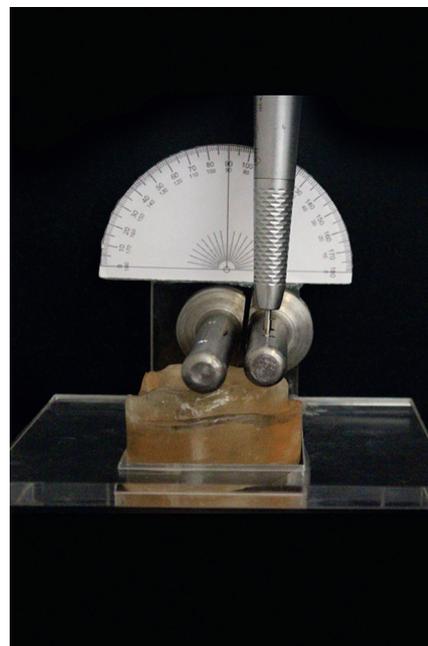


Figure 3. Preparation of implant analog sockets at different angulations on definitive casts.

software; calculations were made according to the following formulae:

For the calculation of angular deviation, $\text{Cos}(Q) = \frac{\vec{v} \times \vec{w}}{|\vec{v}| |\vec{w}|}$ formula was used. The v value in the formula represents coordinates on definitive cast, and the w value represents coordinates on duplicate definitive cast. For the calculation of linear deviation,

$D = \sqrt{(X_{\vec{v}} - X_{\vec{w}})^2 + (Y_{\vec{v}} - Y_{\vec{w}})^2 + (Z_{\vec{v}} - Z_{\vec{w}})^2}$ was used.

A sample size of 10 was selected based on previous studies.^{12,17} The Shapiro-Wilk test was used to confirm that the data were normally distributed. Data were analyzed by 2-way ANOVA. The considered variables were impression technique and implant angulation. Post hoc comparisons were performed by using the Tukey multiple comparison test when significance was detected ($\alpha = .05$).

RESULTS

The mean angular values of the copings with their standard deviations are depicted in Table 1 and the linear deviation, in Table 2. Two-way ANOVA revealed that the impression technique and implant angulation had a statistically significant effect on both angular and linear deviations.

No statistically significant difference was found between the parallel and 10-degree-angulated groups in all impression techniques, whereas a statistically significant difference between parallel and 30-degree-angulated groups was detected in the closed tray with plastic cap

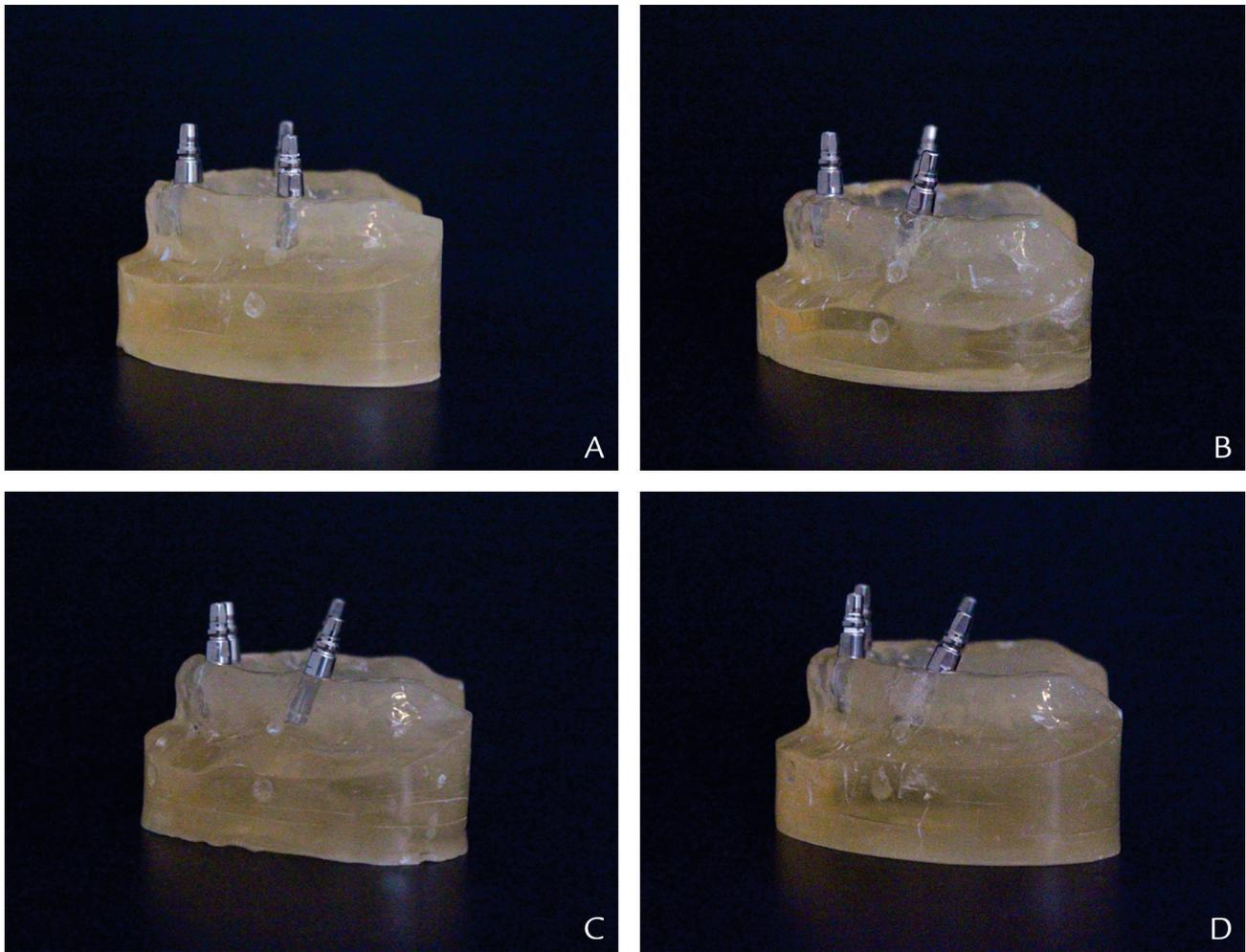


Figure 4. Definitive casts with different angulations between anterior and posterior analogs. A, Parallel. B, 10 degrees angulation. C, 20 degrees angulation. D, 30 degrees angulation.

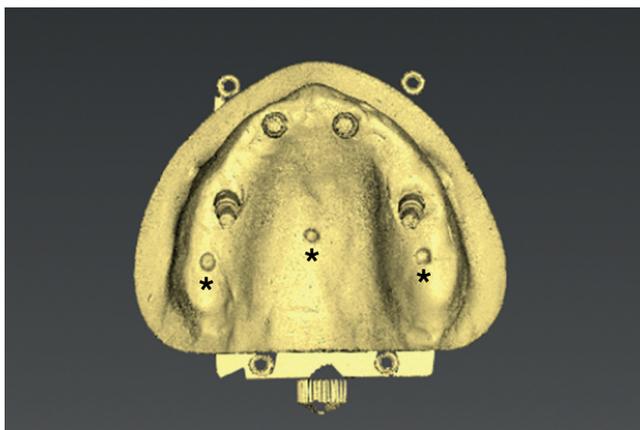


Figure 5. Reference points defined on definitive casts indicated with asterisk.

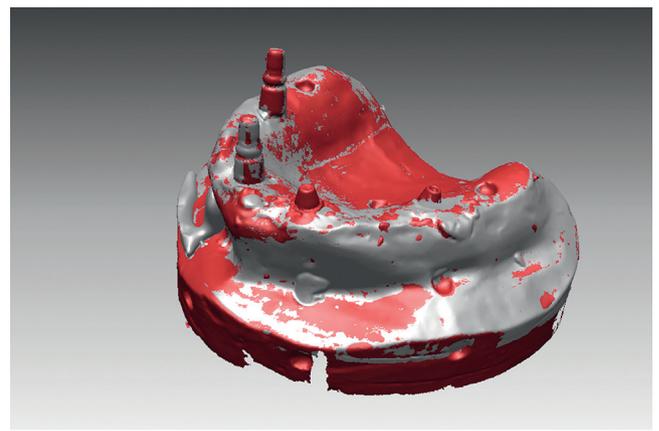


Figure 6. Superimposition of anatomic markers on definitive casts and definitive duplicate casts using 3D software.

technique when the results of the angular deviations of the anterior analogs were evaluated. According to the statistical results of the angular deviation of posterior

analog, for all impression techniques, deviations were greater in the 20- and 30-degree-angulated casts than in the parallel and 10-degree-angulated casts ($P < .05$). No



Figure 7. Measurement of linear differences (A) and angular differences (B) between definitive casts and definitive duplicate copings. *Blue* represents definitive cast coping. *Yellow* represents definitive duplicate cast coping.

statistically significant values were found among the impression techniques in the parallel group ($P > .05$).

During the evaluation of the linear deviations of the anterior analogs, a statistically significant difference was found between the parallel and other angulated groups in the closed-tray technique, whereas in the closed tray with plastic cap technique, a statistically significant difference was observed only between the parallel and 30-degree-angulated groups. No statistically significant difference was found among all impression techniques in the casts with parallelly placed analogs ($P > .05$). Linear deviations of the posterior analogs revealed a statistically significant difference between the parallel and 30-degree groups in the closed-tray impression techniques, whereas in the open-tray impression techniques, no statistical differences were found for the sectioned resplinted open-tray technique in all groups ($P > .05$). No statistically significant difference was found among impression techniques in all models where the analogs were placed parallel ($P > .05$).

DISCUSSION

Different impression techniques and different angulations between the implant abutments influenced the dimensional accuracy of the impression copings on the definitive duplicate casts. Therefore, both null hypotheses were rejected. In addition to the impression technique and angulations of the implants, the mechanical properties of the impression material may

influence the accuracy of the impression.^{5,6,11,14,18} When angulations between the implants are present, the impression has to be removed easily to reduce distortion and thereby to achieve a more accurate impression. Therefore, an additional silicone with an appropriate modulus of elasticity and elastic recovery was used in the present study, which was consistent with other studies.^{6,12}

All the impression techniques provided similar accuracies for both anterior and posterior copings when impressions of parallel impression copings were made. These findings are consistent with previous studies conducted with parallel-placed implants.^{5,20} However, in the angulated groups (10, 20, and 30 degrees), the impression technique affected the accuracy for both anterior and posterior copings. These results of the present study are consistent with those of previously published studies.^{11,12,15} Especially in the tilted analogs (posterior) of the angulated groups, both splinted open-tray and sectioned resplinted open-tray impression techniques exhibited more accurate results than those of the closed-tray impression groups. Studies that compare open-tray and closed-tray impression techniques have reported different conclusions. Some reported more accurate results with open-tray impression techniques,^{7,12} whereas others did not find any differences.^{16,17,20,24} However, unlike the present study, Hazboun et al,²⁰ Jo et al,¹⁷ and Stimmelmayer et al²⁴ evaluated internal conical connection-type implants. During the removal of the tray, due to the angulation differences among the implants, long implant/abutment connection areas of the impression copings may create unfavorable stresses, which can result in deformation of the impression material. Eventually, axial displacements between multiple internal connections can result in less accuracy, as stated by Kim et al.¹³ This statement is supported by recent publications that compared internal⁴ and external connection⁵ implant-level impressions with abutment-level impressions. The authors reported lower displacements with abutment-level impressions, especially when the open-tray impression technique was used.¹³ Therefore, in the present study, abutment-level (multiunit) impressions were used.

Various methods have been proposed to achieve more accurate impressions. Of these methods, the splinted open-tray technique is the most popular for transferring the ideal positions of implants compared with nonsplinted one. Most studies reported better accuracy with the splinted open-tray technique,^{8,12,19,20,24} whereas others^{9,18} reported that the splinting method was a time-consuming procedure and questioned the need for splinting the impression copings. A possible explanation for these confusing results may be derived from the splinting method used. In the studies that

Table 1. Mean \pm standard deviation of linear deviations (mm) of both anterior and posterior copings

	Parallel	10 Degrees	20 Degrees	30 Degrees
Anterior linear deviations (mm)				
Closed tray	0.29 \pm 0.13 ^{A,a}	0.39 \pm 0.21 ^{A,B,a}	0.49 \pm 0.09 ^{B,a}	0.54 \pm 0.22 ^{B,a}
Closed tray with cap	0.29 \pm 0.12 ^{A,a}	0.38 \pm 0.12 ^{A,B,a}	0.43 \pm 0.19 ^{A,B,a}	0.49 \pm 0.09 ^{B,a}
Splinted open tray	0.27 \pm 0.16 ^{A,a}	0.29 \pm 0.06 ^{A,B,a}	0.43 \pm 0.17 ^{B,a}	0.42 \pm 0.09 ^{B,a}
Sectioned resplinted open tray	0.24 \pm 0.13 ^{A,a}	0.28 \pm 0.1 ^{A,B,a}	0.43 \pm 0.08 ^{B,a}	0.39 \pm 0.14 ^{A,B,a}
Posterior linear deviations (mm)				
Closed tray	0.23 \pm 0.18 ^{A,a}	0.43 \pm 0.09 ^{A,a}	0.57 \pm 0.18 ^{B,a}	0.75 \pm 0.17 ^{B,a}
Closed tray with cap	0.27 \pm 0.14 ^{A,a}	0.33 \pm 0.11 ^{A,a,b}	0.66 \pm 0.21 ^{B,a}	0.67 \pm 0.24 ^{B,a,b}
Splinted open tray	0.21 \pm 0.12 ^{A,a}	0.27 \pm 0.09 ^{A,a,b}	0.47 \pm 0.15 ^{B,a,c}	0.60 \pm 0.17 ^{B,b}
Sectioned resplinted open tray	0.1 \pm 0.04 ^{A,a}	0.2 \pm 0.08 ^{A,b}	0.4 \pm 0.07 ^{B,b,c}	0.5 \pm 0.08 ^{B,c}

Same uppercase letters in same column and same lowercase letters in same row show no statistical significance ($P > .05$).

Table 2. Mean \pm standard deviation values of angular deviations (degrees) of both anterior and posterior copings

	Parallel	10 Degrees	20 Degrees	30 Degrees
Anterior angular deviations (degree)				
Closed tray	0.03 \pm 0.02 ^{A,a}	0.08 \pm 0.09 ^{B,a}	0.07 \pm 0.03 ^{B,a}	0.13 \pm 0.15 ^{B,a}
Closed tray with cap	0.07 \pm 0.15 ^{A,a}	0.05 \pm 0.04 ^{A,B,a,b}	0.05 \pm 0.05 ^{A,B,a,b}	0.09 \pm 0.11 ^{B,a}
Splinted open tray	0.06 \pm 0.11 ^{A,a}	0.03 \pm 0.01 ^{A,b}	0.03 \pm 0.02 ^{A,b}	0.07 \pm 0.09 ^{A,b}
Sectioned resplinted open tray	0.03 \pm 0.03 ^{A,a}	0.03 \pm 0.04 ^{A,b}	0.05 \pm 0.12 ^{A,b}	0.06 \pm 0.05 ^{A,b}
Posterior angular deviations (degree)				
Closed tray	0.04 \pm 0.01 ^{A,a}	0.1 \pm 0.08 ^{B,C,a}	0.06 \pm 0.02 ^{A,B,a}	0.16 \pm 0.14 ^{B,a}
Closed tray with cap	0.07 \pm 0.14 ^{A,a}	0.08 \pm 0.05 ^{A,a}	0.07 \pm 0.05 ^{A,B,a}	0.1 \pm 0.12 ^{B,a,b}
Splinted open tray	0.05 \pm 0.11 ^{A,B,a}	0.04 \pm 0.01 ^{A,b}	0.06 \pm 0.02 ^{A,B,a,b}	0.09 \pm 0.08 ^{B,b,c}
Sectioned resplinted open tray	0.04 \pm 0.03 ^{A,a}	0.04 \pm 0.05 ^{A,b}	0.05 \pm 0.12 ^{A,b}	0.07 \pm 0.14 ^{A,c}

Same uppercase letters in same column and same lowercase letters in same row show no statistical significance ($P > .05$).

reported no need for splinting, the sectioned splinting technique was not performed. In the present study, polymerization shrinkage was minimized by cutting the resin and splinting again on the definitive cast. Moreover, Buzayan et al⁹ examined the effect of splinting only on parallel-placed implants and reported that different results can be obtained in case of angulations between implants. In the present study, splinting of the copings exhibited statistically lower angular deviation results in the 30-degree-angulated group than that in the non-splinted group. This finding is consistent with the results of a study by Tsagkalidis et al¹⁹ who reported better results with sectioned resplinted impression technique when 25-degree angulation between the implants occurred.

Of the closed-tray impression techniques, none exhibited superior results. In the present study, a snap-fit technique in which impression copings are screwed to the multiunit analogs was preferred. Other studies with the snap-fit technique reported that this technique was easily handled but time-consuming as the coping parts are directly engaged to the implant by pressing instead of screwing.^{19,25} Therefore, the snap-fit technique (closed-tray impression technique with plastic cap) is not recommended because the screwing procedure is still required.

Inconsistent results found in the literature may also be explained by the use of different techniques to evaluate the accuracy of impression methods. Most of the studies used direct measurement techniques such as coordinate measuring machines^{5,18,19} and measuring microscopes and by measuring the interimplant distances,^{10,17} whereas others used optical techniques including profile projectors¹¹ and photography.²⁰ Consistent with the study conducted by Kurtulmus-Yilmaz et al,¹² the digital evaluation of different impression techniques was used in the present study to achieve more reliable results with 3D analyses.

Unlike in studies that secured the impression components with a torque wrench calibrated to 10 Ncm to achieve standardization,^{5,26} impression copings and analogs were tightened with a hand screwdriver in the present study. Although this may be a limitation of the study, it better reflects the clinical situation. In addition, the removal of the impression trays did not simulate the clinical situation, as the trays were removed in a perpendicular way to the occlusal plane. Stresses can change depending on the removal direction of the impression trays.²⁰ Furthermore, this study did not simulate various clinical conditions such as the presence of blood and saliva and patient movement. Further studies that simulate clinical situations more effectively are required.

CONCLUSIONS

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

1. All impression techniques provided similar accuracy when impressions of parallel impression copings were made.
2. The use of a plastic cap for closed-tray impressions was not found to improve accuracy.
3. All open-tray impression techniques exhibited lower deviations than closed-tray impression techniques when 20-degree or greater angulations existed between the impression copings. When high discrepancies among the implants (30 degrees) are present, the sectioned resplinted open-tray technique can be recommended to improve cast accuracy.

REFERENCES

1. Cochran DL. The evidence for immediate loading of implants. *J Evid Based Dent Pract* 2006;6:155-63.
2. Maló P, Rangert B, Nobre M. "All-on-Four" immediate-function concept with Brånemark System implants for completely edentulous mandibles: a retrospective clinical study. *Clin Implant Dent Relat Res* 2003;5:2-9.
3. Maló P, de Araujo NM, Lopes A, Francischone C, Rigolizzo M. "All-on-4" immediate-function concept for completely edentulous maxillae: a clinical report on the medium (3 years) and long-term (5 years) outcomes. *Clin Implant Dent Relat Res* 2012;14:139-50.
4. Siadat H, Alikhasi M, Beyabanaki E, Rahimian S. Comparison of different impression techniques when using the All-on-Four implant treatment protocol. *Int J Prosthodont* 2016;29:265-70.
5. Alikhasi M, Siadat H, Rahimian S. The effect of implant angulation on the transfer accuracy of external-connection implants. *Clin Implant Dent Relat Res* 2015;17:822-9.
6. Lu H, Nguyen B, Powers JM. Mechanical properties of 3 hydrophilic addition silicone and polyether elastomeric impression materials. *J Prosthet Dent* 2004;92:151-4.
7. Al Quran FA, Rashdan BA, Zomar AA, Weiner S. Passive fit and accuracy of three dental implant impression techniques. *Quintessence Int* 2012;43:119-25.
8. Papaspyridakos P, Benic GI, Hogsett VL, White GS, Lal K, Gallucci GO. Accuracy of implant casts generated with splinted and non-splinted impression techniques for edentulous patients: an optical scanning study. *Clin Oral Implants Res* 2012;23:676-81.
9. Buzayan M, Baig MR, Yunus N. Evaluation of accuracy of complete-arch multiple-unit abutment-level dental implant impressions using different impression and splinting materials. *Int J Oral Maxillofac Implants* 2013;28:1512-20.
10. Akalin ZF, Kulak-Ozkan Y, Ekerim A. Effects of implant angulation, impression material, and variation in arch curvature width on implant transfer model accuracy. *Int J Oral Maxillofac Implants* 2013;28:149-57.
11. Sorrentino R, Gherlone EF, Calesini G, Zarone F. Effect of implant angulation, connection length, and impression material on the dimensional accuracy of implant impressions: an in vitro comparative study. *Clin Implant Dent Relat Res* 2010;12:e63-76.
12. Kurtulmus-Yilmaz S, Ozan O, Ozelcik TB, Yagiz A. Digital evaluation of the accuracy of impression techniques and materials in angulated implants. *J Dent* 2014;42:1551-9.
13. Kim JH, Kim KR, Kim S. Critical appraisal of implant impression accuracies: a systematic review. *J Prosthet Dent* 2015;114:185-92.
14. Carr AB. Comparison of impression techniques for a five-implant mandibular model. *Int J Oral Maxillofac Implants* 1991;6:448-55.
15. Gallucci GO, Papaspyridakos P, Ashy LM, Doukoudakis A, Weber HP, Chronopoulos V. Clinical accuracy outcomes of closed-tray and open-tray implant impression techniques for partially edentulous patients. *Int J Prosthodont* 2011;24:469-72.
16. Mpikos P, Tortopidis D, Galanis C, Kaisarli G, Koidis P. The effect of impression technique and implant angulation on the impression accuracy of external- and internal-connection implants. *Int J Oral Maxillofac Implants* 2012;27:1422-8.
17. Jo SH, Kim KI, Seo JM, Song KY, Park J, Ahn SG. Effect of impression coping and implant angulation on the accuracy of implant impressions: an in-vitro study. *J Adv Prosthodont* 2010;2:128-33.
18. Ehsani S, Siadat H, Alikhasi M. Comparative evaluation of impression accuracy of tilted and straight implants in All-on-4 technique. *Implant Dent* 2014;23:225-30.
19. Tsagkalidis G, Tortopidis D, Mpikos P, Kaisarli G, Koidis P. Accuracy of different impression techniques for internal connection angulated implants. *J Prosthet Dent* 2015;114:517-23.
20. Hazboun GBA, Masri R, Romberg E, Kempler J, Driscoll C. Effect of implant angulation and impression technique on impressions of NobelActive implants. *J Prosthet Dent* 2015;113:425-31.
21. Dehurtevent M, Robberecht L, Béhin P. Influence of dentist experience with scan spray systems used in direct CAD/CAM impressions. *J Prosthet Dent* 2015;113:17-21.
22. Ozan O, Orhan K, Turkyilmaz I. Correlation between bone density and angular deviation of implants placed using CT-generated surgical guides. *J Craniofac Surg* 2011;22:1755-61.
23. Ozan O, Turkyilmaz I, Ersoy AE, McGlumphy EA, Rosenstiel SF. Clinical accuracy of 3 different types of computed tomography-derived stereolithographic surgical guides in implant placement. *J Oral Maxillofac Surg* 2009;67:394-401.
24. Stimmelmayer M, Erdelt K, Guth JF, Happe A, Beuer F. Evaluation of impression accuracy for a four-implant mandibular model a digital approach. *Clin Oral Investig* 2012;16:1137-42.
25. Akca K, Çehreli M. Accuracy of 2 impression techniques for ITI implants. *Int J Oral Maxillofac Implants* 2004;19:517-23.
26. Rashidan N, Alikhasi M, Samadzadeh S, Beyabanaki E, Kharazifard MJ. Accuracy of implant impressions with different impression coping types and shapes. *Clin Implant Dent Relat Res* 2012;14:218-25.

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