Dental Research Journal

Original Article

Three-dimensional accuracy of different impression techniques for dental implants

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ABSTRACT

Background: Accurate impression making is an essential prerequisite for achieving a passive fit between the implant and the superstructure. The aim of this *in vitro* study was to compare the three-dimensional accuracy of open-tray and three closed-tray impression techniques.
Materials and Methods: Three acrylic resin mandibular master models with four parallel implants were used: Biohorizons (BIO), Straumann tissue-level (STL), and Straumann bone-level (SBL). Forty-two putty/wash polyvinyl siloxane impressions of the models were made using open-tray and closed-tray techniques. Closed-tray impressions were made using snap-on (STL model), transfer coping (TC) (BIO model) and TC plus plastic cap (TC-Cap) (SBL model). The impressions were poured with type IV stone, and the positional accuracy of the implant analog heads in each dimension (x, y and z axes), and the linear displacement (ΔR) were evaluated using a coordinate measuring machine. Data were analyzed using ANOVA and *post-hoc* Tukey tests ($\alpha = 0.05$).
Results: The ΔR values of the snap-on technique were significantly lower than those of TC and TC-Cap techniques ($P < 0.001$). No significant differences were found between closed and open impression techniques for STL in Δx, Δy, Δz and ΔR values ($P = 0.444$, $P = 0.181$, $P = 0.835$ and $P = 0.911$, respectively).
Conclusion: Considering the limitations of this study, the snap-on implant-level impression technique resulted in more three-dimensional accuracy than TC and TC-Cap, but it was similar to the open-tray technique.

Key Words: Dental implants, dental impression materials, dental impression technique

Received: December 2014
Accepted: May 2015

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INTRODUCTION

A passively fitting prosthesis is considered an essential prerequisite for maintaining osseointegration.[1,2] This is related to the fact that dental implants, unlike natural teeth, lack the cushioning effect of periodontal fibers and cannot completely accommodate the demands of the superstructure. Misfit of the implant prostheses might induce strains on the components, consequently resulting in mechanical and biological complications.[3,4] Therefore, fastidious and accurate implant prosthodontic procedures are a necessity to achieve a passive fit, and undoubtedly accurate impression making is a crucial step in this process.

Traditionally, there are two different impression techniques: Direct (open-tray) and indirect (closed-tray). Although greater accuracy has been reported for the direct technique,[5,6] certain clinical

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Website: www.drj.ir
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How to cite this article: Nakhaei M, Madani AS, Moraditalab A, Haghi HR. Three-dimensional accuracy of different impression techniques for dental implants. Dent Res J 2015;12:431-7.

situations such as limited access to implants in the posterior region, limited interarch space and a tendency to gag dictate the use of the closed-tray technique.[7,8]

To date, dental implant systems have introduced various components in order to enhance the accuracy and simplicity of the closed-tray impression technique. Most implant systems use a two-piece transfer coping (TC) which remains on the implant after impression removal and must be removed and carefully inserted into its respective position in the impression. While this approach is simple, there is also the potential for inaccuracy due to incorrect insertion of the TC in its original position.[9,10] To solve this problem, some implant systems utilize a plastic cap and a TC for closed-tray impression technique. On removal of the impression from the oral cavity, the plastic cap is picked up in the impression to reduce errors which might occur in repositioning of TCs.[11-13] It has been reported that the application of this technique results in dimensional accuracy similar to that achieved with a direct technique.[11]

The snap-on technique is another approach, in which the impression components are placed on the transmucosal neck of the implant and are picked up in the impression without any screws.[8,13-17] Although not considered a direct impression technique, this method combines the advantages of both direct and indirect techniques.[6,15,17] Similar or even higher transfer accuracy has been reported for the snap-on technique in comparison to the direct technique.[13,15] However, the three-dimensional position of the components might change in the impression during tray removal, especially when multiple nonparallel implants are present.[8,14,15]

The use of these impression techniques is recommended by the manufacturers without any limitation in terms of the number and divergence of implants. However, no investigation was found, comparing the accuracy of different closed-tray impression techniques. Therefore, the aim of this study was to compare the accuracy of three closed-tray impression techniques: Snap-on, TC and TC-Cap, with their corresponding open-tray techniques in three dental implant systems: Straumann tissue-level (STL), Straumann bone-level (SBL), and Biohorizons (BIO). The null hypothesis was that there would be no differences in three-dimensional accuracy between different impression techniques for dental implants.

MATERIALS AND METHODS

Three acrylic resin edentulous mandible reference models were used. Four parallel holes, 4.5 mm in diameter and 12 mm in length, were created in the first premolar and lateral incisor regions of each model with a milling machine (K9, Kavo, Berlin, Germany). BIO (PGR4012, BIO, Alabama, USA) implants, STL implants (043.922S, Straumann AG, Basel, Switzerland) and SBL implants (021.2612, Straumann) were inserted into the prepared holes of each corresponding model using a surveyor. The implants were secured using auto-polymerizing acrylic resin (Acropars, Marlic Co., Tehran, Iran), leaving 1 mm of the implant platforms above the acrylic resin.

Closed-tray and open-tray impressions were made of each model using metal stock trays. For open-tray impressions, a 7 mm hole was made in the area of each implant. One-step putty/wash technique was used for impression making in all the samples in accordance with the manufacturer's instructions (Panasil; Kettenbach Dental, Eschenburg, Germany). The stock trays were painted with polyvinyl siloxane adhesive (VPS Tray Adhesive; 3M ESPE, Seefeld, Germany) 15 min prior to the impression taking procedure. The impression/model set was placed in distilled water at 36 °C ± 1°C during polymerization while a standard 5 kg weight was placed over the tray. After 5 min, the impression was separated from the model.

A direct impression of each model was made using the impression coping from its corresponding implant system [Figure 1a-c]. The impression copings were fastened on the implants with 10 Ncm torque, as recommended by Vigolo *et al*.[18] and Inturregui *et al*.[19] Once the impression was made, the guide pins were loosened and the tray was separated from the model. The implant analogs were fitted to the impression copings and the guide pins were tightened using a 10 Ncm torque.

A closed-tray impression was taken from each model using available components from the corresponding system. A two-piece TC (PXBT and PGREA, BIO) was used for BIO implants [Figure 1d]. The TCs were secured onto the implants and torqued to 10 Ncm. The impression was made and separated while the TCs remained attached to the model. The copings were removed and connected to implant analogs

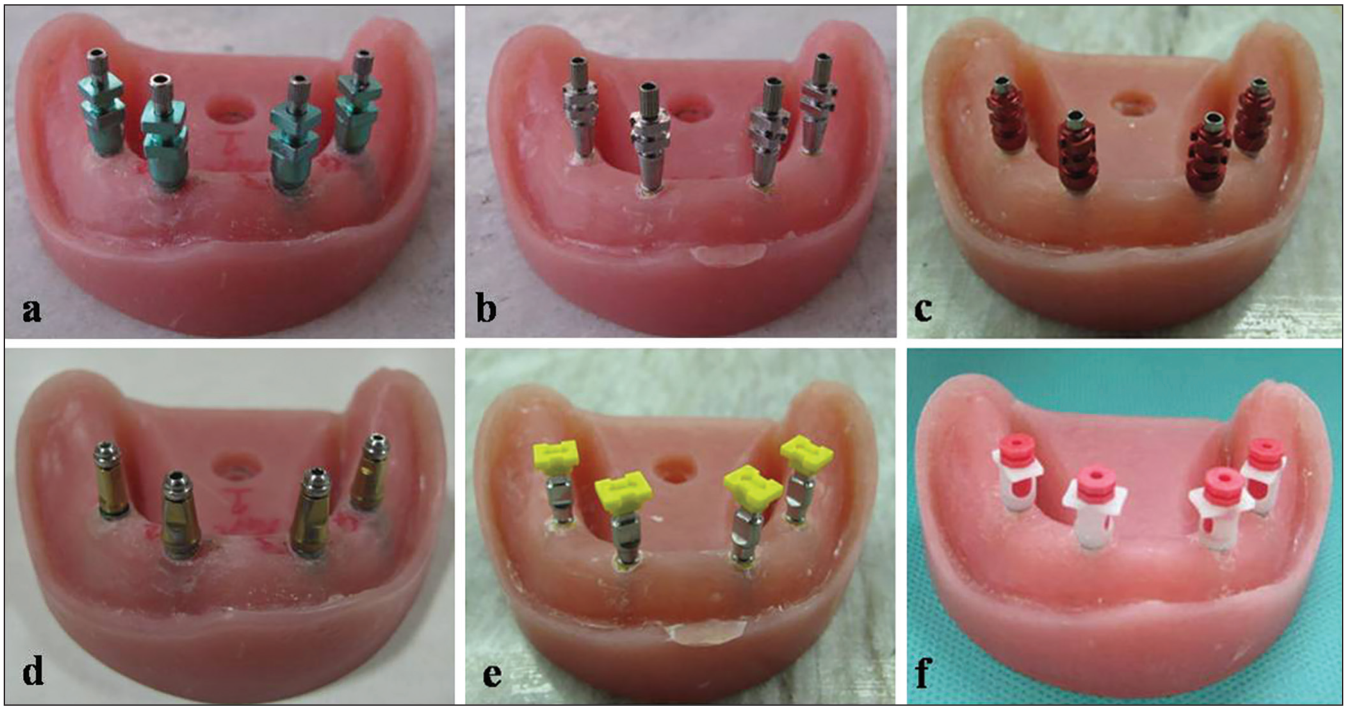

Figure 1: The acrylic resin master models with open-tray and closed-tray impression components. Impression copings with guide screws of Biohorizons (a), Straumann bone-level (b), and Straumann tissue-level (c) implants. (d) Transfer copings of Biohorizons implant system. (e) Transfer copings plus plastic caps of Straumann bone-level system. (f) Snap-on components of Straumann tissue-level system.

(PGIA, BIO) with a 10 Ncm torque. The combined TC-analog unit was inserted into the impression by firmly driving it into place to full depth and slightly rotating it clockwise to feel the antirotational resistance.

A metal TC and a plastic cap (TC-Cap) (025.2201, Straumann) were used for SBL implants [Figure 1e]. The TCs were placed onto the implants and tightened with a 10Ncm torque. The impression caps were then placed on top of the TCs and pushed in an apical direction until they clicked. After the material had set, the tray was removed, the impression caps were retained in the impression and the TCs were left behind. The TCs were adapted to the implant analogs (025.2101, Straumann) and fastened using a 10 Ncm torque. The combined TC-analog units were pushed gently into the impression caps embedded in the impression until a tactile response of engagement was felt.

A snap-on impression cap (048.017V4, Straumann) and a plastic position cylinder (048.070V4, Straumann) were utilized for STL implants. The impression caps were snapped onto the implant shoulder until they clicked into place. The impression caps were turned gently to ensure their correct position. The plastic position cylinders were then pushed into the impression caps [Figure 1f]. Once the impression material had set, the implant analogs (048.124, Straumann) were inserted into the impression caps and the position cylinders were embedded in the impression until they clicked.

A total of 42 impressions, consisting of 7 open-tray and 7 closed-tray impressions for each of the three reference models were made. After 60 min, the impressions were boxed and poured with type IV die stone (Herostone, Vigodent Inc, Rio de Janeiro, Brazil) with a powder-to-water ratio of 30 g/7 ml, according to the manufacturer's instructions. After 120 min the impressions were removed from stone casts.

The three-dimensional position of the implant and the implant analog heads in x, y, and z axes were evaluated using a coordinate measuring machine (CMM) (Cyclone II, Renishaw, Gloucestershire, UK) with an accuracy of 2.8 μm. All the measurements were made by a single calibrated operator who was blinded to the impression techniques used. For each master model, the local coordinate axes were defined with several probe hits on each of the exposed vertical and horizontal surfaces. The respective stone surfaces on the cast models were also used to define the local coordinate axes. Placement of the machine probe in contact with several points on the platform of each implant on the reference models and each implant analog on the casts yielded an imaginary plane. A circle was drawn on this plane, and its center was defined, which allowed determination and recording of the three-dimensional position of the center of each implant or implant analog aperture [Figure 2]. Each experimental cast was measured 3 times (an average was recorded), and the distances from the reference point on the center of the superior surface were compared with the master model.

Linear displacements of implant analogs compared to fixtures were calculated in three axes (Δx, Δy, and Δz). The equation $\Delta R^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$ was also used to calculate the overall three-dimensional linear displacement (ΔR).

Paired-sample *t*-test was used to compare the outcome of the closed-tray technique with that of the open-tray technique in each of the three implant systems. One-way ANOVA was used for comparison of the three implant systems in each of the two impression techniques. *Post-hoc* Tukey test was applied when there was a significant difference. A significance level of $P < 0.05$ was used for all the comparisons.

RESULTS

The means and standard deviations of linear displacement (Δx, Δy and Δz) and ΔR values of abutments in the three systems are presented in Table 1. The one-way ANOVA test revealed significant differences between close tray techniques ($P < 0.001$) [Table 2]. According to the Tukey test, the ΔR values of the snap-on technique were significantly lower than those of TC and TC-Cap techniques ($P < 0.001$) [Table 1]. However, there was no significant difference between open-tray techniques in the systems examined ($P = 0.367$) [Table 2]. No significant differences were found between the snap-on and open impression techniques for STL in Δx, Δy, Δz and ΔR values ($P = 0.444$, $P = 0.181$, $P = 0.835$ and $P = 0.911$, respectively) [Table 1].

DISCUSSION

The results of this study indicated that among the closed-tray impression techniques, snap-on technique had the highest accuracy, comparable to the open-tray technique. Thus, the null hypothesis indicating no difference between the different impression techniques for dental implants was rejected.

To date, several studies have evaluated the accuracy of the snap-on technique.[8,9,14-16] Akça and Cehreli[15] found that the angular and positional accuracy of the snap-on closed-tray technique with stock tray and vinyl polysiloxane impression material were similar to the open-tray and polyether impression material. Wegner *et al.*[13] also reported similar or even less three-dimensional displacement for the snap-on technique in comparison to the direct technique.

Similar findings were reported by Teo *et al.*,[14] who found that the three-dimensional accuracy of the snap-on abutment-level impression technique was comparable to that of the direct implant-level impression technique when the inter-implant angulations were up to 15°. Cehreli and Akça[17] evaluated the strain magnitude in screw-retained superstructures supported by two or four implants fabricated using the open-tray and snap-on impression

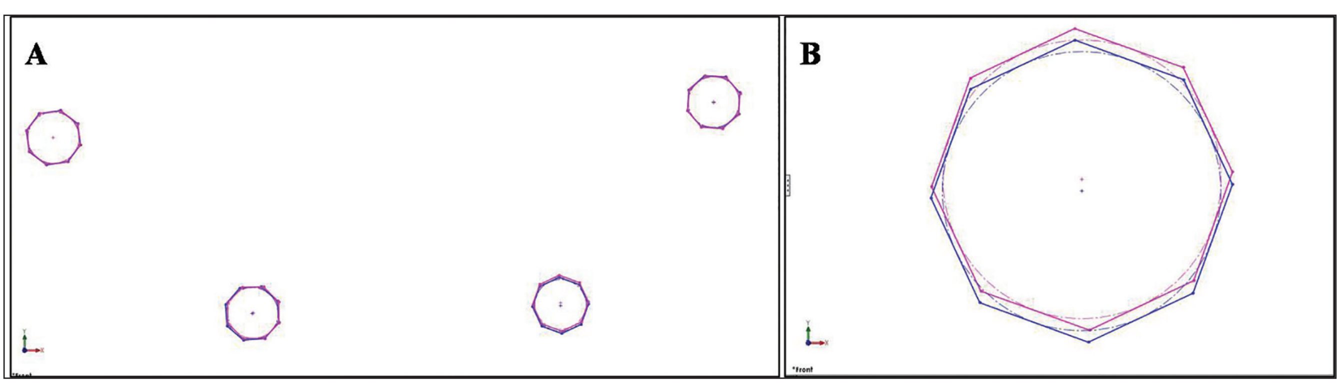

Figure 2: Schematic drawing of the coordinate measuring machine measurements. (a) The red drawing indicates measurement on the master model. (b) The blue lines show the measurements on the cast superimposed on the original diagram. + indicates the center of implant or implant analog aperture.

Table 1: Means (SD) of three-dimensional displacements (mm) in the implant systems studied

Measurement	Impression technique	Implant system		
		BIO	STL	SBL
ΔR	Open	$0.225 (0.118)^{A}_{a}$	$0.218 (0.075)^{A}_{c}$	$0.184 (0.102)^{A}_{d}$
	Close	$0.388 (0.186)^{A}_{b}$	$0.220 (0.114)^{B}_{C}$	$0.373 (0.097)^{A}_{e}$
ΔX	Open	$0.131 (0.122)^{A}_{a}$	$0.150 (0.065)^{A}_{c}$	$0.067 (0.072)^{A}_{d}$
	Close	$0.237 (0.161)^{A}_{b}$	$0.147 (0.087)^{B}_{c}$	$0.115 (0.061)^{A}_{e}$
ΔY	Open	$0.043 (0.028)^{A}_{a}$	$0.094 (0.052)^{A}_{c}$	$0.070 (0.081)^{A}_{d}$
	Close	$0.144 (0.130)^{A}_{b}$	$0.114 (0.078)^{B}_{c}$	$0.157 (0.115)^{A}_{e}$
ΔZ	Open	$0.156 (0.078)^{A}_{a}$	$0.094 (0.079)^{A}_{c}$	$0.130 (0.077)^{A}_{d}$
	Close	$0.227 (0.122)^{A}_{b}$	$0.097 (0.065)^{B}_{c}$	$0.284 (0.118)^{A}_{e}$

Different lowercase letters in the columns mean the values are significantly different ($P < 0.05$); Different uppercase letters in the rows mean the values are significantly different ($P < 0.05$). BIO: Biohorizons; STL: Straumann tissue-level; SBL: Straumann bone-level; SD: Standard deviation.

Table 2: Results of one-way ANOVA test performed separately for close and open-tray techniques

Impression technique	Source	df	Mean square	*F*	*P*
Close tray	Between groups	2	0.182	9.491	<0.001
	Within groups	60	0.019		
	Total	62			
Open-tray	Between groups	2	0.010	1.018	0.367
	Within groups	60	0.010		
	Total	62			

techniques. They demonstrated that the strain magnitude in superstructures supported by two implants was similar in both techniques. Nonetheless, the strain magnitude was less when a superstructure supported by four implants and snap-on technique were used. In another investigation by Alikhasi *et al*.[16] the accuracy of the snap-on abutment-level impression method was compared to implant-level impression methods (open and closed-tray). The authors reported no differences in Δx, Δy, Δz and ΔR among the three implant impression methods tested, although implant-level impression methods exhibited less angular displacement. It should be noted that the two latter studies employed 2-implant master models to simulate three-unit fixed partial dentures. In contrast, Walker *et al*.[8] reported that the closed-tray impression technique with metal impression coping was more accurate than the snap-on abutment-level impression technique.

It has been reported that incorrect replacement of impression copings into their original position is the primary source of error in the transfer impression technique.[9] In the TC-Cap technique, the plastic cap serves as a guide to correct replacement of the TC in the impression. Nevertheless, no difference was observed in impression accuracy between TC and TC-Cap in the current study, consistent with the findings of Lorenzoni *et al*.[12] This can be attributed to low stability of the TC inside the impression cap that is, embedded in the impression because a small section of the TC (its head) is engaged inside the resin cap. This can lead to the displacement of TC due to the movement of the impression (such as during impression pouring with gypsum).

It has been demonstrated that the shape and geometry of the metal impression coping could affect the accuracy of the open-tray impression technique.[20] In the current study, the impression copings were nearly similar in terms of length, width and indentation depth, which might explain why no difference was detected in the accuracy of the open-tray technique in the implant systems studied. It is true that different results might have been obtained if nonparallel implants had been employed since internal connections of the systems evaluated were not identical, and this would have resulted in different distortions during impression removal.[14]

The polyvinyl siloxane was chosen as the impression material in this investigation due to its acceptable outcome for complete-arch multi-implant impressions.[11,21-23] Ideal properties, including high modulus of elasticity, excellent resistance to permanent deformation and high rigidity of putty, make it a favorable material for implant impression making.[24,25] Although polyether has been the material of choice in many studies, using putty/wash polyvinyl siloxane impression material, especially when employed with the stock tray, has gained popularity in recent years.[15,26,27]

An osseointegrated implant is extremely restricted in bone and has very little movement, that is, approximately 10 µm. Therefore, inter-abutment or inter-implant cast discrepancies larger than 10 µm have the potential to cause misfit of multiple implant-supported restorations.[8,13] Thus, any increase in the number of and distance between implants is anticipated to exacerbate misfit problems.

Studies comparing the accuracy of implant impression techniques with methods such as micrometers, Vernier calipers, strain gauges, or measuring microscopes could merely carry out two-dimensional measurements.[9,14,17,25,28] Hence, CMM was selected because it made three-dimensional evaluation of any distortion possible.

The presence of an angle between the implants is a factor that influences impression accuracy. Although the present study demonstrated that the snap-on impression technique had accuracy comparable to the open-tray technique, the results of this study are limited to four parallel implants and could not be extrapolated to clinical situations in which there are multiple, tilted, widely apart implants. Another factor that limits extrapolation of these findings to clinical situations is that tray removal was not similar to the mouth and was performed perpendicular to the occlusal plane. Further studies are needed to determine the effect of different closed-tray techniques on accurate transfer of implant position in the presence of nonparallel implants.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. The snap-on impression technique exhibited better three-dimensional transfer compared to TC and TC-Cap.
2. The three-dimensional accuracy of snap-on impression technique was comparable to that of the open-tray technique.
3. The open-tray impression technique exhibited higher accuracy in comparison to closed-tray technique with TC and TC-Cap.

ACKNOWLEDGMENTS

This study was supported by a grant (No. 901158) from the Vice Chancellor for Research of Mashhad University of Medical Sciences. The results presented here are based on a postgraduate thesis (No. 476) submitted to Mashhad School of Dentistry and Dental Research Center.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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