The Effect of Implant Angulation on the Transfer Accuracy of External-Connection Implants

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ABSTRACT

Background: Accurate recording of implant location is required in every implant-supported prostheses. Implant angulation, which is inevitable in various clinical situations, could affect the impression accuracy.

Purpose: The purpose of this in vitro study was to compare the transfer accuracy of straight and tilted implants of All-on-4 protocol with implant or abutment level impression making and different techniques of direct and indirect.

Materials and Methods: One reference model of edentulous maxilla with four external connection implants (Brånemark) inserted according to All-on-4 protocol was made. Forty impressions of this model were made at implant (groups 1 and 2) or abutment (groups 3 and 4) levels with different techniques of direct or indirect, respectively. Impressions were poured with type IV dental stone. Coordinate measuring machine was used to record x, y, and z coordinates and also angular dislocation of implants. These measurements were compared with the equals calculated on the reference model. Data were analyzed with univariate analysis of variance and *t*-test at $\alpha = 0.05$.

Results: The results showed that abutment level impression making (groups 3 and 4), either with direct or indirect technique, produced the same results for straight and tilted implants of Δr variable ($p > .05$), though in implant level groups (groups 1 and 2), it was statistically significant ($p < .05$). However, only implant level impression making with direct technique (group 1) had the same results of angular accuracy for straight and tilted implants.

Conclusion: Impression technique (direct or indirect) had significant effect on the impression accuracy of tilted implants, and direct technique produced less inaccuracy. Also, abutment level impressions showed more accuracy than implant level impressions.

KEY WORDS: abutment, angled abutment, implant, impression, tilted implant

INTRODUCTION

One of the common mistakes in prosthodontic treatment is failure to achieve a passive fit between the implants and superstructures.[1,2] The lack of passive fit could increase misfit and the incidence of mechanical complications, such as fracture and/or loosening of screws of abutment or superstructure.[1,2] Such misfit might enhance plaque accumulation, affecting soft and/or hard tissues around the implants, and cement washout.[1,2] To date, most authors believe that the passive fit between the implants and superstructure is a valuable factor for long-term serviceability of the restorations.[1,2] One approach for improving fitness is to increase the accuracy of impression.[3] Several factors could affect this accuracy including impression material, impression technique, implant angulation, number of implants, splinting of the impression copings, and impression trays.[3–13] The impressions transfer abutment or fixture positions from the oral cavity to master cast with either of direct (open tray) or indirect (closed tray) techniques. Both of these impression techniques are generally used for transferring implant position to the final cast in

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dental practice.[3,14] Comparing the square and conical transfer impression copings in different implant systems has been addressed in the literature.[3,5,6,13,14] Some studies showed that the indirect impression technique (transfer) created a more accurate working cast compared with the direct techniques (pick-up).[6,15,16] They concluded that this technique required less working time, was easier for the operator,[17] and also more comfortable for the patient.[18] Other researchers reported direct technique to be more accurate than the indirect technique.[14,16,17,19] However, the pick-up technique may present some disadvantages including the possible inaccurate positioning of the copings caused by different angulations and different subgingival implant position.[18,20]

Most researchers have evaluated the precision of the impressions with parallel implants,[5,8,10,12–18] whereas few investigations were performed to evaluate the effect of nonparallel implants on the accuracy of final casts.[4,6,9,19,21] To date, the use of angulated implants has been established as an alternative to bone grafting and sinuses lifting.[22–25] The tilted distal implants could position and anchor in the cortical bone wall of the sinuses to improved primary stability and the anterior implants could be parallel.[22–25] This approach is well documented in the literature.[22–27] In vivo and biomechanical studies demonstrated that the use of four implants in All-on-4 protocol could be a successful treatment for complete-arch prostheses.[24–27] There is no report to evaluate the accuracy of the impression and working casts in this new concept. According to Sorrentino and colleagues, the angulated implants with internal connection may cause strains in impressions during the impression removal.[21] The literature showed addition silicones (vinyl polysiloxanes [VPSs]) using rigid trays[21,28] as a suitable impression materials for accurate transferring of tilted implants.[16,29,30]

The purpose of this in vitro study was to compare the impression accuracy of straight and tilted implants of All-on-4 protocol with implant or abutment level impression making and different techniques of direct and indirect. The null hypothesis was that there would be no significant difference in the accuracies of straight and tilted implants with various impression techniques.

MATERIALS AND METHODS

A reference model of edentulous maxilla with four implants was made while the insertion of the implants followed standard procedures of All-on-4 technique.[25–27] All-on-4 guide (All-on-4, Nobel Biocare AB, Göteborg, Sweden) used for insertion of four regular platform implants of Brånemark system (Brånemark System® Mk III, Nobel Biocare AB) in canines and second premolars sites. Implants were 3.75 mm in diameter and 12 mm in length. Anterior and posterior implants were inserted in parallel and tilted position of 45 angulation, respectively. The longitudinal axes of anterior implants were parallel to each other and perpendicular to the edentulous plane of the model, whereas the axes of posterior implants were diverted 45 away from the midline. A metal reference cylinder was inserted in the midline of palate in the model as a reference of measurement and was defined as zero point (Figure 1A).

Description of the groups is presented in Table 1. In groups 3 and 4, four abutments (Multi-unit, Nobel Biocare AB) were screwed into the implants on the model. Two anterior abutments were straight and others were 30 in angulation (Figure 1B). All straight

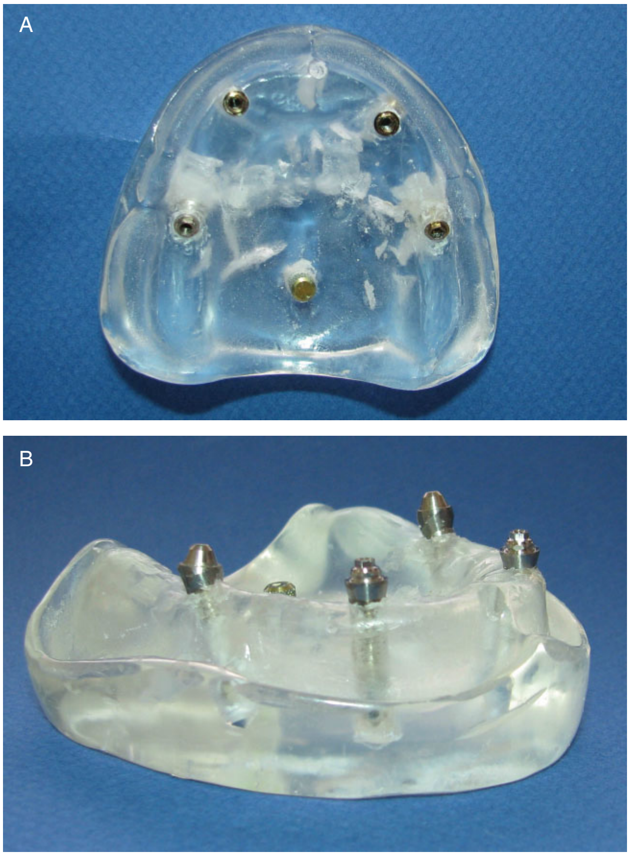

Figure 1 *A*, Reference model of edentulous maxilla with four Brånemark implants (groups 1 and 2). *B*, Low profile straight (for anterior implants) and angled (for distally tilted implants) abutments attached to the implants (groups 3 and 4).

TABLE 1 Definition of the Groups in the Study

Impression Level	Group	Impression Technique		Number
Implant level	1	Open tray	Square copings	10
	2	Closed tray	Conical copings	10
Abutment level	3	Open tray	Square copings	10
	4	Closed tray	Conical copings	10

abutments torqued to 30 Ncm and angulated abutments torqued 15 Ncm according to manufacturer recommendation.

After 24 hours, the conical impression copings (Nobel Biocare AB) were fastened to the implants and abutments, and base-plate wax (Modeling wax; Dentsply DeTrey, Konstanz, Germany) was adapted around and over the impression coping and irreversible hydrocolloid (Alginoplast, Heraeus Kulzer GmbH & Co., Wehrheim, Germany) impressions were made to obtain two casts. These casts were used to mold custom trays. The obtained casts covered by two layers of base-plate wax (modeling wax, Dentsply) to allow a reliable thickness of impression material. Tissue stops were included in the impression trays to standardize tray positioning during impression making. Forty 2 mm-thick custom impression trays (20 open trays and 20 closed trays) were made with light polymerizing resin (Megatray, Megadenta, Radeberg, Germany) (Figure 2, A and B). Each tray was perforated, and the internal part and 5 mm outside the borders was coated with adhesive 30 minutes before each impression was made. Addition silicone (Zhermack Elite HD + Regular Body, Kouigo, Italy) was the impression material of choice for all transfer procedures and was managed according to manufacturers' recommendations and the specification number 19 of ADA.[31] All impressions were made in a temperature-controlled environment (23 ± 1°C) with a relative humidity of 50 ± 10%.

In groups 1 and 3, square copings and in groups 2 and 4, conical copings of Brånemark implants system (Nobel Biocare AB) were adapted to the implants and abutments, respectively. According to Inturregui and colleagues,[32] all impression copings were secured with a torque wrench calibrated at 10 Ncm torque on the implants and abutments (Figure 3, A and B).

An auto-mixing cartridge was used for mixing the impression material. For each impression, 12 mL of the material was carefully injected around and over the copings to ensure complete coverage of the copings. The 35 mL of the remaining impression material was used to fill the impression special tray. To standardize the seating load for each impression, a 5 kg weight was placed over the trays during material polymerization. The impression materials were allowed to polymerize for 12 minutes after the start of the procedure according to the manufacturer's recommendation. The impression/matrix set was placed in distilled water at 36 ± 1°C during the setting time.

Once the impression had been obtained, implant or abutment analogues were adapted and screwed into the

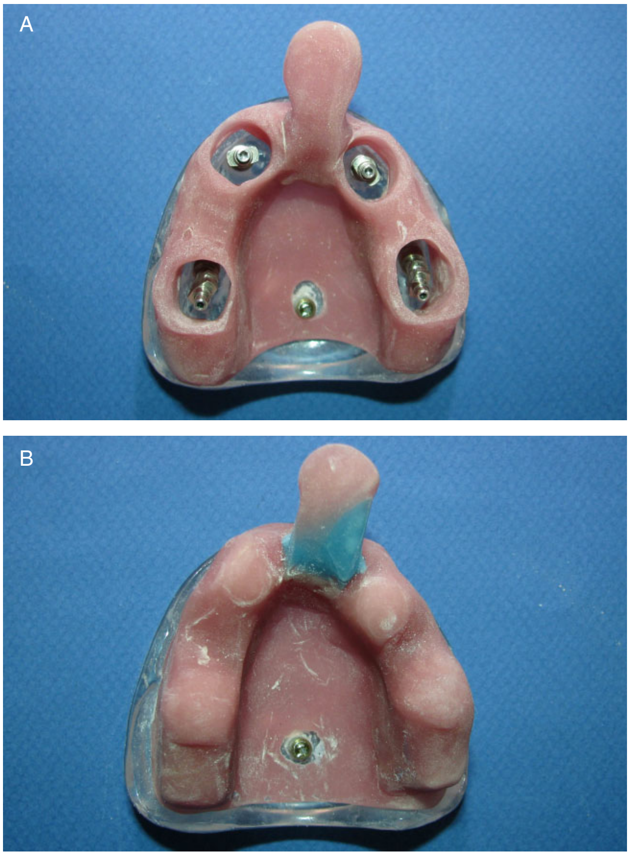

Figure 2 Light polymerizing acrylic resin trays made for direct (A) and indirect (B) impression technique.

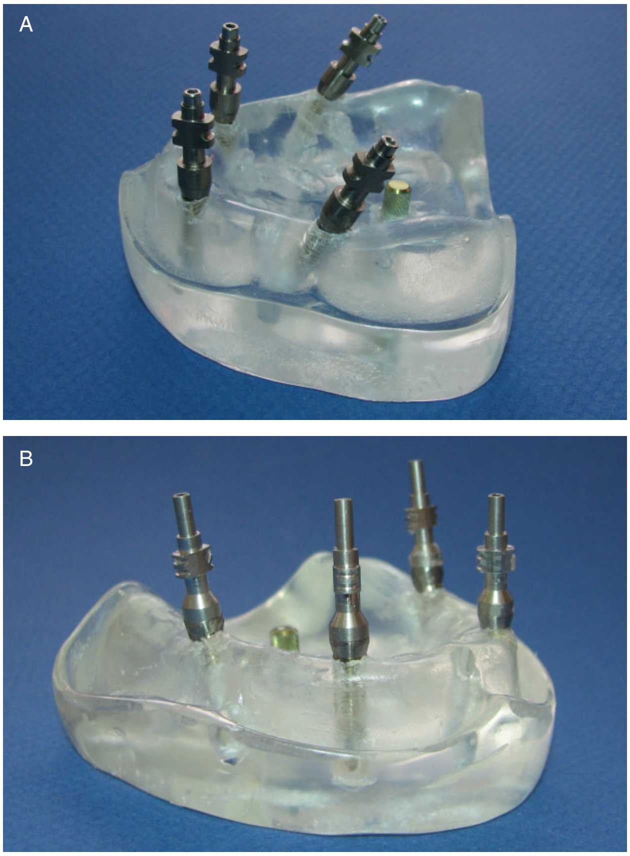

Figure 3 Implant level square impression copings attached to the implants (A) and abutments (B).

pick-up impression copings. In groups 2 and 4, the impression/matrix set was separated. Then, the conical transfer impression copings were unscrewed from the matrix and fitted to the implant or abutment analogues, and they were immediately replaced in each respective notch left in the impression. The combined impression 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 antirotational resistance. Casts were made by pouring dental stone type IV (Herostonel Vigodent Inc., Rio de Janeiro, RJ, Brazil), which was vacuum mixed with a powder/water ratio of 30 g/7 mL, as recommended by the manufacturer's instructions. When set (120 minutes after pouring), the impression was separated from the cast. The same operators prepared all 40 impressions in all clinical and laboratory procedures.

Measurements

A single calibrated blinded examiner performed all readings randomly without any notification of previously described information about the code of each cast. Coordinate measuring machine (CMM) (Mistral, DEA Brown & Sharpe, Grugliasco, Italy) was used for recording the x, y, and z dimensions and also angular dislocation simultaneously.

Each working cast was measured three times, and an average was obtained. The distances from the reference point on the center of the superior surface were compared with the model (Figure 4). Additionally, readings were performed in each of four implants of the groups (abutment and implant level). A 1-mm-wide straight CMM probe recorded the distances between centers of

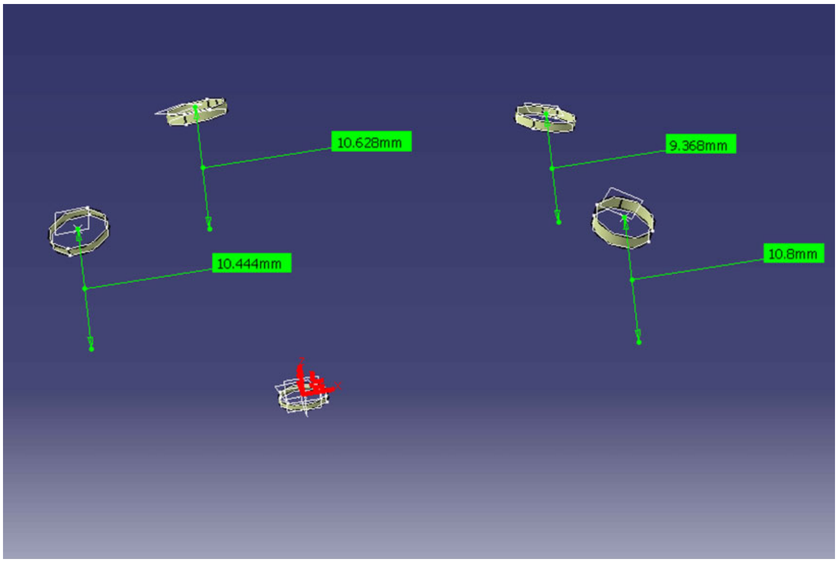

Figure 4 Schematic drawing of the measurements according to the reference point (red one in the figure). The measurements done in x, y, and z directions and also rotational displacement.

TABLE 2 The Absolute Mean Values (±SD) and Their Comparison of the Recorded Measurements in Each Group

Impression Level	Impression Technique	Group	Implant Angulation	Δr Mean (SD)	*p* Value	Δθ Mean (SD)	*p* Value
Implant level	Open tray	1	Straight	.647 (.41)	<.001	1.281 (1.11)	.95
			Tilted	.178 (.30)		1.261 (.79)	
	Closed tray	2	Straight	.702 (.65)	.005	26.804 (15.32)	<.001
			Tilted	.233 (.22)		4.392 (3.85)	
Abutment level	Open tray	3	Straight	.285 (.24)	.49	6.177 (5.95)	.009
			Tilted	.358 (.41)		13.315 (9.87)	
	Closed tray	4	Straight	.743 (.55)	.99	5.325 (6.08)	.004
			Tilted	.747 (.66)		19.627 (18.93)	

the implant aperture in each direction (x, y, and z). To evaluate angular changes (Δθ), the flat side of the external implant was used as reference for measuring the rotations. These linear and angular measurements performed on the master models were repeated for all study casts. To represent three-dimensional linear displacement, Δr was calculated using $\Delta r^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$, where Δx, Δy and Δz were displacements at x-, y-, and z-directions, respectively.

Statistical Analysis

The data obtained from readings were recorded and summarized in tables. Means of various coordinates in all groups were compared using univariate analysis of variance with three variables of impression technique (direct and indirect), impression level (abutment-level and implant-level), and implant angulation (straight and tilted), and *t*-test with significance level set at $p = 0.05$.

RESULTS

The measurements of displacements in angular dislocation (Δθ) and Δr are presented as means (standard deviations) in Table 2. Univariate analysis showed a statistically significant difference between straight and tilted, implant level and abutment level, and also direct and indirect impression techniques.

The Effect of Implant Angulation

The effect of implant angulation was analyzed by comparing the inaccuracy values for each group at the impression levels and techniques (Table 2). The results showed that abutment level impression making (groups 3 and 4), either with direct or indirect technique, produced the same results for straight and angled implants for Δr variable ($p > .05$) though in implant level groups (groups 1 and 2), it was significantly different. However, measuring Δθ showed that the only group that had the same result for straight and tilted implants was group 1 (Table 2).

The Effect of Impression Level

The effect of impression level was analyzed in the same way, and the results showed that impression level (abutment vs. implant level) had significant effect in the linear transfer accuracy (Δr) of straight implants ($p = .002$) with direct technique and tilted implants ($p = .002$) with indirect technique. Measuring Δθ showed that there was significant difference between implant and abutment level impression making in all comparisons ($p < .001$) (Table 3).

The Effect of Impression Technique

Evaluating the effect of impression technique showed that direct technique of abutment level impression making produced more linear accuracy (Δr) either in tilted ($p = .03$) or straight ($p = .002$) implants. Regarding angular accuracy (Δθ), direct technique also produced better results in implant level impressions of either tilted ($p = .001$) or straight ($p < .001$) implants (Table 4).

DISCUSSION

One of the factors that may contribute to lack of passive adaptation of the framework to its supporting abutments and/or implants is the accuracy of the impression procedure.[3] The precision of impression procedure is influenced by several factors including impression materials, impression technique, angulations of the implants, number of the implants, and impression trays.[3–10,21,28] The mechanical properties of an impression material, such as accuracy and rigidity, may influence the precision of impression, cast, and final suprastructure.[17,18,21,30]

TABLE 3 The Effect of Impression Level by Comparing the Inaccuracy Values for Each Group at the Implant Angulation and Impression Techniques

Impression Technique	Implant Angulation	Impression Level	Group	Δr *p* Value	Δθ *p* Value
Open tray	Straight	Implant level	1	.002	.001
		Abutment level	3		
	Tilted	Implant level	1	.12	<.001
		Abutment level	3		
Closed tray	Straight	Implant level	2	.83	<.001
		Abutment level	4		
	Tilted	Implant level	2	.002	.001
		Abutment level	4		

[Correction added on January 15 after first online publication: Implant Angulation, Impression Level and Impression Technique column headers were transposed.]

As the addition silicones have lower modulus of elasticity, it could be considered as a feasible alternative, particularly when nonparallel implants are present, allowing for the easy removal of the impression and reducing the permanent distortion caused by the stress between the impression material and the copings.[29,30] As described in previous studies, because of the presence of a nonparallel positioning of the implants in this study, additional silicone (VPS) was used.[29,30]

The null hypothesis was rejected as the implant angulation had a significant effect on the accuracy of the experimental casts compared with the master model. This is in agreement with other study that showed that tilted implants could affect the accuracy of impression.[9,19,21] Sorrentino and colleagues showed that nonparallel implants in the present of physical undercuts may affect distortion negatively.[21] Assuncao and colleagues evaluated impression accuracy in a model contained 65–90 degree angulated implants.[19] They discussed that when implants are in angulated position, square copings are indicated to avoid inaccuracy.[19] However, Conrad and colleagues showed no inaccuracy in impression transfer of three implants with 15 degree divergence. This might be related to less angulation and implant number in Conrad's study.[33]

The results of this study also showed that there was a significant difference between implant level and abutment level impression making, and the abutment level method showed more linear accuracy (Δr). In All-on-4 reconstruction, angulation of distal implants (tilted) is compensated with angled abutments. However, implant level impression making produced less angular displacement (Δθ) that could be related to the hexagonal implant connection. An external hexagon antirotation with direct impression technique would result in an exact impression. It has been showed that a direct impression of external hexagonal implants produces lower level of stress between impression material and

TABLE 4 The Effect of Impression Technique by Comparing the Inaccuracy Values for Each Group at the Implant Angulation and Impression Levels

Implant Angulation	Impression Level	Impression Technique	Group	Δr *p* Value	Δθ *p* Value
Straight	Implant level	Open tray	1	.75	<.0001
		Closed tray	2		
	Abutment level	Open tray	3	.002	.66
		Closed tray	4		
Tilted	Implant level	Open tray	1	.51	.001
		Closed tray	2		
	Abutment level	Open tray	3	.03	.19
		Closed tray	4		

impression copings.[14] Daoudi and colleagues advocated the use of the implant-level impression technique especially in malpositioned implants to produce less inaccuracy.[34] However, total movement of the square impression coping during attachment of the implant analogue to the impression coping might result in a misfit of components.[18] This can be worsened without antirotation situation such as abutment level direct impression making in this implant system.

Other factors that appear to play an important role in the accuracy of impression procedure in many implant systems are length, shape, and different geometry of impression copings.[13] Square impression copings in pick-up method in comparison with conical impression copings in transfer method show more retentive elements. Carr's study[18] indicated that the inaccuracy of the indirect impression technique may occur due to apparent deformation of a stiff impression material such as polyether. Therefore, a more elastic impression material such as additional silicon (VPSs) could reduce the permanent deformation of the impression.[14,19] It has been showed that the impression copings with more retentive elements would result in less discrepancies.[14,19]

This study showed significant differences in the Δr and $\Delta\theta$ of tilted and straight implants between direct and indirect impression techniques, and direct impression technique showed better results. These results were compatible with other studies that showed direct impression technique was more accurate than indirect impression technique.[3,18] As the square impression coping of the direct impression technique remains in the impression, the effect of the implant angulation and the deformation of the impression material upon recovery from the mouth will be reduced.

A possible limitation that makes extrapolation of the data to the clinical situation difficult is that all trays were removed perpendicular (for standardization) to the occlusal plane that is not similar to the mouth. Several studies showed that terminal implants are representative of the greatest stress created when recovering the indirect impression from the master cast that this could be more important in All-on-4 protocol.[35,36] Another limitation is that results are limited to four implants of All-on-4 protocol and may not be relevant for impressions that have higher or lower numbers of implants. Future research is needed to determine the amount of discrepancy produced with a different connection, more implants, and different depth of implant insertion.

CONCLUSION

Within the limitations of this study, it could be concluded that impression level could affect the impression accuracy, as abutment level impression produced more accuracy in representing three dimensional positions of tilted implants in the impressions made with additional silicone impression material. The results of this study also showed that impression method (direct or indirect) had a significant effect on the impression accuracy of tilted implants. These results could help the clinicians to choose a better implant component and impression technique.

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