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Effect of different impression materials and techniques on the dimensional accuracy of implant definitive casts

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ABSTRACT

Background: Different factors such as impression techniques and materials can affect the passive fit between the superstructure and implant. The aim of this study was to determine the effect of different impression materials and techniques on the dimensional accuracy of implant definitive casts.

Materials and Methods: Four internal hex implants (Biohorizons Ø4 mm) were placed on a metal maxillary model perpendicular to the horizontal plane in maxillary lateral incisors, right canine and left first premolar areas. Three impression techniques including open tray, closed tray using ball top screw abutments and closed tray using short impression copings and two impression materials (polyether and polyvinyl siloxane) were evaluated (n = 60). The changes in distances between implant analogues in mediolateral (x) and anteroposterior (y) directions and analogue angles in x/z and y/z directions in the horizontal plane on the definitive casts were measured by coordinate measuring machine. The data were analyzed by multivariate two-way analysis of variance and one sample t-test ($\alpha = 0.05$).

Results: No statistical significant differences were observed between different impression techniques and materials. However, deviation and distortion of definitive casts had a significant difference with the master model when short impression copings and polyvinyl siloxane impression material were used ($P < 0.05$). In open tray technique, there was a significant difference in the rotation of analogs compared with the master model with both impression materials ($P < 0.05$).

Conclusion: There was no difference between open and closed tray impression techniques; however, less distortion and deviation were observed in the open tray technique. In the closed tray impression technique, ball top screw was more accurate than short impression copings.

Key Words: Dental implants, dental impression materials, dental impression techniques, dental models

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INTRODUCTION

Passive fit is a necessary requirement for the long-term success in implant-supported prostheses. The first step to ensure the passive fit of the implant-supported framework is accurate recording of the implants' positions and distances through the impression procedure.[1-4] Prosthesis misfit may lead to mechanical and biological problems in supporting implants. Mechanical complications that might arise from prosthesis misfit include screw loosening, abutment or implant screw fracture and occlusal inaccuracy.[1,2,4,5] In addition, misfit and consequently marginal gap between the abutment and prosthesis can cause plaque accumulation and undesirable reactions in the soft and hard tissues adjacent to dental implants.[6,7]

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There are many potential factors which influence the accuracy of implant-supported superstructures such as mandibular flexure, impression technique, impression material and fit tolerance between intra-oral abutments using the impression copings.[5] Various techniques have been suggested to achieve an accurate master cast. Open and closed trays are the most common techniques. In some situations, closed tray technique is preferable; however, it might be very difficult to place the impression copings into the impression material precisely.[8-10]

In open tray technique, rotation of impression copings is possible during fastening of impression copings into analogs, which may cause the misfit of components.[8]

Some studies have not shown any difference between the two techniques.[9,11] However, the other studies indicated that open tray impression technique is a more accurate technique.[8,12]

Different impression materials and techniques for splinting impression copings have been proposed to improve the accuracy of open impression technique. A study by Herbst *et al*.[13] found no difference between splinting or non-splinting impression copings. Assuncao *et al*.[14] concluded that splinting impression copings with acrylic resins was a better technique in angled implants. Papaspyridakos *et al*.[15] claimed that the splinted technique made more accurate master casts than the non-splinted technique for one-piece implant-supported fixed dental prosthesis in edentulous jaws. Rhyu *et al*.[16] suggested polyvinyl siloxane bite registration material as a splinting material and found this material to have better results than acrylic resin material for splinting. Controversial results have been obtained from different studies regarding splinting or non-splinting impression copings.[17,18]

Different impression materials have been proposed for making an impression. Polyethers and polyvinyl siloxane have been selected as materials of choice.[11,19] Lee *et al*.[20] believe polyvinyl siloxane impression materials are more precise than polyether impression materials when implants are placed deep into the gingiva.

The goal of this study was to evaluate the effect of type of impression materials and impression techniques on the dimensional accuracy of implant definitive casts.

The first null hypothesis was that there would be no difference between impression materials and techniques to make implant definitive casts. The second null hypothesis was that there would be no difference between master model and implant definitive casts made by different impression materials and techniques.

MATERIALS AND METHODS

In this experimental study, a stainless steel model of maxillary arch with 4 internal connection implants with 4 mm diameter and 10.5 mm length (SGR40105, Biohorizons, Birmingham, AL, USA) in maxillary right canine (implant no: 1) lateral incisors (implants no: 2 and 3) and left first premolar (implant no: 4) areas were used [Figure 1]. The implants were placed into their positions with one side of the internal hexagons parallel to the external side of the ridge. The crest of the ridge was made parallel to the horizontal plane with accuracy of 0.01 mm. Three spherical holes with 2 mm diameter and 1 mm depth were prepared at the distal end of both sides of the ridge and on the anterior area of the palate. Furthermore, three V-shaped notches were cut at the intersection of buccal slopes of the ridge and the base of the model to standardize the tray positioning during impression making.

To evaluate the rotation of impression copings during impression making, a U-shaped stainless steel superstructure was designed in 4 pieces. Long impression copings (PGRDC, Biohorizons) were attached to each implant fixture and the superstructure was designed by computerized numerical control machine (Siemens, Munich, Germany) so that its occlusal and gingival surfaces were parallel to the horizontal plane and each segment could seat on each implant and show the buccal or lingual rotation. The guiding lines connecting the center of adjacent implants were made on the occlusal surface of the segments [Figure 2].

In this study, impressions were made via three techniques: Open tray with long impression copings, closed tray with short impression copings and closed tray with ball top screw abutments. The custom impression trays with 2 layers of Base Plate Wax (Modeling wax, Dentsply, Fort Lauderdale, FL, USA) as the spacer was fabricated using light-polymerizing acrylic resin tray material (Megadenta, Radeberg, Germany) according to the manufacturer's instruction.

Twenty special open trays and 40 special closed trays for short impression copings and abutments accompanied by ball top screws were made by the same method.

Polyether impression material (Impregum F, 3M ESPE, Seefeld, Germany) and additional polyvinyl siloxsane (Monopren, Kettenbach, Eschenburg, Germany) plus bite registration material (Futar D, Kettenbach) as splinting material were used to make the impression.

Experimental groups consisted of six groups including open and closed tray impression techniques and two impression materials: Impregum with open tray (IO), impregum with closed and short impression coping (ICS), impregum with closed tray and ball top screw abutments (ICB), monopren with open tray (MO), monopren with closed tray and short impression coping (MCS) and monopren with closed tray and ball top screw abutments (MCB). In each group, special trays were painted with appropriate adhesive, 24 h prior to impression making.

Impregum was hand mixed and syringed around impression copings and loaded into the special tray. Automix Futar D was syringed around impression copings and tray was filled with automix monopren impression material and put on the model until tray border met the V-shaped notches and maintained in position with hand pressure until setting.

In open tray groups, tray was removed from the model by unscrewing the impression post and placing the removal force from anterior to the posterior part of the tray. Fixture analogues were screwed into impression copings inside the impression. In the closed tray technique, short impression copings and abutments with ball top screw were unscrewed from the fixtures and implant analogues were screwed to impression copings and repositioned into the impression properly. Impressions were poured with type IV dental stone (Ernest hinrichs, Osterode, Germany) 30 min after impression making.

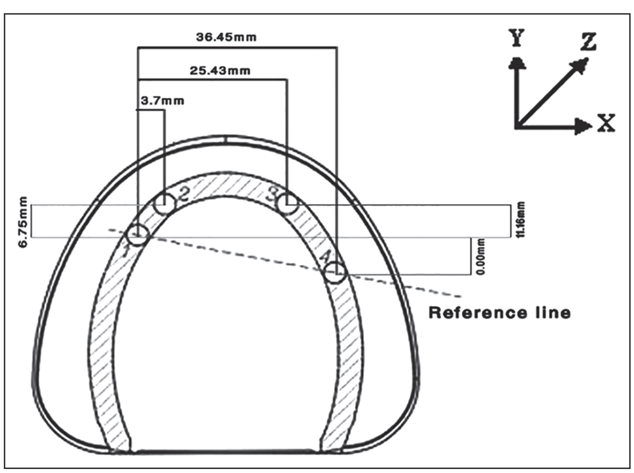

Figure 1: Schematic figure of reference line and point measured distances in x and y planes compare to reference point on master model

The changes in the distance between analogues in mediolateral (x) and anteroposterior (y) directions (distortion) and in analogue angles in xz and yz directions in the horizontal plane (deviation) were measured by coordinate measuring machine, (CMM) (Zeiss, Industrial Mess Technique, Oberkochen, Germany). The accuracy of CMM for the x, y and z axes was <0.0001 mm. The same operator used probe head and single probe in all measurements. Umess software (SW, Umess UNIX/LINUX, Zeiss, Oberkochen, Germany) was used for geometric transformation and data collection.

The center of fixture or analogue 1 was designated as the reference point for calibration of distance changes in measurements. The crest of the ridge was described as a horizontal reference plane (xy plane). An imaginary reference line was created between implants 1 and 4 to measure the deviation of analogs. Thus, the center of implant or analogue 1 was mounted on the origin (0, 0, 0) and the center of implant or analogue 4 was mounted on the (x, 0, z) [Figure 2]. With regard to our aim, only mediolateral or anteroposterior (x, y) positions for each implant or analog were recorded compared with this reference point. Angles of each implant or analog axes in mediolateral (xz) and anteroposterior (yz) planes were determined in the same way compared with the reference line [Figure 2].

To evaluate the accuracy of each impression technique and material, centers and angles of implants on the

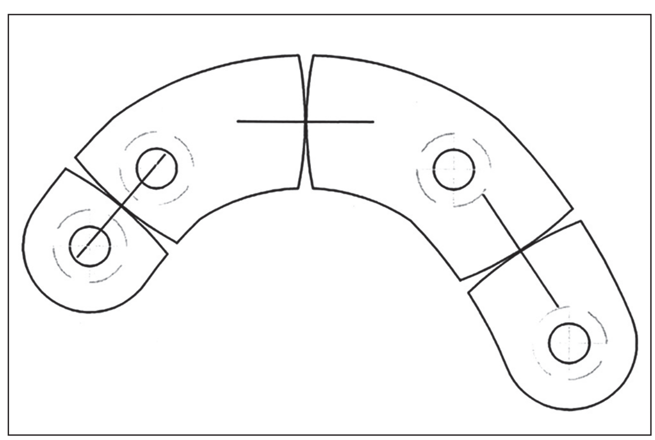

Figure 2: Schematic figure of 4-segmented u-shaped superstructure

master model were located in three dimensions and compared with the centers and angles of analogs in the experimental casts of 6 test groups.

Analog rotations, compared with the master model, were measured by the travelling microscope (Axio Imager Vario Zeiss, Oberkochen, Germany). An imaginary line between implants 1 and 4 was superimposed on the x axis of the travelling microscope as the reference line. Superstructure segments were screwed to the related implant or analog and the angle of the existing line on the occlusal surface of each segment was measured with respect to the x axis or frontal plane. For segments 1 and 4, one angle and for segments 2 and 3, two angles were measured.

Rotation of implant analog in the impression material caused a misfit between segments that were connected to their relative implant in the original model and showed a difference in the angle relative to the original model.

The operator was blind about test groups. Multivariate two-way analysis of variance (ANOVA) was undertaken to determine whether significant differences existed between groups and one sample *t*-test was used to compare the test groups with master model ($\alpha = 0.05$).

RESULTS

Multivariate two-way ANOVA showed no significant differences between two impression materials and three different impression techniques. ($F = 1.713$, $df = 20$, $P = 0.09$ for impression materials, $F = 1.346$, $df = 40$, $P = 0.147$ for impression techniques, $F = 1.512$, $df = 40$, $P = 0.072$ for interaction).

One sample *t*-test was used to evaluate the distances differences between implants no. 2, 3 and 4 with respect to implant no. 1 compared with the master model.

Table 1 shows mean changes in distances of implants 2, 3 and 4 in x (mediolateral) and y (anteroposterior) directions with respect to implant no. 1.

Statistical significant differences were observed in short impression coping technique with monopren on anteroposterior (y) direction in implants 2, 3 and 4 and all three techniques with impregum impression material in anteroposterior (y) direction in implant no. 4 compared to master model.

Changes in implant angles were evaluated from perpendicular to the horizontal plane in mediolateral (xz) and anteroposterior (yz) directions with one sample *t*-test. Table 2 shows the mean changes of implant angles with respect to the horizontal plane in xz and yz directions.

Table 1: Mean difference (SD) of distances between studied groups and master model in x and y directions respect to implant no. 1

Implant no.	Groups	IO	ICS	ICB	MO	MCS	MCB
2	X	0.03 (0.10)	0.05 (0.15)	0 (0.16)	0.03 (0.06)	0.02 (0.05)	0.02 (0.05)
	Y	0 (0.06)	0.07 (0.25)	−0.03 (0.12)	0 (0.07)	0.07 (0.04)**	0.24 (0.63)
3	X	0 (0.16)	0 (0.26)	−0.04 (0.17)	−0.04 (0.12)	0.03 (0.05)	0.03 (0.16)
	Y	−0.03 (0.11)	0.13 (0.37)	−0.11 (0.22)	−0.02 (0.03)	0.04 (0.03)**	0.08 (0.23)
4	X	0.02 (0.21)	0.03 (0.17)	−0.02 (0.13)	0.04 (0.10)	0.04 (0.06)	0 (0.09)
	Y	0.08 (0.08)**	0.23 (0.26)*	0.13 (0.09)**	0.11 (023)	0 (0.002)**	0.08 (0.03)

*Statistical significant difference ($P < 0.05$), **Statistical significant difference ($P < 0.01$), SD: Standard deviation, IO: Impregum with Open tray, ICS: Impregum with Closed and Short coping, ICB: Impregum with Closed and Ball top screw abutments, MO: Monopren with Open tray, MCS: Monopren with Closed and Short coping, MCB: Monopren with closed and Ball top screw abutments

Table 2: Mean difference (SD) of implant angles between studied groups and master model (in degrees)

Implant no.	Groups	IO	ICS	ICB	MO	MCS	MCB
1	X/Z	+0.06 (0.40)	+0.50 (0.72)*	+0.04 (0.58)	−0.29 (0.53)	−0.33 (0.50)	−0.15 (0.05)
	Y/Z	+0.39 (0.89)	−0.21 (2.33)	−0.98 (0.97)**	−0.09 (0.86)	−0.91 (0.47)**	+0.53 (0.86)
2	X/Z	−0.07 (0.45)	+0.38 (0.41)*	+0.03 (0.51)	+0.12 (0.98)	+0.41 (0.95)	−0.12 (0.77)
	Y/Z	+0.24 (0.90)	−0.75 (2.67)	−1.09 (1.22)*	+0.29 (1.48)	−0.85 (0.64)**	−0.33 (0.76)
3	X/Z	−0.30 (0.60)	−0.19 (0.99)	−0.33 (1.31)	−0.58 (0.97)	−0.70 (0.80)*	−0.75 (0.62)*
	Y/Z	−0.31 (0.89)	−1.38 (2.20)	−0.95 (0.92)	+0.27 (1.36)	+1.64 (0.69)**	−0.50 (0.83)
4	X/Z	−0.28 (0.94)	−0.15 (1.08)	−0.54 (1.68)	−0.96 (1.15)*	−1.21 (0.94)**	−0.10 (1.13)
	Y/Z	+0.13 (1.17)	−0.53 (0.68)	−0.88 (0.65)**	+0.25 (1.66)	−1.37 (0.59)**	−0.27 (0.50)

*Statistical significant difference ($P < 0.05$), **Statistical significant difference ($P < 0.01$), SD: Standard deviation

In the short impression coping technique with impregum, implants 1 and 2 in mediolateral (xz) direction and in ball top technique, implants 1, 2 and 4 in anteroposterior (yz) direction showed a statistically significant difference compared with the original model.

In the ball top impression technique with monopren, implant no. 3 in mediolateral (xz) direction and in short impression coping, all four implants in anteroposterior (yz) directions and implants 3 and 4 in mediolateral (xz) direction showed a statistically significant difference with the original model.

Rotation of superstructure segments which indicates the degree of rotation of analogues compared with the master model is described in six numbers, which consist of segment 1, segment 2 (rotation of no. 2 and 3), segment 3 (4 and 5) and segment 4 (6) [Figure 1]. Mean changes of analogue positions or angles of superstructure segments in degrees relative to the master model are shown in Table 3.

Rotations of segments 1, 2, 3 and 4 with impregum and segments 1, 2 and 4 with monopren in the open tray technique were significantly different compared with the original model.

In both closed tray impression techniques with impregum, implant no. 2 (angles 2 and 3) showed statistical difference in comparison with the original model.

In most of the studied groups, rotation of analogs was negative or counterclockwise.

DISCUSSION

Many clinical studies emphasize the passive fit of implant-supported superstructures for the long-term success of treatment.[1-4] It seems that there is a tolerance limit for prosthesis misfit in osseointegrated implants.[21]

Misfit can result in mechanical problems such as abutment screw loosening and breakage of the screw or prosthesis.[22] There are several factors and errors during prosthesis construction which can affect the precision of the cast and prosthesis fit such as precise connection of the impression post to the implant or abutment, distortions of the impression materials, connection of implant analogue or abutment and impression coping and movement of the analogue in impression materials and within the cast due to the dimensional changes of the dental stone.[18]

In this study, the accuracy of three impression techniques including, open tray, closed tray with short coping and ball top screw abutment and two impression materials including impregum and monopren with Futar D as the splinting material was evaluated. The statistical analysis showed no differences between groups; therefore, the first null hypothesis could not be rejected. However, the mean changes of the studied groups showed some differences with master model; therefore, the second null hypothesis was partially rejected.

The mean change in distances between analogues in samples in the anteroposterior direction was more than mediolateral direction compared with the original model. The reason for more distortion in anteroposterior direction (y) may be due to the path of removal of the impression tray from the model which exerts more stress on the impression materials from anterior to posterior direction compared to buccal and lingual directions.

The distance change in the anteroposterior direction was more in monopren with Futar D and short coping group, but in ball top group, distance changes were not significantly different from master model, which may be due to more precise placement of ball top abutments in impression.

Changes in the anteroposterior position of analogue number 4 in three impression techniques were

Table 3: Mean difference (SD) of implants rotation between studied groups and master model (in degrees)

Angel no.	IO	ICS	ICB	MO	MCS	MCB
1	−1.27 (0.44)**	−9.42 (14.07)	−2.51 (14.43)	−1.12 (0.40)**	−1.46 (13.48)	−0.92 (12.95)
2	−1.37 (0.47)**	−1.86 (10.07)**	−8.34 (7.72)**	3.73 (0.84)**	−7.02 (3.45)	−1.41 (9.61)
3	1.43 (0.51)**	13.98 (8.93)**	−0.38 (19.74)	3.73 (6.00)	−7.02 (30.61)	1.43 (9.56)
4	1.23 (0.32)**	2.95 (9.01)	−1.21 (10.58)	1.28 (0.48)**	−8.60 (15.62)	−4.37 (12.52)
5	−2.85 (13.26)	3.72 (9.38)	−1.15 (10.63)	−3.21 (14.61)	−10.50 (16.67)	15.17 (55.28)
6	−2.92 (13.21)	−4.83 (16.34)	−5.16 (10.22)	−0.83 (8.89)	−2.88 (6.08)	−6.47 (17.97)

*Statistical significant difference ($P < 0.05$), **Statistical significant difference ($P < 0.01$), SD: Standard deviation significantly different from the master model. This may be due to more distance of this implant from the location of application of lifting force during the removal of impression tray from the model. This finding is in line with Carr's[11] study which showed more misfit between the superstructure and posterior abutment.

The mediolateral rotation of the implant axis (x/z) ranged from −1.2 to +0.5 and in the anteroposterior rotation (y/z), it ranged from −1.37 to +1.64. These differences are less than those of dentate models.[23]

Changes of analog axis deviation in anteroposterior and mediolateral directions (x/z and y/z) were more in the closed impression tray groups than in the open impression tray groups and short impression coping technique showed more rotation changes in analogue axis than in ball top screw technique compared with master model. The reason for this might be due to less surface area in short impression coping or its shape, which can result in its deviation in the impression material.

Changes in the analogue axis in anteroposterior direction (y/z) were more than mediolateral direction (x/z) and most of the changes were in the negative (counterclockwise) direction, which was associated with the direction of lifting of the tray from the model. There was no relationship between the implant position in the dental arch and deviation angle of analogues.

Changes in analog axis angles were more in monopren group than in impregum group, which may be due to better elastic recovery of impregum than Futar D.[10]

Rotation of the superstructure segment in all samples in comparison with master model showed changes in the range of −10.50° to +15.17°. Rotation of segment in closed tray impression group with short coping was more than in ball top abutment group compared with master model, which indicates more precise fit of ball top into the impression. Rotation of analogs in closed tray techniques was consistent with previous studies which indicate the exact placement of impression copings into the impression materials is not possible and there is always some error due to either distortion of impression material or replacing error of the impression coping into the impression material.[10,24]

Rotation of analogs in the open tray samples is due to the rotation of the impression coping with a long screw in the material when unscrewing and removing the impression from the model or while screwing the analogue into the impression coping.[25]

In this study, rotation of segments in the open tray technique was counterclockwise which may indicate rotation of copings during unscrewing the screw from top of the tray. It seems that setting of the impression material around the copings with long screws will cause a higher necessary force to unscrew the impression coping from top of the tray than the force necessary to screw the impression coping into the analogue. In this study, there was no difference between two impression materials regarding the rotation of impression copings.

While some studies showed no difference between open and closed impression techniques when 3 or less implants were used,[8,12,26] a study by Daoudi *et al*.[27] found closed tray technique to be more accurate.

Some studies reported a higher accuracy for open impression technique than closed impression technique when impression was made from 4 or more implants.[11,28-32] While some studies reported no difference between two techniques,[8,13,33] in this study, no difference was found between impression techniques. Positioning of the implants when perpendicular or parallel to each other will cause easier removal of the tray form the model. Removing the impression tray when the implants are not parallel or have a labial or lingual tilt is more difficult and will cause more stress in the impression material resulting in less accurate final cast.[11,29] Many studies have recommended splinting of implants to increase the accuracy of the impression, although the success of this technique is questionable.[15,34] Splinting can be done with different materials such as autopolymerized acrylic resins,[29] light-polymerized acrylic resins[18] or dental stones.[35] Splinting with acrylic resin may be difficult and time-consuming and distortion of this material may be a problem.[34] In this study, Futar D bite registration material was used for splinting impression copings in both open and closed impression techniques. This material is stiff and easy to handle clinically. No difference was observed between two impression materials. However, none of the materials could prevent the rotation of impression copings in the impression material. Wenz and Hertrampf[33] showed better results with polyether to prevent the rotation of impression copings in comparison with polysulfide and additional silicone impression materials. In a study by Holst *et al*.,[36] additional silicones were used with Futar D in open tray technique and its accuracy was reported to be less than impregum. The results of these studies are contradictory with this study. Also, differences in the machine's tolerances between surfaces that are connected will cause differences in the position of components.[37,38] This tolerance is reported to be 22-100 µm for Branemark system.[37] Machining tolerance is an intrinsic characteristic between machined implant components that identifies the amount of possible horizontal movement between paired components. Machining tolerances between implant components (abutment, impression coping and component analogous) were measured by a CMM.[37] In Biohorizons implant system, which was used in the present study, the machine's tolerance is not reported.

There are some limitations to the present study. It has been tried to standardize the injection of splinting materials, but the volume of materials (Futar D) around impression copings in all tested groups were not equal exactly. In addition, the path of removal of impression tray was from anterior to posterior direction that may be different from the clinical situations; hence, the results may differ from a clinical study.

CONCLUSION

Considering the limitations of this study, these conclusions can be drawn:

1. There were no differences between open and closed tray impression techniques, but open impression technique showed better results with regard to the changes in implant distances and their axes deviation from perpendicular compared with the original model.
2. The accuracy of abutments with ball top technique was more than short impression copings compared to the master model in closed tray impression technique.
3. Monopren impression material when used with Futar D to make an impression for several parallel implants in edentulous model had the same accuracy as impregum impression material.
4. Impression distortion during tray removal from the model was more probable for posterior implants.
5. Rotation of the impression copings in the impression material was more in open tray technique than in closed tray technique.

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