Three-dimensional accuracy of innovative implant-level impression techniques with plastic snap-on impression copings

Hamid Neshandar Asli^{1,A,C,E,F}, Yasamin Babaee Hemmati^{2,B,C,E,F}, Mehran Falahchai^{1,B,D-F}

¹ Department of Prosthodontics, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran

² Department of Orthodontics, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online)

Dent Med Probl. 2021;58(3):351–357

Address for correspondence

Mehran Falahchai

E-mail: mehran.falahchai@gmail.com

Funding sources

None declared

Conflict of interest

None declared

Received on September 17, 2020

Reviewed on September 28, 2020

Accepted on November 4, 2020

Published online on August 26, 2021

Abstract

Background. Several studies have assessed the accuracy of the indirect snap-on impression technique. However, some impression techniques that utilize plastic snap-on impression copings have not yet been investigated.

Objectives. This study aimed to assess the three-dimensional (3D) accuracy of innovative implant-level impression techniques with plastic impression copings and the splinted open-tray technique with metal impression copings.

Material and methods. This in vitro study used a reference model of the mandible with 4 parallel dental implants. Forty impressions were made with polyether impression material, using the splinted open-tray technique with metal impression copings (SOM group), the non-splinted closed-tray technique with snap-on impression copings (NCS group), the non-splinted open-tray technique with snap-on impression copings (NOS group), or the splinted open-tray technique with snap-on impression copings (SOS group); $n = 10$ per group. Linear discrepancies in the inter-implant distances on the obtained casts were determined in the X, Y and Z axes with the use of a coordinate measuring machine. Subsequently, the 3D accuracy of each impression technique was calculated. Data was analyzed by means of the one-way analysis of variance (ANOVA) followed by Tukey's post-hoc tests.

Results. Among different impression techniques, the amount of linear discrepancy was significant only for the Z axis. The SOM, NOS and SOS groups showed less discrepancy in this axis as compared to the NCS group ($p < 0.001$). A significant difference was also noted in 3D discrepancy ($p = 0.022$), with the SOM group showing a significantly higher discrepancy as compared to the SOS group ($p = 0.016$).

Conclusions. The 3D accuracy of the implant-level splinted open-tray impression technique with plastic snap-on impression copings was significantly higher than that of the splinted open-tray technique with metal impression copings.

Keywords: dental implants, dental impression technique, implant-supported dental prosthesis

Cite as

Neshandar Asli H, Babaee Hemmati Y, Falahchai M. Three-dimensional accuracy of innovative implant-level impression techniques with plastic snap-on impression copings. *Dent Med Probl.* 2021;58(3):351–357. doi:10.17219/dmp/130089

DOI

10.17219/dmp/130089

Copyright

© 2021 by Wrocław Medical University

This is an article distributed under the terms of the

Creative Commons Attribution 3.0 Unported License (CC BY 3.0)

(<https://creativecommons.org/licenses/by/3.0/>).

Introduction

Dental implants are currently a common treatment option for completely or partially edentulous patients.¹ The success rate of dental implant treatment is approx. 97–99%.² Nonetheless, the risk of failure still exists, which is mainly due to incorrect surgical or prosthetic approaches.² Achieving a passive fit is a fundamental goal for implant-supported prostheses, and it is a prerequisite for the preservation of osseointegration.^{3,4} However, it has been suggested that obtaining a prosthesis with an absolute passive fit is impossible in practice.⁵ Evidence shows that, unlike natural teeth, dental implants have highly limited mobility (~10 µm) due to the absence of the periodontal ligament.⁶ This means that any misfit in superstructures can result in applying loads to the implant, causing the accumulation of tension and subsequent complications, including screw loosening, screw fracture, implant fracture, prosthetic framework fracture, veneer fracture, or even osseointegration loss.^{7,8}

Errors in any step of the fabrication of implant-supported restorations can affect the passive fit. However, many of these errors can be avoided by dental clinicians. Precise impression-making and the three-dimensional (3D) simulation of the intraoral implant or abutment positions on a master/working cast are critical steps for the long-term success of prosthetic restorations.^{5,9,10} A number of factors can affect the accuracy of impressions, such as the impression technique,¹¹ the splinting of impression copings,^{12,13} the number of implants,¹⁴ the angulation of the implant or the abutment,¹⁵ the type of impression material,¹⁶ the type of implant connection,¹⁷ and the depth of implant placement.¹⁸

Impressions can be performed at the implant level or the abutment level, and can be made directly (the open-tray or pick-up technique) or indirectly (the closed-tray or repositioning technique). Many studies have evaluated and compared impression techniques in fully or partially edentulous patients.^{5,16,19,20} According to a systematic review, in both completely and partially edentulous patients, the splinted and open-tray impression techniques have a higher accuracy than the non-splinted and closed-tray impression techniques.²¹

At present, the manufacturers of implant systems have introduced various components to enhance impression techniques and increase their accuracy. However, evidence supporting the effectiveness of these components is limited. To minimize the frequency of tightening the abutments, many implant systems have introduced plastic snap-on impression copings for abutment-level impressions,¹⁹ which can also be used for implant-level impressions. Some studies have evaluated the accuracy of these impression copings, reporting conflicting results.^{3,4,11,19,22–27} In some implant systems, plastic impression copings have a unique property that enables the passage of a guide pin through them. Thus, these systems also allow for open-tray impressions,

and can potentially be applied as an alternative to other implant impression techniques. To date, no previous study has assessed the accuracy of this modified impression technique. Thus, the purpose of this study was to compare the 3D accuracy of different innovative implant-level impression techniques, namely the non-splinted closed-tray technique, the non-splinted open-tray technique, and the splinted open-tray technique with plastic snap-on or metal impression copings. The null hypothesis was that no differences in the 3D accuracy of these different impression techniques would be found.

Material and methods

This in vitro experimental study evaluated 4 implant-level impression techniques: the splinted open-tray technique with metal impression copings (SOM group); the non-splinted closed-tray technique with snap-on impression copings (NCS group); the non-splinted open-tray technique with snap-on impression copings (NOS group); and the splinted open-tray technique with snap-on impression copings (SOS group). Ten impressions were made with each technique ($n = 10$). The working casts were poured and the inter-implant measurements were made separately on each cast. The discrepancies between the measured values and the actual values measured on the reference model were calculated and statistically analyzed.

For the fabrication of the reference model, several layers of sticky wax were applied on the edentulous ridge of an edentulous model of the mandible to obtain adequate ridge diameter and height for implant placement. Next, it was flaked and auto-polymerizing acrylic resin (Technovit® 4000; Heraeus Kulzer GmbH, Wehrheim, Germany) was used for the fabrication of the model. Four holes, at a distance of 10 mm from each other, parallel to each other and perpendicular to the horizontal plane between the 2 mental foramina were created in the reference model. Bone-level dental implants (Dio® SM-submerged; Dio Corporation, Busan, South Korea) with Torx® internal connections, measuring 4.5 mm in diameter and 12 mm in length, were fixed in place by means of auto-polymerizing acrylic resin (Technovit 4000). A surveyor was used for the parallel insertion of the dental implants.

To ensure the accurate and reproducible positioning of the special tray, 3 stops were created in the land area of the reference model. The transfer copings were tightened onto the implants, and then a primary impression was made with a prefabricated tray, using condensation silicon putty and light material (C-silicone Speedex®; Coltène/Whaledent AG, Altstätten, Switzerland). The primary impression was poured with type IV dental stone (GC Fujirock® EP; GC America Inc., Alsip, USA). A primary cast was fabricated as such for the fabrication of the special tray. Forty special trays ($n = 10$ for each impression technique) were fabricated on the primary cast with

the use of light-polymerized acrylic resin (Megatray™; MEGADENTA Dentalprodukte GmbH, Radeberg, Germany). All trays had a thickness of 2 mm and an internal space of 3 mm. The trays were perforated at 1-centimeter intervals. Fifteen minutes prior to impression-making, tray adhesive was applied on the internal surface of the trays and 5 mm around the tray borders.¹⁶

For the SOM technique, the metal open impression copings (regular Torx pick-up impression copings, SIP 4813T; Dio Corporation) were first tightened on the reference model implants with a torque of 10 Ncm. Auto-polymerizing acrylic resin (Pattern Resin™; GC Corporation, Tokyo, Japan) and dental floss were used for the splinted techniques. To ensure the standardization of the shape and amount of the splint material used for each impression, a silicon putty index was made. Next, the acrylic resin was mixed and packed in the index, and the impression copings were attached. After 17 min and ensuring an adequate setting of the acrylic resin, the attachments were separated with a disk. After 24 h, the space was filled with a minimum amount of fresh acrylic resin by means of a brush head and it was allowed to set (Fig. 1). Direct impressions were then made so that the impression material was injected into the tray and around the copings. The tray was then placed over the reference model. An adequate amount of time was allowed for the setting of the impression material, as outlined in the manufacturer's instructions. Next, the guide pins were removed from the implants and the tray, and the splinted impression copings were removed from the reference model. Eventually, the implant analogs were connected to the copings with the help of the guide pins and the impression was poured.

For the other techniques (snap-on), the abutments (Dio SM cemented abutments; Dio Corporation), 4.3 mm diameter and with a 1-millimeter cuff, were attached to the implants with a torque of 10 Ncm, and for making impressions with the abutments, plastic snap-on impression copings (regular impression caps, SASI 4810(II); Dio Corporation) were used. These snap-on copings were uniquely designed to enable the passage of a guide pin through them. In the case of the NCS technique, the plastic

snap-on impression copings were placed on the abutments (Fig. 2) and an indirect impression of the assembly was made. In the NOS and SOS techniques, the plastic snap-on impression copings were used for direct impressions. For this purpose, the abutments, along with the plastic impression copings, were placed on the implants, and then a guide pin was used to tighten the abutment and impression coping assembly (Fig. 3). In the SOS technique, unlike in the NOS technique, splinting was performed, as described for the 1st technique (Fig. 4).

Fig. 2. Non-splinted closed-tray snap-on technique (NCS). The abutments were tightened on the model and the plastic impression copings were placed over them

Fig. 3. Non-splinted open-tray snap-on technique (NOS). The abutment–plastic impression coping assembly was tightened to the model with a long guide pin

Fig. 1. Splinted open-tray technique with metal impression copings (SOM). The impression copings were splinted with auto-polymerizing acrylic resin

Fig. 4. Splinted open-tray snap-on technique (SOS). The abutment–plastic impression coping assembly was tightened to the model with a long guide pin and splinted with auto-polymerizing acrylic resin

All impressions were made using polyether elastomeric impression material (Impergum™; 3M ESPE, St. Paul, USA) by an experienced technician in a temperature-controlled environment. A 1.5-kilogram metal block was used for standard load application to each tray during the polymerization of the impression material.²² To simulate intraoral conditions, the impressions were set in distilled water at $37 \pm 2^\circ\text{C}$. The impressions were poured after 2–3 h with type IV dental stone (GC Fujirock EP) at a 30 g/7 mL ratio, according to the standard technique.¹⁶ Prior to the removal of the impression from the cast, the casts were allowed to set for 2 h. One technician performed all laboratory procedures and new pieces were used for each impression. To achieve dimensional stability, the casts were stored for 7 days prior to measurements.²⁶

All 40 casts were analyzed in terms of 3D accuracy with a coordinate measuring machine (Miracle Series CMM; Qingdao Leader Metrology Instruments Co., Ltd., Qingdao, China) connected to a computer. After ensuring the calibration of the device, all measurements were made by a researcher blinded to the group allocation of the casts (different impression techniques). The measurements on each cast were performed in triplicate and the mean values were calculated. The measurements were made according to Buzayan et al.²⁸; the implants were numbered 1–4 from left to right. The center of each implant was determined by the coordinate measuring machine probe touching 4 points at the periphery of its external margin. The center of implant #1 was considered as the reference point for all measurements in the X, Y, and Z axes. A hypothetical line passing through the centers of implants #1 and #4 indicated the Y axis. The distance between the center of each implant and that of implant #1 in the X and Y axes, and the vertical distance between the planes of each implant relative to implant #1 were measured to determine the inter-implant distances in the Z axis. The discrepancies between the measured values and the corresponding values on the reference model were calculated (ΔX , ΔY and ΔZ). The mean values of the discrepancies for each implant in each of the X, Y and Z axes were then calculated for each cast. The following formula was used to calculate the 3D discrepancy value for each implant (Equation 1):

$$d = \sqrt{(X_r - X_i)^2 + (Y_r - Y_i)^2 + (Z_r - Z_i)^2} \quad (1)$$

where:

d – 3D discrepancy;

X_r , Y_r , Z_r – inter-implant distances relative to the reference point in the reference model; and

X_i , Y_i , Z_i – inter-implant distances relative to the reference point on the master cast.

Next, the mean spatial position of each cast was calculated. The data was then statistically analyzed.

Statistical analysis

The Shapiro–Wilk test confirmed a normal distribution of the data. Thus, the one-way analysis of variance (ANOVA) followed by Tukey's post-hoc tests were used to compare the mean linear discrepancies in each of the X, Y and Z axes, and the 3D discrepancies between different impression techniques. The level of significance was set at 0.05. In data analysis, since deviation in any direction is equally unacceptable, all distortion values were considered 'positive'.^{28,29}

Results

Table 1 shows the means (M) and standard deviations (SD) of the linear discrepancies in each of the X, Y and Z axes, and the 3D discrepancies for different impression techniques. The overall analysis showed significant differences in the 3D discrepancy values ($p = 0.022$) and the linear discrepancy values ($p < 0.001$) in the Z axis between different impression techniques, whereas differences for the X and Y axes were not significant ($p = 0.055$ and $p = 0.080$, respectively). In the Z axis, the discrepancy values in the SOM, NOS and SOS groups were significantly lower as compared to the NCS group ($p < 0.001$). In terms of 3D discrepancy, the SOM group showed the maximum and the SOS group showed the minimum discrepancy, and the difference between these 2 groups was statistically significant ($p = 0.016$).

Discussion

Accurate implant impression-making and the subsequent fabrication of a precise master cast are critical steps for achieving a passive fit and minimizing clinical complications.¹⁶ Thus, many attempts have been made to introduce novel impression techniques. This study evaluated modified impression techniques using plastic snap-on impression copings. The results revealed significant differences in the 3D accuracy of different implant-level impression techniques with plastic snap-on and metal impression copings. Thus, the null hypothesis of the study regarding the absence of a significant difference in the 3D accuracy of master casts fabricated by means of different impression techniques was refuted.

Many factors, i.e., the type of impression material, can affect the accuracy of impression techniques.¹⁶ In this study, polyether impression material was used for all impressions. Polyether impression material has excellent properties, such as a high tear resistance, the favorable reconstruction of details, a high accuracy, and excellent dimensional stability, which make it suitable for dental implants.³ Nonetheless, some studies have reported no differences in accuracy between polyether and polyvinyl siloxane impression material for implant impressions.^{30,31}

Table 1. Linear and three-dimensional (3D) discrepancies [mm] for the 4 impression techniques ($n = 10$)

Impression technique	X axis	Y axis	Z axis	3D
SOM	0.229 $\pm$ 0.152	0.137 $\pm$ 0.106	0.017 $\pm$ 0.017	0.280 $\pm$ 0.165
NCS	0.164 $\pm$ 0.115	0.096 $\pm$ 0.082	0.075 $\pm$ 0.044	0.221 $\pm$ 0.119
NOS	0.146 $\pm$ 0.082	0.096 $\pm$ 0.087	0.014 $\pm$ 0.009	0.187 $\pm$ 0.098
SOS	0.125 $\pm$ 0.071	0.057 $\pm$ 0.061	0.023 $\pm$ 0.014	0.149 $\pm$ 0.076

Data presented as mean $\pm$ standard deviation ($M \pm SD$).

Although splinting in impression-making is time-consuming, it can transfer the inter-implant relationship to the cast more accurately and prevent the rotation of impression copings.³² Various materials, such as impression plaster, polyether, light-polymerized composite resin, and auto-polymerizing acrylic resin with or without dental floss, are used for splinting; however, auto-polymerizing acrylic resin is most commonly used for this purpose.¹¹ A previous work has shown that the volumetric shrinkage of acrylic resin is 7.9% in the first 24 h, 80% of which occurs in the first 17 min after mixing at room temperature.³³ Thus, it is recommended to fabricate the splint 1 day prior to impression-making.^{6,34} Also, it is recommended to cut the fabricated splint after setting and reattach it again with the same material to minimize volumetric shrinkage.³⁵ In this study, auto-polymerizing acrylic resin and dental floss were used for the splinted techniques. Also, since the shrinkage is proportionate to the amount of resin, the thickness of the splint bar was standardized using a silicon mold.^{11,28}

Many studies have assessed the accuracy of implant impressions with the use of a Vernier caliper, a micrometer, a strain gauge, or a measuring microscope, which only enable two-dimensional (2D) measurements and cannot specify the direction of distortion.^{36–38} Thus, a coordinate measuring machine was used in the current study, as it has a high accuracy and reproducibility, and is less dependent on the operator as compared to other methods.²⁶ Moreover, we used the “relative” distortion analysis suggested by Buzayan et al.,²⁸ which allowed for the inter-implant distances to be measured linearly and three-dimensionally relative to implant #1.

According to the current results, the implant-level splinted open-tray snap-on impression technique was significantly more accurate than the splinted open-tray technique with metal impression copings. As mentioned earlier, no previous study has compared these 2 impression techniques, and thus there is no previous work to compare our results with. However, many studies have compared the accuracy of indirect snap-on and direct impression techniques with metal impression copings. In the current study, the 2 abovementioned impression techniques showed no significant difference in the 3D accuracy of the casts, which is in line with the findings of some previous research.^{3,4,19,24,26} However, some differences exist in the methodology and the techniques employed across these studies.

Nakhaei et al. found that the implant-level snap-on impression technique had similar 3D accuracy to the open-tray technique.⁴ These authors used the non-splinted open-tray technique and a specific implant-level impression coping for the snap-on impression technique.⁴ Similarly, Teo et al. showed that the 3D accuracy of the abutment-level snap-on impression technique was comparable to that of the implant-level non-splinted direct technique when the inter-implant angulation was lower than 15°.¹⁹ According to the results of Akça and Cehreli, the angular and positional accuracy of the snap-on closed-tray technique with a stock tray and polyvinyl siloxane impression material was similar to that of the non-splinted open-tray technique with metal impression copings and polyether impression material.²⁴ In a study by Wegner et al., the 3D accuracy of the snap-on technique was comparable to that of the non-splinted direct technique.²⁶ Alikhasi et al. evaluated the 3D accuracy of the abutment-level snap-on impression technique and the implant-level open-tray and closed-tray techniques for a three-unit fixed partial denture.³ It was found that the magnitude of displacement in the X, Y and Z axes was similar for those different techniques, while the angular displacement was greater in the snap-on technique.³

Some studies have also reported contradictory results. Walker et al. observed that the 3D accuracy of the indirect impression technique with metal impression copings was higher than that of the impression technique with plastic impression caps at the implant level or the abutment level.²³ Tsagkalidis et al. studied the 3D accuracy of the indirect snap-fit techniques (impression copings along with impression caps) and the splinted and non-splinted direct techniques, and reported that the splinted impression technique provided maximum accuracy, while the snap-fit indirect technique showed minimum accuracy.¹¹ A study by Izadi et al. was among the limited studies that, similar to the current study, used the snap-on technique and the respective abutment for the implant-level impression; however, the authors used the closed-tray technique.²² That study showed that the accuracy of the snap-on technique was lower than that of the non-splinted open-tray technique and similar to that of the closed-tray technique with metal impression copings.²² Fernandez et al. showed that the comparison of impression techniques would yield different results for different implant systems.²⁵ For example, with the use of the Straumann® implant system, metal impression copings yielded a higher accuracy than

the snap-on technique, while with the use of NobelReplace® implant system, no difference was detected between different impression techniques. Thus, impression techniques should be evaluated with regard to different implant systems.²⁵

The current results revealed no significant differences in the 3D accuracy of different snap-on impression techniques. The difference between the open-tray and closed-tray snap-on techniques was not significant, and splinting did not yield a higher accuracy. Several studies have compared the accuracy of the open-tray and closed-tray impression techniques, reporting conflicting results. A systematic review by Kim et al. evaluated relevant articles published in 1990–2013.²⁰ Of the retrieved articles, most supported the open-tray technique, and only one study supported the use of the closed-tray technique.²⁰ Other studies found no significant differences between the 2 techniques. Several studies have also evaluated the effect of splinting on the accuracy of impressions, reporting conflicting results. However, the majority of them noted that the splinting of impression copings yielded superior results.^{5,20,39,40} The current results are in line with studies that found no significant differences in the accuracy of the implant-level splinted and non-splinted impression techniques for a complete dental arch.^{41–43} The discrepancies across studies may be due to differences in the study design, the number of implants, the implant system or the impression material used, splinting, the choice of the implant-level or abutment-level impression, the operator's expertise, the implant angulation, and dental stone expansion.^{11,28} However, it should be noted that no study compared the open-tray and closed-tray or splinted and non-splinted snap-on techniques. This can largely explain the differences in results.

Limitations

One limitation of the current study is the assessment of the accuracy of the impression techniques in the parallel placement of implants in the reference model, which is an ideal situation. Different results may be obtained with the angulated placement of implants, as the effect of the implant angulation on the impression accuracy has been previously confirmed.²⁰ On the other hand, factors such as temperature, moisture and saliva in the oral cavity, which could not be simulated in this in vitro study, might affect the results. Moreover, the reference model used in this study was rigid and made of acrylic resin, different from flexible intraoral soft tissues, which easily undergo distortion upon load application. Due to the different nature of tissue undercuts in the oral cavity in comparison with the in vitro setting, load, the direction of the removal of the impression tray and its subsequent distortion in vitro are different from the clinical setting. Thus, long-term in vivo studies are required to obtain more accurate results.

Conclusions

Within the limitations of this in vitro study, it may be concluded that in a completely edentulous dental arch with 4 parallel dental implants, the 3D accuracy of different snap-on impression techniques (non-splinted closed-tray, non-splinted open-tray and splinted open-tray) is the same. However, the implant-level splinted open-tray impression technique with plastic snap-on impression copings showed a significantly higher accuracy than the splinted open-tray impression technique with metal impression copings.

ORCID iDs

Hamid Neshandar Asli <https://orcid.org/0000-0003-3883-1195>

Yasamin Babaee Hemmati <https://orcid.org/0000-0002-6739-9971>

Mehran Falahchahi <https://orcid.org/0000-0001-9661-5509>

References

1. Tandon A, Bulbule NS, Jagtap AK, Kakade DM. Comparative evaluation of the dimensional accuracy of closed tray and open tray impression technique for dental implants using two different impression materials. *J Clin Diagn Res.* 2018;12(11):34–38. doi:10.7860/JCDR/2018/36235.12296
2. Ekelund JA, Lindquist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: A prospective study on Brånemark system implants over more than 20 years. *Int J Prosthodont.* 2003;16(6):602–608.
3. Alikhasi M, Siadat H, Monzavi A, Momen-Heravi F. Three-dimensional accuracy of implant and abutment level impression techniques: Effect on marginal discrepancy. *J Oral Implantol.* 2011;37(6):649–657. doi:10.1563/AAID-JOI-D-09-00112.1
4. Nakhaei M, Madani AS, Moraditalab A, Haghi HR. Three-dimensional accuracy of different impression techniques for dental implants. *Dent Res J (Isfahan).* 2015;12(5):431–437. doi:10.4103/1735-3327.166190
5. Moreira AHJ, Rodrigues NF, Pinho ACM, Fonseca JC, Vilaça JL. Accuracy comparison of implant impression techniques: A systematic review. *Clin Implant Dent Relat Res.* 2015;17(Suppl 2):e751–e764. doi:10.1111/cid.12310
6. Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. *Int J Oral Maxillofac Implants.* 1996;11(2):216–222.
7. Naert I, Quirynen M, van Steenberghe D, Darius P. A study of 589 consecutive implants supporting complete fixed prostheses. Part II: Prosthetic aspects. *J Prosthet Dent.* 1992;68(6):949–956. doi:10.1016/0022-3913(92)90557-q
8. Carlson B, Carlsson GE. Prosthodontic complications in osseointegrated dental implant treatment. *Int J Oral Maxillofac Implants.* 1994;9(1):90–94.
9. Arora A, Upadhyaya V, Parashar KR, Malik D. Evaluation of the effect of implant angulations and impression techniques on implant cast accuracy – an in vitro study. *J Indian Prosthodont Soc.* 2019;19(2):149–158. doi:10.4103/jips.jips_337_18
10. Osman MS, Ziada HM, Abubakr NH, Suliman AM. Implant impression accuracy of parallel and non-parallel implants: A comparative in-vitro analysis of open and closed tray techniques. *Int J Implant Dent.* 2019;5(1):4. doi:10.1186/s40729-019-0159-5
11. Tsagkalidis G, Tortopidis D, Mpikos P, Kaisarlis G, Koidis P. Accuracy of 3 different impression techniques for internal connection angulated implants. *J Prosthet Dent.* 2015;114(4):517–523. doi:10.1016/j.prosdent.2015.05.005
12. Papaspyridakos P, Lal K, White GS, Weber HP, Gallucci GO. Effect of splinted and nonsplinted impression techniques on the accuracy of fit of fixed implant prostheses in edentulous patients: A comparative study. *Int J Oral Maxillofac Implants.* 2011;26(6):1267–1272.
13. Pera F, Pesce P, Bevilacqua M, Setti P, Menini M. Analysis of different impression techniques and materials on multiple implants through 3-dimensional laser scanner. *Implant Dent.* 2016;25(2):232–237. doi:10.1097/ID.0000000000000353

14. Ma J, Rubenstein JE. Complete arch implant impression technique. *J Prosthet Dent.* 2012;107(6):405–410. doi:10.1016/S0022-3913(12)60100-0
15. 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(Suppl 1):e63–e76. doi:10.1111/j.1708-8208.2009.00167.x
16. Tabesh M, Alikhasi M, Siadat H. A comparison of implant impression precision: Different materials and techniques. *J Clin Exp Dent.* 2018;10(2):e151–e157. doi:10.4317/jced.54457
17. Mpikos P, Kafantaris N, Tortopidis D, Galanis C, Kaisarlis 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(6):1422–1428.
18. Lee H, Ercoli C, Funkenbusch PD, Feng C. Effect of subgingival depth of implant placement on the dimensional accuracy of the implant impression: An in vitro study. *J Prosthet Dent.* 2008;99(2):107–113. doi:10.1016/S0022-3913(08)60026-8
19. Teo JW, Tan KB, Nicholls JL, Wong KM, Uy J. Three-dimensional accuracy of plastic transfer impression copings for three implant systems. *Int J Oral Maxillofac Implants.* 2014;29(3):577–584. doi:10.11607/jomi.3382
20. Kim JH, Kim KR, Kim S. Critical appraisal of implant impression accuracies: A systematic review. *J Prosthet Dent.* 2015;114(2):185–192.e1. doi:10.1016/j.prosdent.2015.02.005
21. Papaspyridakos P, Chen CJ, Gallucci GO, Doukoudakis A, Weber HP, Chronopoulos V. Accuracy of implant impressions for partially and completely edentulous patients: A systematic review. *Int J Oral Maxillofac Implants.* 2014;29(4):836–845. doi:10.11607/jomi.3625
22. Izadi A, Heidari B, Roshanaei G, Allahbakhshi H, Fotovat F. Comparative study of dimensional accuracy in three dental implant impression techniques: Open tray, closed tray with impression coping, and snap cap. *J Contemp Dent Pract.* 2018;19(8):974–981.
23. Walker MP, Ries D, Borello B. Implant cast accuracy as a function of impression techniques and impression material viscosity. *Int J Oral Maxillofac Implants.* 2008;23(4):669–674.
24. Akça K, Cehreli MC. Accuracy of 2 impression techniques for ITI implants. *Int J Oral Maxillofac Implants.* 2004;19(4):517–523.
25. Fernandez MA, Paez de Mendoza CY, Platt JA, Levon JA, Hovijitra ST, Nimmo A. A comparative study of the accuracy between plastic and metal impression transfer copings for implant restorations. *J Prosthodont.* 2013;22(5):367–376. doi:10.1111/jopr.12015
26. Wegner K, Weskott K, Zenginel M, Rehmann P, Wöstmann B. Effects of implant system, impression technique, and impression material on accuracy of the working cast. *Int J Oral Maxillofac Implants.* 2013;28(4):989–995. doi:10.11607/jomi.2938
27. Saboury A, Asli HN, Kajan ZD. The accuracy of four impression-making techniques in angulated implants based on vertical gap. *J Dent (Shiraz).* 2017;18(4):289–297.
28. 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(6):1512–1520. doi:10.11607/jomi.2958
29. 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(6):676–681. doi:10.1111/j.1600-0501.2011.02219.x
30. Yeshwante BJ, Gaikwad SV, Baig N, Patil S, Shaikh WA. Comparative evaluation between accuracy of implant impression techniques: A systematic review. *IOSR J Dent Med Sci.* 2015;14(4):30–36. doi:10.9790/0853-144103036
31. Wee AG. Comparison of impression materials for direct multi-implant impressions. *J Prosthet Dent.* 2000;83(3):323–331. doi:10.1016/S0022-3913(00)70136-3
32. Hariharan R, Shankar C, Rajan M, Baig MR, Azhagarasan NS. Evaluation of accuracy of multiple dental implant impressions using various splinting materials. *Int J Oral Maxillofac Implants.* 2010;25(1):38–44.
33. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. *J Prosthet Dent.* 1990;64(6):684–688. doi:10.1016/0022-3913(90)90296-o
34. Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An evaluation of impression techniques for multiple internal connection implant prostheses. *J Prosthet Dent.* 2004;92(5):470–476. doi:10.1016/j.prosdent.2004.08.015
35. Kurtulmus-Yilmaz S, Ozan O, Ozcelik TB, Yagiz A. Digital evaluation of the accuracy of impression techniques and materials in angulated implants. *J Dent.* 2014;42(12):1551–1559. doi:10.1016/j.jdent.2014.10.008
36. Daoudi MF, Setchell DJ, Searson LJ. A laboratory investigation of the accuracy of two impression techniques for single-tooth implants. *Int J Prosthodont.* 2001;14(2):152–158.
37. Spector MR, Donovan TE, Nicholls JL. An evaluation of impression techniques for osseointegrated implants. *J Prosthet Dent.* 1990;63(4):444–447. doi:10.1016/0022-3913(90)90235-5
38. Liou AD, Nicholls JL, Yuodelis RA, Brudvik JS. Accuracy of replacing three tapered transfer impression copings in two elastomeric impression materials. *Int J Prosthodont.* 1993;6(4):377–383.
39. Dorigatti de Avila E, de Matos Moraes F, Castanharo SM, Antonialli Del'Acqua M, de Assis Mollo F Jr. Effect of splinting in accuracy of two implant impression techniques. *J Oral Implantol.* 2014;40(6):633–639. doi:10.1563/AAID-JOI-D-12-00198
40. Yamamoto E, Marotti J, de Campos TT, Neto PT. Accuracy of four transfer impression techniques for dental implants: A scanning electron microscopic analysis. *Int J Oral Maxillofac Implants.* 2010;25(6):1115–1124.
41. Chang WG, Vahidi F, Bae KH, Lim BS. Accuracy of three implant impression techniques with different impression materials and stones. *Int J Prosthodont.* 2012;25(1):44–47.
42. Mostafa TMN, Elgendy MNM, Kashef NA, Halim MM. Evaluation of the precision of three implant transfer impression techniques using two elastomeric impression materials. *Int J Prosthodont.* 2010;23(6):525–528.
43. Lee YJ, Heo SJ, Koak JY, Kim SK. Accuracy of different impression techniques for internal-connection implants. *Int J Oral Maxillofac Implants.* 2009;24(5):823–830.