Original Article

Accuracy of Implant Position Transfer and Surface Detail Reproduction with Different Impression Materials and Techniques

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Abstract
Objectives: The purpose of this study was to compare the accuracy of implant position transfer and surface detail reproduction using two impression techniques and materials.
Materials and Methods: A metal model with two implants and three grooves of 0.25, 0.50 and 0.75 mm in depth on the flat superior surface of a die was fabricated. Ten regular-body polyether (PE) and 10 regular-body polyvinyl siloxane (PVS) impressions with square and conical transfer copings using open tray and closed tray techniques were made for each group. Impressions were poured with type IV stone, and linear and angular displacements of the replica heads were evaluated using a coordinate measuring machine (CMM). Also, accurate reproduction of the grooves was evaluated by a video measuring machine (VMM). These measurements were compared with the measurements calculated on the reference model that served as control, and the data were analyzed with two-way ANOVA and t-test at P= 0.05.
Results: There was less linear displacement for PVS and less angular displacement for PE in closed-tray technique, and less linear displacement for PE in open tray technique (P<0.001). Also, the open tray technique showed less angular displacement with the use of PVS impression material. Detail reproduction accuracy was the same in all the groups (P>0.05).
Conclusion: The open tray technique was more accurate using PE, and also both closed tray and open tray techniques had acceptable results with the use of PVS. The choice of impression material and technique made no significant difference in surface detail reproduction.
Keywords: Dental Implants; Dental Impression Materials, Dental Impression Technique
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INTRODUCTION
Using appropriate impression materials and techniques guarantees accurate transfer of implant position and precise surface details of prepared teeth to the definitive cast [1,2]. Making accurate impressions is necessary as the first step for achieving passive fit in implant-supported restorations [3].

Otherwise, many mechanical and biological complications such as screw loosening, fixture fracture, occlusal discrepancy and bone loss may occur [4-6].

Different implant impression techniques including direct (open tray) and indirect (closed tray) techniques are commonly used [7-15]. While most authors advocated the direct technique [8-11], some have found the indirect technique to be more accurate [12,13], requiring less working time, and being easier for the operator and the patient [9,12]. This technique is frequently indicated when there is limited inter-arch space or tendency to gag, or working in the posterior region of the mouth [11].

Making an accurate impression is affected by several factors, such as impression material, impression tray, and impression technique [14-21]. Among impression materials, PVS and PE are of the best choices in fixed prosthesis and implant dentistry because of their improved physical and mechanical properties [14-18]. Several studies have compared the accuracy of PE and PVS as implant impression materials and most of them found no significant difference between them [14,18]. Wee [16] reported that the torque resistance of PE was of the greatest value, which would make it more suitable for the open tray technique.

On the other hand, impression of prepared teeth must be dimensionally accurate, and also must reproduce the surface details of prepared teeth [2,19]. The PVS and PE are both dimensionally stable, because their polymerization reaction involves no loss of byproducts [19,20]. Surface detail reproduction of PVS and PE impression materials is excellent as well [19]. This characteristic has been evaluated according to the criteria of ADA specification No. 19 which is continuous replication of at least two of the three horizontal grooves [20,22].

Therefore, to obtain accurate impressions of implants and teeth simultaneously, dimensional accuracy and surface detail reproduction both should be taken into account. Chee and Alexander [22] defined a technique to make an impression of both implants and natural teeth. First an impression was made of teeth using two-step putty wash technique with PVS impression material and a custom tray and in the next step, after securing transfer copings, an over impression was made by using regular body PVS. However, no original article has evaluated this topic.

The purpose of this in vitro study was to evaluate and compare the accuracy of different impression materials (regular-body PE vs. regular-body PVS) and different impression techniques (open tray vs. closed tray) for transfer of implant position and surface detail reproduction of three grooves. Two null hypotheses were postulated: a) There would be no significant difference in the accuracy of implant position transfer with the use of different impression techniques and impression materials, and b) there would be no significant difference in the accuracy of detail reproduction using different impression techniques and impression materials.

MATERIALS AND METHODS

A maxillary complete-arch metal reference model was fabricated (Fig. 1A). Two parallel holes, 3.8mm in diameter and 10mm in length according to the size of implants, were created in the site of the left first and second molars. Two implants (Implantium, Dentium, Seoul, South Korea) were inserted and secured with auto-polymerizing acrylic resin (Technovits 4000, Heraeus Kulzer GmbH & Co., Wehrheim, Germany).

The fixture adaptor was secured on the vertical rod of a surveyor (J.M. Ney Co., Bloomfield, CT, USA) and was used to orient implants vertically on the surveyor while inserting them in the holes. Also, three horizontal grooves of 0.25, 0.50 and 0.75mm depths were inscribed between two vertical grooves on the flat superior surface of a die according to the ISO 4823 (Fig. 1B).
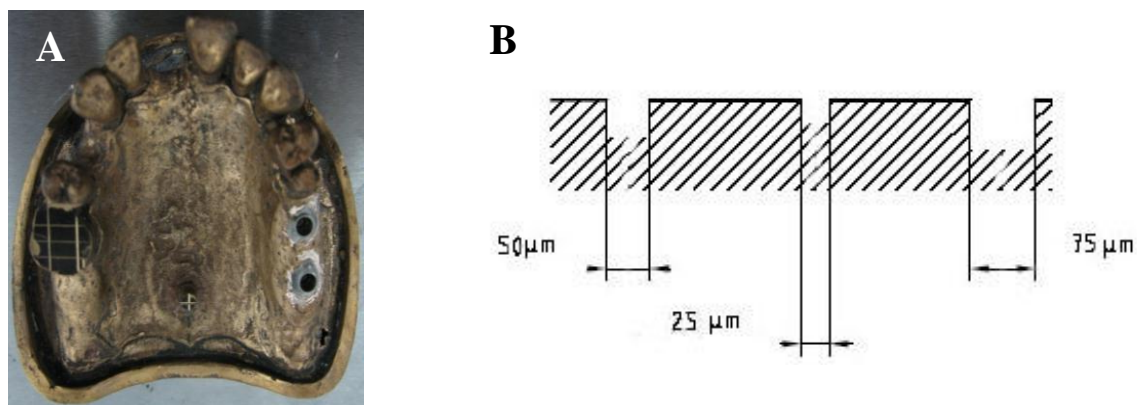
Fig. 1. The metal reference model (A). The schematic view of three grooves with 0.25, 0.50 and 0.75 mm depths (B).

Conical transfer copings were adapted to the implants in the metal model and an irreversible hydrocolloid (Alginoplast, Heraeus Kulzer GmbH & Co., Wehrheim, Germany) impression was made to obtain a single cast on which forty custom trays were molded. Two layers of baseplate wax (modeling wax, Dentsply, Weybridge, UK) were used to cover the primary cast before making the custom trays. In order to ensure proper tray positioning, tissue stops were created in the trays. Forty identical 2mm thick custom trays were made with light polymerizing resin (Megatray, Megadenta, Radeberg, Germany) to be used with open tray and closed tray techniques with the use of square and conical transfer copings, respectively (Fig. 2).

Regular-body PE (Impregum F, 3M ESPE, Seefeld, Germany) and regular-body PVS (Elite HD+, Zhermack, Rovigo, Italy) were the impression materials of choice, and were prepared according to the manufacturers' instructions and the ADA specification number 19 [22]. Impression making was performed in an environment with controlled temperature and humidity of 23 ± 2°C and 50 ± 10%, respectively. Adhesive (Universal, 3M ESPE, Seefeld, Germany) was used to coat the interior surface and 5mm beyond the borders of all custom trays 15 minutes before impression making.

The specimens were assigned into four groups. In closed tray groups, conical transfer copings and in open tray groups, square-shaped transfer copings of Implantium (Dentium) were adapted to the implants using uniform 10 N/cm torque. The impression materials were machine-mixed (Pentamix, 3M ESPE, Seefeld, Germany), and some of them were meticulously injected around the transfer copings and on the die to ensure complete coverage. The remaining impression material was loaded onto the impression trays. Before securing the transfer copings and mixing the material for each group, the model was cleaned ultrasonically to remove any residue and was then air-dried.

The impression tray was lowered over the reference model until the tray was fully seated on the location marks. To simulate the impression material polymerization conditions in the mouth, a 5 kg weight was placed over the impression trays which were placed in distilled water at 36 ± 1°C [14]. After five minutes, in all groups, the impression/matrix set was separated and impressions were inspected and repeated when inaccuracies such as air voids were found.

In closed tray groups, the conical transfer copings were unscrewed from the matrix and fitted to the implant analogues, and immediately replaced in each respective notch left in the impression.

Fig. 2. The closed-tray and open-tray transfer copings.

The combined transfer coping-analogue unit was inserted into the impression by firmly pushing it into place to full depth and slightly rotating it clockwise to feel for the anti-rotational resistance. This tactile feel indicated that the three grooves on the coping were locked into place and that the implant orientation was accurately transferred. In open tray groups, the screws of the copings were removed with a screwdriver, and then the impression/matrix set was separated. Afterwards, the implant analogues were secured to the impression copings by hand.

Impressions were poured with vacuum-mixed dental stone type IV (Herostonel Vigodent Inc., Rio de Janeiro, RJ, Brazil) using a powder/water ratio of 30 g/7 mL, according to the manufacturer's recommendation. The impressions were separated from the definitive casts 120 minutes later. All impression making procedures were performed by a single operator.

A single calibrated blinded examiner performed all readings randomly and out of sequence to evaluate the positional accuracy of the implant replica heads using a CMM (Mistral, DEA Brown & Sharpe, Grugliasco, Italy) capable of simultaneously recording –x and -y dimensions. The accuracy of CMM was 2.8 µm for the x- and y- axes.

A 0.5-mm-wide straight probe recorded the distance between the implant apertures in each direction (-x and -y) and the reference point (Figs. 3A and 3B). To evaluate angular changes, the flat side of the transfer copings was used as reference for measuring the rotations (Figs. 4A and 4B). These measurements were made on the master model and the working casts. Each experimental cast was measured three times to obtain an average value.

To determine the accuracy of surface detail reproduction by evaluating the reproducibility of the grooves, VMM (Starrett, Galileo Vision System, Birmingham City, England) was used. A 0.2-mm-wide straight probe recorded the three points in the deepest part of grooves. The average depth was calculated by dividing the sum of depth measurements by three. The data obtained from the readings were recorded and presented in absolute values in each direction. SPSS version 18 software (SPSS Inc. Chicago, IL, USA) was used for statistical analysis. The mean values and standard deviations (SD) were calculated and then submitted to the ANOVA with two variables (impression technique and impression material) at a significance level of 5% ($P<0.05$). After detecting differences among the groups, t-test was applied.

RESULTS

Measurements of implant replica head dislocations in the x and y directions, linear (Δr) and angular displacements ($\Delta \theta$), and also accuracy of surface detail reproduction of three grooves are presented as means ($\pm$SD) in Table 1. The Δr was calculated using the equation $\Delta r^2 = \Delta x^2 + \Delta y^2$. Two-way ANOVA indicated the significant effect of impression technique, material and their interactions on all the tested parameters, except for no effect of impression material and technique on the vertical displacement. Also, surface detail reproduction (groove depth) was not affected by the impression technique, material or their interaction (Table 2).
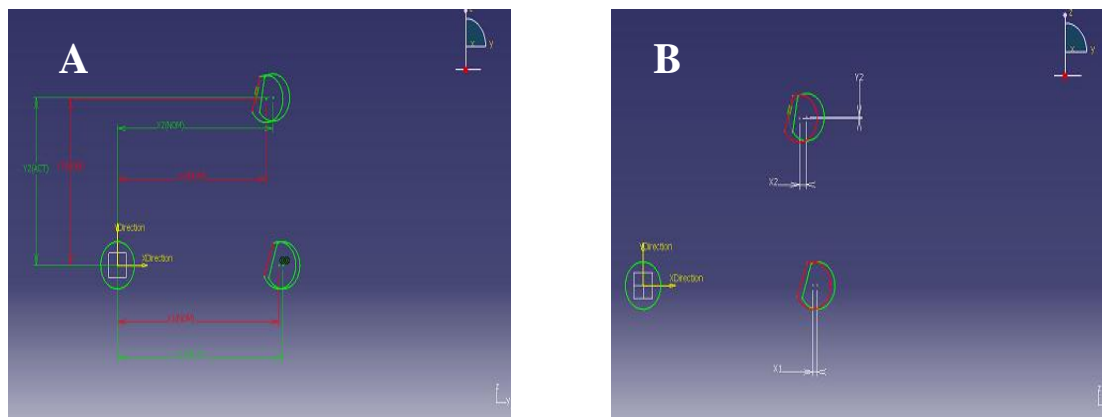
Fig. 3. Schematic drawings of the measurements of implants in x, and y directions. The red drawing indicates baseline measurements on the reference model (A). The green lines show the measurement on the cast superimposed on the original diagram (B).
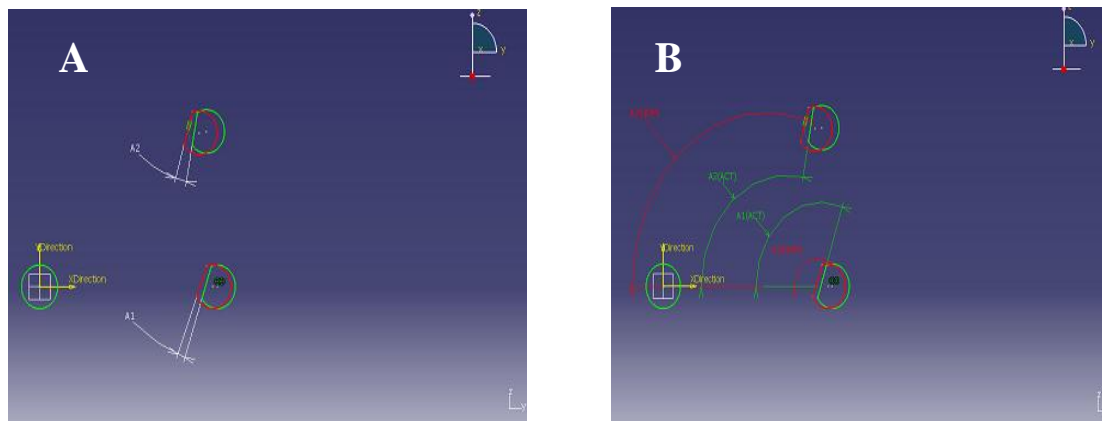

Fig. 4. Schematic drawings of the measurements of implants for rotational displacement on the reference model (A), and on the cast superimposed on the original diagram (B).

Effect of impression technique

According to t-test, the comparison between open tray and closed tray techniques using PVS impression material revealed less Δx and Δr for closed tray technique (P<0.001). However, there was less displacement in vertical (P=0.04) and angular (P<0.001) directions when open tray technique was used.

Also, in comparison between the accuracy of open tray and closed tray techniques using PE impression material, significant differences were found between the two techniques, and open tray technique showed less discrepancies in terms of Δx and Δr parameters (P<0.001).

However, there was less Δy using closed tray technique (P=0.01). The result showed no significant difference for angular displacement between these groups (P=0.16) (Tables 1 and 3).

Effect of impression material

According to t-test, in comparison between the accuracy of impressions made with PVS and PE impression materials using closed tray technique, PVS produced less Δr, while impressions made with PE showed smaller $\Delta\theta$ (P<0.001). Also, there was a significant difference between the two impression materials in open tray groups, and less Δr was

observed using PE impression material (P<0.001). The results also revealed that the detail reproduction, measured by VMM, was affected by neither the impression material, nor the impression technique (P>0.05)(Tables 1 and 4).

DISCUSSION

Making an impression to simultaneously transfer the 3-dimentional position of implants and reproduce details of prepared teeth is sometimes needed in partially edentulous patients.

Table 1. The absolute mean values (±SD) and comparison of the recorded measurements in the groups.

Measurement	Open tray technique		Closed tray technique	
	Regular Polyether	Regular poly vinyl	Regular Polyether	Regular poly vinyl
	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)
Horizontal displacement (µm)	.23 (±.09)	.60 (±.19)	1.08 (±.23)	.15 (±.05)
Vertical displacement (µm)	.06 (±.05)	.03 (±.01)	.02 (±.01)	.05 (±.03)
Angular displacement (Degree)	.75 (±.42)	.51 (±.15)	.53 (±.24)	2.37 (±1.12)
Linear displacement (µm)	.24 (±.09)	.60 (±.19)	1.08 (±.23)	.16 (±.05)
Shallow line (µm)	7.6 (±6.9)	9.1 (±4.8)	9.9 (±4.7)	6.1 (±2.9)
Medium line (µm)	10.7 (±11.4)	7.7 (±3.9)	8.7 (±6.1)	7.5(±2.3)
Deep line (µm)	14.1 (±13.3)	8.2 (±3.6)	13.9 (±8.4)	7.9(±4.0)

Table 2. Evaluation of the effect of impression technique, material and their interaction effect on the variables of horizontal, vertical, linear and angular displacements and also line depth by two-way ANOVA

	Horizontal displacement	Vertical displacement	Angular displacement	Linear displacement	Shallow line	Medium line	Deep line
Technique	<.001*	0.240	<.001*	<.001*	0.835	0.584	0.920
Material	<.001*	0.893	<.001*	<.001*	0.424	0.391	0.065
Technique* Material	<.001*	0.001*	<.001*	<.001*	0.119	0.654	0.984

*: significant effect in 0.05 level of significancy

Table 3. Calculated P-values of the effect of impression technique on horizontal, vertical, linear and angular displacement variables by t- test

Material	Measurement	P value
Poly ether	Linear	<0.001*
Poly ether	Horizontal	<0.001*
Poly ether	Vertical	0.01*
Poly ether	Angular	0.16
Poly vinyl	Linear	<0.001*
Poly vinyl	Horizontal	<0.001*
Poly vinyl	Vertical	0.04*
Poly vinyl	Angular	<0.001*

*: significant effect in 0.05 level of significancy

Using appropriate impression materials and techniques helps to achieve precise and passively fitting superstructure in implant supported prosthesis [3] and proper fit for the cast restorations [2]. There is a variety of impression techniques for impression making of implants [7-15] and yet there is no agreement on the most accurate technique and material for all the situations. Although there is a technical report about an impression technique for arches requiring impression making of both implants and natural teeth by Chee and Alexander [22], this issue has not been investigated as an original research before.

In the current study, regular-body PVS and PE were used with open tray and closed tray impression techniques. Both techniques require a blind manipulation, one in attaching an analogue, the other in fully seating the coping-analogue combination. According to most previous studies, both impression materials used in this study have excellent dimensional accuracy and are capable of precise surface detail reproduction [14-21]. To measure the dimensional and rotational displacement of implants during transfer to the definitive casts, the CMM was used which had considerable precision and its accuracy was 2.8 μm. However, most other studies have used traveling microscopes in which inaccuracy was expressed in only two dimensions [12], or strain gauges to indirectly quantify distortion [10].

According to the results of this study, the null hypothesis emphasizing no significant difference between two impression techniques and materials for the implant position transfer was refuted. However, the results supported the second null hypothesis declaring no significant difference in the surface detail reproduction using different impression techniques and materials. Data analysis showed that when open tray technique was used, PE impression material showed less linear displacement compared to PVS impression material ($P<0.001$). Inaccuracy of open tray technique is partly related to rotation of transfer copings during unscrewing, and also during securing the analogue to them in the impression. Thus, a stiff impression material such as PE [19-21] that has greater torque resistance than PVS [16], could better resist the rotational tendency of transfer copings.

This finding is in agreement with the result of Del'Acqua et al, [18] who showed better results with PE rather than PVS, using open tray technique. However, blind attachment of the implant analogue to the transfer coping in open tray technique, unlike closed tray technique, may result in a misfit of components [9].

This could explain less vertical displacement in closed tray group using PE as compared to the open tray group. Also, use of PE for closed tray technique resulted in less rotational displacement compared to when PVS was used.

Table 4. Calculated P-values of the effect of impression material on linear and angular displacement variables by t- test.

Technique	Measurement	Comparison between groups		P value
Closed	Linear	Regular poly ether	Regular poly vinyl	<0.001*
	Angular	Regular poly ether	Regular poly vinyl	<0.001*
Open	Linear	Regular poly ether	Regular poly vinyl	<0.001*

*: significant effect in 0.05 level of significancy

This may be due to greater torque resistance of PE that would resist excessive rotation of tapered transfer coping as it is being repositioned into the impression. However, in PE groups, there were less horizontal and linear displacements using the open tray technique (P<0.001). This finding might be explained by lower elastic recovery of PE impression material, which could resist precise repositioning of tapered transfer copings back into their respective notches, as compared to the remaining square-shaped transfer copings in the impression after tray removal.

When PVS impression material was used, there was less horizontal and linear displacement for closed tray technique. Also, in a comparison between two impression materials for closed tray technique, less linear displacement was observed with PVS. These findings are probably related to the properties of PVS impression material. Carr [9] reported that the inaccuracy of closed tray impression technique may be due to permanent deformation caused by a stiff impression material such as PE. Therefore, it is possible that impression materials with more elasticity, such as PVS [19-21], be a more suitable choice for closed tray technique.

On the other hand, when PVS was used for both techniques, there was less displacement in vertical (P=0.04) and angular (P<0.001) directions for open tray technique. This may be because of the need for repositioning of conical transfer copings, which are often shorter than square-shaped transfer copings [9,21]. Furthermore, although PVS is less rigid than PE, its stiffness might be sufficient to resist the rotational movement of the square-shaped transfer copings if handled properly. Therefore, it may be concluded that both closed tray and open tray techniques yield acceptable results when used with PVS impression material. Conrad et al, [15] also reported that there was no significant difference between open-tray and closed tray techniques with PVS in presence of perpendicular and angulated implants.

Regarding the results of this in vitro study, it could be stated that when closed tray impression technique is used, both PE and PVS impression materials may yield good results. However, regarding the accuracy of the CMM and the low values of displacement in different directions acquired in the current study, the difference between different impression techniques and materials might not be clinically significant.

Our results also showed that there was no significant difference in the surface detail reproduction accuracy among the groups (P>0.05).

Thus, it can be stated that both PVS and PE are appropriate choices for fabricating cast restorations. According to the American Dental Association specification no.19, elastomeric impression materials should be able to reproduce fine details of 25 μm or less to be considered suitable for fabrication of precision castings [22].

While in this study, VMM with 0.3 μm accuracy was used to evaluate surface detail reproduction of three different depths of grooves on the definitive casts, some studies used the criteria of ADA specification no.19 for this purpose, which is continuous replication of at least 2 of the 3 horizontal grooves under ×10 magnification [19] or by use of a measuring microscope with an accuracy of 0.001 mm [20]. In some groups, the SDs were in the same order of magnitude as the mean values. There may be some factors contributing to these deviations, including errors in impression procedure, contraction of the impression material, investment expansion or higher accuracy of VMM compared to the wire cutting machine, which was used for inscribing the grooves on the reference model.

One advantage of the current study was to consider the importance of transferring the exact dimensional position of implants and recording the detailed information simultaneously, which has not been investigated by other pertinent articles.

The main concern in the impression making of implants is to transfer their 3D spatial status intra-orally to the definitive casts, while reproducing the surface details of the prepared tooth is an important concern as well. Another advantage of this study is using measuring systems with high degree of accuracy, while most previous studies used 2D measuring devices with less accuracy.

Further studies should be conducted with different number and angulation of implants of various systems in presence of prepared teeth, which may require a tray removal path not perpendicular to the horizontal plane. One of the limitations of the current study was that the surface detail reproduction of impression materials was investigated in a dry condition. Therefore, further research is needed to determine the accuracy of impressions in wet conditions similar to the mouth and also to evaluate the effect of another limiting factor on surface detail reproduction, which is the ability of gypsum die materials to replicate the fine details.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that the choice of impression material and impression technique may be influenced by one another, and it is better to choose certain impression materials in combination with a certain impression technique.

There was less inaccuracy for open tray technique when PE impression material was used, and also generally, open tray technique seemed to be a better choice when using PE. Both closed tray and open tray techniques were acceptable when they were used with PVS. Also, when closed tray technique was used, both PE and PVS impression materials produced acceptable results. Also, the choice of impression material caused no significant difference in surface detail reproduction accuracy.

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