Accuracy of Implant Impressions with Different Impression Coping Types and Shapes

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ABSTRACT

Background: Accurate recording of implant location is required so that definitive restorations are properly supported and do not place additional stresses on the implants. Movement of impression copings inside the impression material using an open-tray or close-tray impression technique during clinical and laboratory phases may cause inaccuracy in transferring the three-dimensional spatial orientation of implants intraorally to the definitive cast. Consequently, the restoration may require corrective procedures.

Aim: This in vitro study compared the accuracy of two different impression techniques with two different impression coping shapes using polyether impression material to obtain precise definitive casts.

Materials and Methods: Two reference acrylic resin models (Technovits 4000, Heraeus Kulzer GmbH & Co., Wehrheim, Germany) with five internal connection implants having different shapes of impression copings (Implantium [Dentium, Seoul, South Korea] and Replace Select [Nobel Biocare AB, Göteborg, Sweden]) were fabricated. Twenty medium-consistency polyether impressions of these models were made with square and conical impression copings of each system using open-tray and close-tray techniques. Matching implant replicas were screwed into the impression copings in the impressions. Impressions were poured with type IV stone, and the positional accuracy of the implant replica heads in x-, y-, and z-axes (represented in [Δr]) and also rotational displacement ($\Delta\Theta$) were evaluated using a coordinate measuring machine (Mistral, DEA Brown&Sharpe, Grugliasco, Italy). These measurements (linear and rotational displacements) were compared with the measurements calculated on the reference resin models that served as control, and data were analyzed with a two-way analysis of variance at $\alpha = 0.05$.

Results: Less inaccuracy occurred in less retentive shape impression copings (Replace Select) compared with the more retentive one (Implantium) ($p_r < .001$ and $p_\Theta < .001$), but there was no significant difference between direct and indirect impression techniques (p_r and $p_\Theta > .05$).

Conclusion: The impression coping shape had more impact on impression inaccuracy than impression technique did. Understanding of the magnitude and variability of distortion when employing certain impression-making methods and impression coping shapes helps the clinician to select a better implant component and impression technique.

KEY WORDS: impression coping, impression technique, polyether impression material

INTRODUCTION

Dental implants, unlike natural teeth cushioned in the alveoli by periodontal fibers, are intolerant of movement in their adaptation to the demands of the metal or ceramic supporting structure.[1] Imprecise superstructure fit may submit the components to strain and consequently result in mechanical and biologic consequences.[2,3] These include prosthesis and abutment screw loosening and fracture, occlusal inaccuracies, fracture of the implant, microfracture of the surrounding implant bone, and bone loss.[4] Several techniques have been suggested to improve the fit of an implant-supported

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prosthesis, but universal guidelines to define an acceptable fit are not available.[5] Assif and colleagues[6] proposed that the discrepancies might be less than 10 µm at each abutment. Because discrepancies of less than 30 µm in the fit of an implant-retained framework on multiple abutments cannot be detected clinically by experienced operators, this value could serve as a criterion between acceptable and inacceptable frameworks.[6] Authors have reported that true passive fit of multi-implant-supported prostheses does not seem attainable as a result of the number of variables involved in the prosthesis fabrication process.[2,3,7–13] These include tolerance among the components of the implant systems, changes in the materials, inaccurate repositioning of impression copings, improper connection of components, investing, casting, and alloy properties as well as clinician skill.[13,14]

One of the major concerns in implant-retained prostheses is the accuracy of impressions, which is the first step in achieving an accurate, passively fitting prosthesis.[13–15] Numerous reports have evaluated the importance of various clinical and laboratory steps in the elaboration of accurate master casts in regular crown and fixed partial denture procedures such as impression materials, use of custom trays, and use of adhesives in the impression trays.[16,17]

For implant impression making, transfer techniques have a decisive influence on the fabrication of accurate working casts. Both direct (open-tray) and indirect (close-tray) techniques for transferring implant position to the working cast are commonly used in dental practice.[18] Comparing of the square and conical transfer impression copings in various implant systems has been recorded in the literature.[7–10,18–23] While some authors reported better results with the direct technique[7,8,11,15,24], Humphries and colleagues[9] found that the indirect technique was more accurate, required less working time, was easier for the operator,[9] and also more comfortable for the patient.[7,11] These widely different results are likely because of the use of different components and study designs.

Several techniques have been suggested for splinting implant transfer copings of direct impression technique to improve its accuracy. These include splinting with acrylic resin using dental floss, prefabricated acrylic resin bars, stainless steel burs, and orthodontic wires as a scaffold.[12,24,25] Besides being time-consuming and the complexity of the procedure, because of a large amount of acrylic resin needed to splint the impression copings, and tresultant shrinkage and inaccuracies, no consensus is found in the literature about splinting impression copings.[22,23,25]

Figure 1 Different shapes of direct and indirect impression copings in various systems. Upper and lower rows show the square and conical impression copings, respectively. The two first left impression copings in each row were used in this study.

However, not only are there various impression materials and techniques, but also there is a great variety of implant systems with different prosthetic component shapes, demanding an investigation into the quality of these implant components so that the most desirable shape, and consequently, implant system, may be indicated (Figure 1). Most of the research has focused on techniques to improve accuracy of impressions. However, no research was found comparing different shapes of impression copings of different implant systems that could affect implant system selection. The purpose of this study was to evaluate and compare the effect of different shapes of impression copings (Replace Select and Implantium implant system) and impression-making techniques (direct and indirect) on the accuracy of implant impression transfers.

MATERIALS AND METHODS

Two reference acrylic resin models (Technovits 4000, Heraeus Kulzer GmbH & Co., Wehrheim, Germany) were made, and by using a dental milling machine (K9, Kavo, Berlin, Germany), five parallel holes 4.5 mm in diameter and 12 mm in length were created in each model. Five internal connection dummy implants (Implantium, Dentium, Seoul, South Korea), 10 mm in length with 4.3 mm diameter, were inserted in one

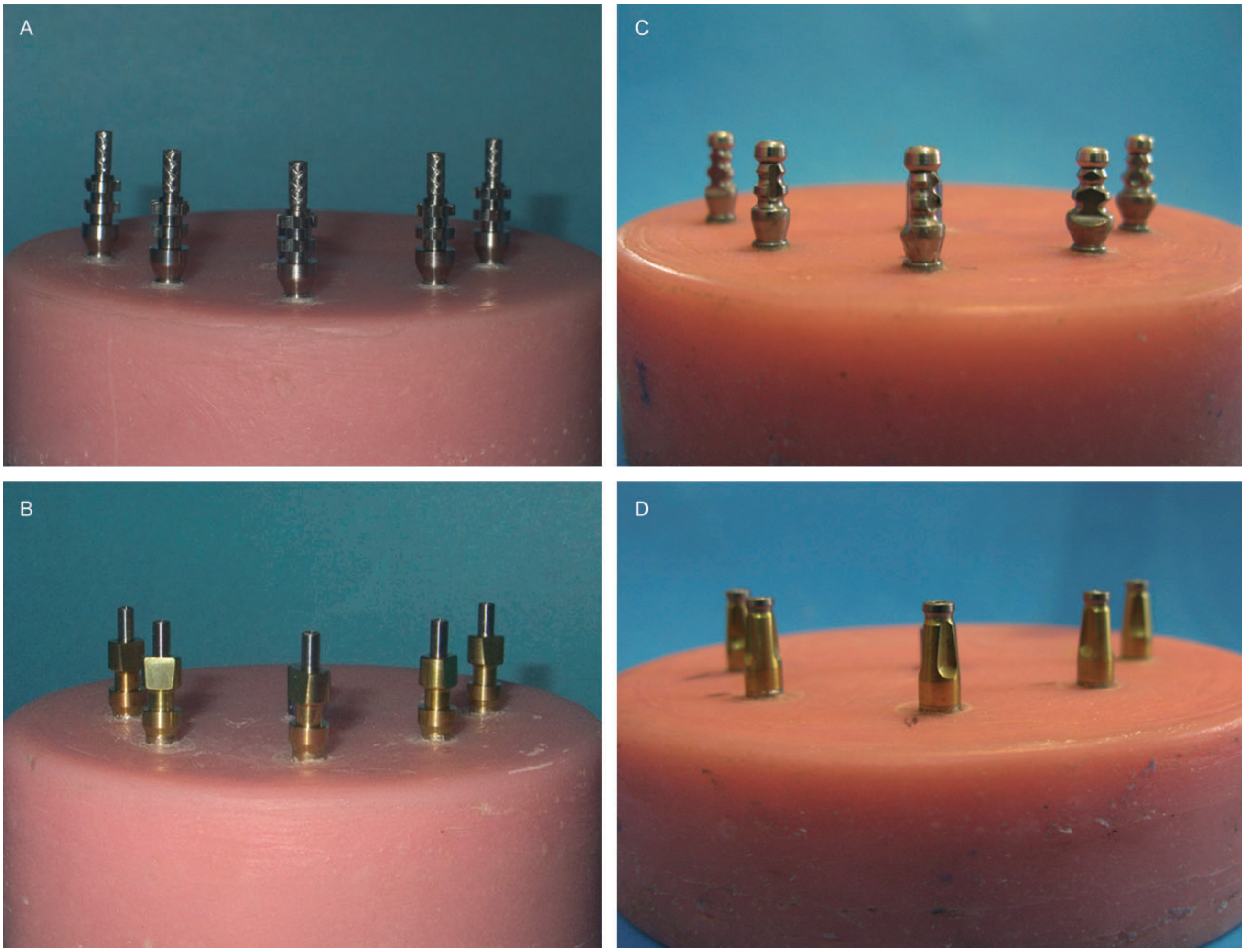

Figure 2 The acrylic resin models with impression copings. *A*, Square transfer copings of Implantium implant system. *B*, Square transfer copings of Replace Select implant system. *C*, Conical transfer copings of Implantium implant system. *D*, Conical transfer copings of Replace Select implant system.

model, and in the other model, five 11×4.3 mm–diameter Replace Select dummy implants (Nobel Biocare AB, Göteborg, Sweden) were substituted and were secured with auto-polymerizing acrylic resin (Technovits 4000, Heraeus Kulzer GmbH & Co.). 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 in the holes. The five implants in the acrylic resin models were sequentially numbered 1 through 5 from left to right.

At least 1 week later, the transfer copings were adapted to the implants in the resin models (Figure 2), and irreversible hydrocolloid (Alginoplast, Heraeus Kulzer GmbH & Co., Wehrheim, Germany) impressions were made to obtain a single cast for each model on which all custom trays were molded. The obtained casts covered by two layers of baseplate wax (modeling wax, Dentsply, Weybridge, UK) to allow a consistent thickness of impression material and tissue stops were included in the impression trays to standardize tray positioning during impression making. Forty identical 2 mm thick custom impression trays (10 open trays and 10 close trays for each model) were made with light-polymerizing resin (Megatray, Megadenta, Radeberg, Germany). The trays had the same internal space (3 mm) and held the same amount of impression material so that they reproduced the dimensions of the master framework. Regular-viscosity polyether (Impregum F, Espe Dental, Seefeld, Germany) was the impression material of choice for all transfer procedures, and was managed according to its respective manufacturers' recommendations and the specification number 19 of ADA.[26] All impressions were made in a controlled temperature environment (23 ± 2°C) with a relative humidity of 50 ± 10%. The internal part and 5 mm beyond the borders of all perforated impression trays were coated with polyether adhesive (Impregum, 3M ESPE, Seefeld, Germany) 15 minutes before each impression was made.

In groups 1 and 2, conical copings, and in groups 3 and 4, square copings of Implantium (Dentium) and Replace Select implant systems (Nobel Biocare AB), respectively, were adapted to the implants using uniform 10 N/cm torque, according to Vigolo and colleagues[21] and Inturregui and colleagues.[22] The impression material was machine-mixed (Pentamix, 3M ESPE), and part of the material was meticulously injected around the transfer copings to ensure complete coverage of the copings. The remaining impression material was used to load the impression tray. The impression tray was lowered over the reference resin model until the tray was fully seated on the location marks. A standard 5 kg weight was placed over the trays during the material setting, and the impression/matrix set was placed in distilled water at 36 ± 1°C during the polymerization time. After 5 minutes, in groups 1 and 2, the impression/matrix set was separated. Then, the conical copings were unscrewed from the matrix and fitted to the implant analogues, and 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. This tactile feel indicated that the three grooves on the coping were locked into place and that the implant orientation was accurately transferred.

In groups 3 and 4 (square copings of Implantium and Replace Select implant systems), the screws of the copings were removed with a screwdriver, and then the impression/matrix set was separated. Once the impression had been obtained, implant analogues were adapted and screwed into the copings using 10 N/cm torque, which remained inside the impression in both groups 3 and 4.

Following recovery, impressions were inspected and repeated when any inaccuracies were found such as air voids, impression material between the analogue–impression coping interface, and impression material separation from the custom tray. Sixty minutes later, to provide the matrix replicas, the impressions were boxed to form a base height of 2 to 3 cm. Dental stone type IV (Herostonel Vigodent Inc., Rio de Janeiro, RJ, Brazil) was manipulated with a vacuum machine, with a powder/water ratio of 30 g/7 mL, as recommended by the manufacturer, and then poured under constant vibration. The stone was mixed with distilled water in the amounts recommended by the manufacturer and poured into each impression. When set (120 minutes after pouring), the impression was separated from the cast. The same operators prepared all 40 impressions.

Readings

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 coordinate measuring machine (CMM) (Mistral, DEA Brown&Sharpe, Grugliasco, Italy) that is capable of simultaneously recording −x, −y, and −z dimensions. The accuracy of CMM was 2.8 μm for the x-, y-, and z-axes. Each experimental cast was measured three times (an average was obtained), and the distances from the reference point on the center of the superior surface were compared with the master models (Figure 3). Additionally, readings were performed in each of five implants of the two resin models. A 1-mm-wide straight CMM probe recorded the distance between centers of the implant aperture in each direction (−x and −y) and the perpendicularity of each implant in comparison with the horizontal crestal plane in the master model. To evaluate angular changes (ΔΘ), the flat side of the impression copings was used as reference for measuring the rotations. These linear and angular measurements performed on the master models were repeated for all working casts. The data obtained from the readings were recorded and summarized in tables. All data were presented in absolute values in each direction. Their means and SDs were calculated and then submitted to the analysis of variance, with two variables (impression technique and system) at a significance of 5% ($p < .05$) using SPSS v. 14.0 for Windows (SPSS Inc., Chicago, IL, USA). After differences had been detected among the groups, the post hoc Tukey test was applied.

RESULTS

The measurements of displacements in the x, y, and z directions, and also angular dislocation, are presented as means (SDs) in Table 1. For the y direction, significant differences were found between impression techniques for the two systems and direct impression technique

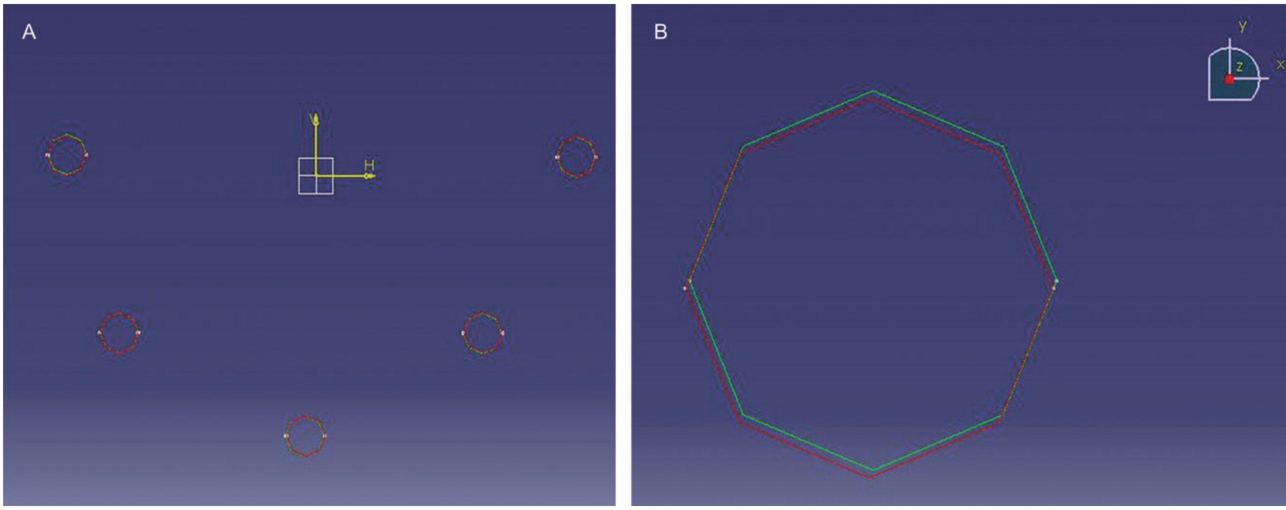

Figure 3 Schematic drawing of the measurements according to the reference point. The red drawing indicates baseline measurements on the reference model (A). The green lines show the measurement on the cast superimposed on the original diagram (B).

produced less displacement ($p < .05$). The differences between direct and indirect impression techniques did not produce significant difference in the x and z direction. For the z direction, differences were found between two systems ($p < .001$), and also for angular direction ($p < .001$). The results show that both square and conical impression copings of Implantium system produced more inaccuracies in implant transfer ($p < .001$). Δr was calculated using the equation $\Delta r^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$, and it represents three-dimensional linear displacement. Statistical analysis confirmed that Replace Select system showed significantly smaller Δr ($p < .001$) than Implantium system. Considering the total distortion introduced from different techniques of impression making, there was no significant difference in Δr between direct and indirect techniques ($p > .05$).

DISCUSSION

An important factor that influences precision of fit is impression accuracy. In a good impression, there is a possibility of finding a discrepancy of 50 µm in any axis.[14] Manufacturers have made options available for impression making; however, an understanding of which method predictably provides the most accurate transfer given various clinical situations is needed.

The single chosen impression material in this investigation was a single-mix polyether exhibiting good resistance to permanent deformation, low strain in compression (flexibility), favorable shore A hardness at 1 hour, and high initial tear strength.[27] As the attention was on transfer technique accuracy and not on the material accuracy, each technique was subjected to similar material dimensional changes (impression material shrinkage of 0.17%).

Both techniques require a blind manipulation, one in attaching an analogue, the other in fully seating the coping-analogue combination. For practical clinical purposes, an understanding of the magnitude and variability of distortion when employing certain impression-making methods and impression coping

TABLE 1 The Absolute Amount (mm) of Displacement in Each System and Impression Technique

Implant System	Impression Technique	Number of Impression	Mean Δx (SD)	Mean Δy (SD)	Mean Δz (SD)	Mean Δr* (SD)	Mean ΔΘ† (SD)
Implantium	Direct	10	0.09 (0.04)	0.07^a (0.05)	0.22^c (0.06)	0.28^e (0.07)	4.96^g (0.18)
	Indirect	10	0.09 (0.06)	0.08^a (0.05)	0.21^d (0.06)	0.26^f (0.08)	7.34^h (0.75)
Replace Select	Direct	10	0.09 (0.04)	0.06^b (0.03)	0.08^c (0.05)	0.16^e (0.06)	2.30^g (1.2)
	Indirect	10	0.11 (0.05)	0.09^b (0.05)	0.08^d (0.04)	0.19^f (0.05)	2.27^h (1.7)

Identical letters indicate that values are significantly different at $p < .05$.
*Δr is calculated using the equation Δr2 = Δx2 + Δy2 + Δz2, and it represents three-dimensional linear displacement.
†ΔΘ represents rotational displacement.

shapes helps the clinician determine which procedure and which implant system provide the best chance for accuracy. All values of distortion in this study were expressed as positive for analysis because clinical deviations in either directions are equally unacceptable.

In this context, studies related to impression making have focused on impression techniques and/or materials.[14] Other investigations tried to compare different impression copings with dissimilar connection into implant. Vigolo and colleagues[20] hypothesize that a higher level of stress between impression material and impression copings is created when an impression with impression copings is removed from internal connection implants rather than from regular external-hexagonal implants. Long walls of relative parallelism of an internal connection could make withdrawal of an impression difficult. Although the internal connections of the two systems in the study were not the same, perpendicular removal of impression trays nearly removes this effect on the impression accuracy of direct impression. Besides connection, impression copings of different implant systems have various length, width, indentation depth, shape, etc., which could affect the accuracy of final impression. Implant systems used in this study have a different geometry of both impression copings. Although the length was the same, Replace Select has less retentive element of both square and conical copings. Although more indentation would have better retention in the impression material, material deformation could result in inaccuracy. Carr[7] indicated that the inaccuracy of the indirect technique may arise from the apparent deformation of a stiff impression material such as polyether. Therefore, a more elastic impression material could hypothetically reduce the permanent deformation of the impression,[14,20] and impression copings with more retentive elements would result in less discrepancy. Also, it could be hypothesized that wider retentive element of Replace Select square impression coping could better entrap a stiff impression material such as polyether. In addition, the advantage of stiffness of polyether for direct impression making could be the same as splinted impression techniques.

The results of this study showed that although significant difference was found in the y direction between direct and indirect impression techniques, there was no statistical significant difference in whole dimensions ($p_r > .05$ and $p_\Theta > .05$), which is inconsistent with several other investigations.[10,18,19,22,23] Although these studies reported more accuracy for direct technique, most of them used splinted square impression copings.[18] Another explanation is that inaccuracies with recovery and subsequent deformation of conical impression copings may be encountered with nonparallel implants.[14] Carr[7] indicated that the inaccuracy of the indirect technique may arise from nonparallel implants. As the impression coping of the direct 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 of this study is the fact that the five implants were parallel to each other. It can be speculated that tissue undercuts and implant misalignment may cause a greater inaccuracy of the impression procedures, especially for the indirect technique.

However, rotational movement of the square impression coping during securing the implant analogue, and blind attachment of the implant analogue to the impression coping may result in a misfit of components,[7] and no scientific evidence is available to document their accuracy or superiority over the conical impression copings. Furthermore, the significance of such discrepancies may not be substantial in clinical situations, and no consensus has been reached on the accuracy of transfer techniques. The contradictory reported in the literature may be partially explained by the use of different methodologies to assess accuracy and reliability of the investigator.[28] Some experiments used direct measurement methods such as traveling microscopes in which inaccuracy was expressed in only two dimensions.[9,10,13] However, Assif and colleagues[8,12] used strain gauges to indirectly quantify distortion. The CMM used in this study had considerable precision, and its accuracy was 0.0028 mm.

The SDs of the different groups were sometimes of the same order of magnitude of the mean distortion. Contraction of the impression material, technique and operator errors, investment expansion, and machining tolerance of implant components and several other factors could be responsible for this deviation. Also, this study might imply that polyether did not behave homogeneously, which is inconsistent with Assuncao and colleagues'[14] study. This variability limits routine clinical application of the tested techniques and decreases their predictability.

Another limitation that makes extrapolation of the data to the clinical situation is that tray removal was not similar to the mouth and was perpendicular to the occlusal plane. Several studies showed that terminal implants are representative of the greatest stress created when recovering the indirect impression from the master cast. However, in this study, as the impression trays were removed perpendicular to the implant plane, the implant position was not a critical variable as it is in the mouth. The results of this study also are limited to five implants 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 alteration in shape (length, width, indentation depth, number, etc.) of impression copings, and it could be more correct to design custom impression copings to better determine the effect of each shape parameter of impression copings on the impression accuracy.

CONCLUSION

Within the limitations of this study, it could be concluded that impression coping shape (Implant System) had a significant effect on the impression accuracy, and Replace Select implant system produced less inaccuracy in the impressions made with polyether impression material. The results of this study also showed that although significant difference was found in the y direction between direct and indirect impression techniques, there was no statistical significant difference in whole dimensions ($\Delta\Theta$ and Δr) of both systems. These results could help the clinician to select a better implant component and impression technique.

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DISCLOSURE

The authors claim to have no financial interest in any company or any of the products mentioned in this article.

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