RESEARCH

Three-Dimensional Accuracy of Implant and Abutment Level Impression Techniques: Effect on Marginal Discrepancy

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Impression techniques should precisely represent the 3-dimensional status of implants to allow for the fabrication of passively fitting prostheses and subsequently the elimination of strain on supporting implant components and surrounding bone. The aim of this study was to compare the accuracy of an abutment level impression method with that of an implant level (direct and indirect) impression method using polyether impression material to obtain precise definitive casts and prostheses. A reference acrylic resin dentoform with 2 internal connection implants (Implantium) was made. A total of 21 medium-consistency polyether impressions of the dentoform, including 7 direct implant level, 7 indirect implant level, and 7 abutment level (after 2 straight abutments were secured), were made. Impressions were poured with American Dental Association (ADA) type IV stone, and the positional accuracy of the implant replica heads and abutment analogs in each dimension of x-, y-, and z-axes, as well as angular displacement ($\Delta\theta$), was evaluated using a coordinate measuring machine. Noble alloy 3-unit castings were fabricated and seated on the abutments in 3 groups; marginal discrepancies were measured at 4 points between prostheses and abutments. Data were analyzed using Mann-Whitney *U* test, 1-way analysis of variance (ANOVA), and Kruskal-Wallis tests. In comparisons of different impression techniques, only significant statistical $\Delta\theta$ differences were noted between the abutment level method and other techniques ($P < .001$). Results of this study reveal that although the implant level impression method could better transfer the angular position of the implants ($\Delta\theta$), the impression method could not affect Δy, Δx, and Δz coordinates of the implants or marginal discrepancy of the 3-unit fixed partial dentures (FPD).

Key Words: abutment level impression, implant level impression, impression technique, polyether impression material

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Introduction

A passively fitting prosthesis is a precondition for the maintenance of osseointegration, and its use is dependent upon the fact that the bone-implant interface allows limited movement of 10 μm; therefore, it is unlike natural teeth, which are cushioned in alveoli by periodontal fibers.[1] A misfit of superstructures generates initial stress and strain on implants; mechanical complications such as fracture of the prosthetic framework or veneering material and fracture or loosening of occlusal and/or abutment screws may be seen with functional loading.[2] An in vitro study demonstrated that a misfit of 3–5 unit prostheses, whether cement or screw-retained, may lead to strains ranging between 26 and 637.6 μm/mm at the level of the implant collar.[3,4] Owing to the fact that the minimum prosthesis-to-implant misfit is clinically acceptable and obscure, fastidious and accurate implant prosthodontic procedures such as accurate impression making are advised and necessary to achieve maximum fit.[1–4] Precise 3-dimensional transfer of implant or abutment positions from the mouth to working casts is the aim, along with attention to obtaining "optimum" fit between the implant and the superstructure during fabrication.[4] The cause of fixed implant-supported framework misfit is usually multifactorial. Distortions may occur in the x-, y-, and z-dimensions[5] and may be introduced by 1 or more of the following factors: implant alignments, impression techniques and materials used, and framework design and fabrications.[6–8]

Furthermore, problems related to investing, casting, alloy properties, and clinician/technician experience should not be omitted.[6,9] The importance of accurate impression making is strongly emphasized in achieving passive fit.[6,9,10,11] The impression can be made at the abutment level or at the implant level using 2 methods of direct (open tray or pickup) and indirect (closed tray or reposition) techniques.[12] The implant level technique can provide multiple benefits, including facilitation of temporary restoration provision,[13] easier abutment selection in the laboratory,[14] and availability of a variety of abutment types.[15–19] Although several studies have reported the accuracy of the implant level impression technique,[10,11,19–21] no concurrence is found in the literature regarding the most accurate impression technique. Little is known about the effect of imprecise impressions on the marginal discrepancy of a 3-unit fixed partial denture (FPD).

The purpose of this experimental study was to compare the accuracy of the abutment level impression method versus implant level impression techniques (direct and indirect). Toward this goal, 4 possible types of displacement were assessed, including x ordinate, y ordinate, z ordinate, and angular displacement. Moreover, marginal discrepancies of frameworks were recorded and compared among groups.

Materials and Methods

Technical procedures

A dentate maxillary acrylic resin model missing the left second premolar and first and second molars was used. With the use of a dental milling machine (K9, Kavo, Berlin, Germany), 2 parallel holes were created in the dentoform in the positions of second premolar and molar. Two internal connection dummy implants (Implantium, Dentium, Seoul, South Korea) 10 mm in length with 4.3 mm diameter were inserted into the dentoform and were fixed using autopolymerizing acrylic resin. A third hole at the posterior midline of the dentoform was prepared, and a cylindrical metal was inserted and fixed with autopolymerizing acrylic resin to provide a reference point for coordinating measurements. The fixture adaptor was secured on the vertical rod of a surveyor (J.M. Ney Co, Bloomfield, Conn) and was used to orient implants vertically on the surveyor during insertion into the holes.

One week later, the transfer copings were adapted to the implants in the resin dentoforms, and irreversible hydrocolloid (Alginoplast, Heraeus Kulzer GmbH & Co, Wehrheim, Germany) impressions were made to achieve a cast on which all custom trays were molded. Twenty-one custom trays were made; 7 trays were prepared for the abutment level impression method and 14 for implant level impression making (7 closed trays and 7 open trays). To allow consistent thickness of impression material, tissue stops were included in the impression trays to standardize tray positioning during impression making. The trays had the same internal space (3 mm) and held the same amount of impression material. All trays had 2-mm thickness and were made from a visible light polymerizing material (Triad TruTray, Dentsply Intl, York, Pa). 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 specification number 19 of the ADA.[22] All impressions were made in a controlled temperature environment (23°C ± 2°C) with 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. Conical and square impression copings (Implantium) were adapted to the implants and were tightened using uniform 10 Ncm torque, according to Vigolo[20] and Inturregui[21] et al (Figure 1). The impression material was mixed, and part of the material was precisely 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 dentoform until the tray was fully seated on the location marks. A standard 5 kg weight was placed over the trays during material setting, and the impression/matrix set was placed in distilled water at 36°C ± 1°C during the polymerization time. After 5 minutes, in an indirect group, the impression/matrix set was separated. Then, the conical copings used for indirect technique were unscrewed from the matrix, fitted to the implant analogs, and immediately replaced in each respective notch left in the impression by firmly pushing them into place to full depth and slightly rotating clockwise to feel for antirotational resistance. In the direct implant level group, after the impression material was set, the direct transfer coping screw was unthreaded to allow removal of the impression from the mouth. After this was done, implant analogs were secured to transfer copings in the impression.

For abutment level impression making, 2 straight 2-piece abutments (Dual Abutment; Implantium) were tightened to implants on the reference dentoform with 35 Ncm torque (Figure 1). Plastic impression copings (Implantium) were seated on the abutments so that click sounds were heard (Figure 1). The impression material was injected around the transfer copings, and a loaded tray was lowered over the dentoform until the tray was fully seated on the location marks. All other conditions were similar to those of implant level techniques. After material setting, the tray was removed and abutment analogs were inserted into the transfer coping, embedded in the impression, so that the click sound was heard again. A single operator made all impressions, and new components were used for each procedure throughout the study.

Sixty minutes later, dental stone type IV (Herostonel Vigodent Inc, Rio de Janeiro, Brazil) was manipulated with a vacuum machine with a powder/water ratio of 30 g/7 mL, as recommended by the manufacturer,

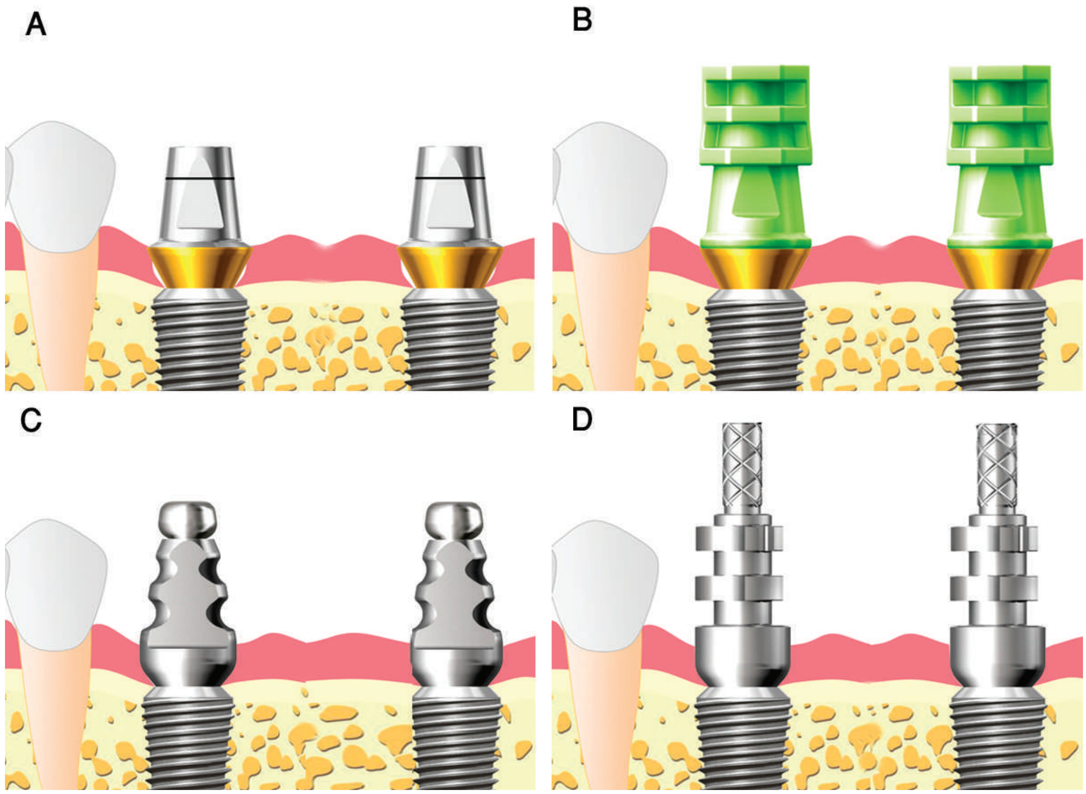

Figure 1. (A) Straight abutments connected to implants in the abutment level group. (B) Plastic impression copings seated on the abutments for impression making. (C) Conical transfer copings attached to the implants for indirect impression making. (D) Square impression copings secured to the implants for direct impression making.

and then was poured into each impression. When set (120 minutes after pouring), the impression was separated from the cast.

Straight abutments (Dual Abutment) were hand screwed at 10 Ncm into the implant analogs in the implant level groups, and cast frameworks were fabricated in all groups following the conventional lost wax technique. The frameworks were waxed up on the prefabricated plastic burn-out caps using the silicone index as a guide for dimensions of the framework. The frameworks were cast in precious metal alloy (Begostar, Bego, Bremen, Germany). The whole procedure, including wax-up, casting, and finishing, was carried out by the following recommended protocols. After the castings were divested and cleaned, the internal aspect of the casting was inspected under a stereomicroscope (Model BM 38834, Meiji Techno, Tokyo, Japan) at ×10, and surface irregularities were removed with a small round carbide bur.

Readings

A single calibrated examiner performed all readings randomly and out of sequence to evaluate the positional accuracy of the heads of implants or abutment replicas using a coordinate measuring machine (CMM) (Mistral, DEA Brown & Sharp, Grugliasco, Italy) capable of simultaneously recording in 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 3 times (an average was obtained), and the distances from the reference point on the center of the superior surface were compared with the dentoforms. To evaluate angular changes ($\Delta\theta$), the flat side of impression copings or abutment analogs was used as a reference for measuring rotations (Figure 2). These

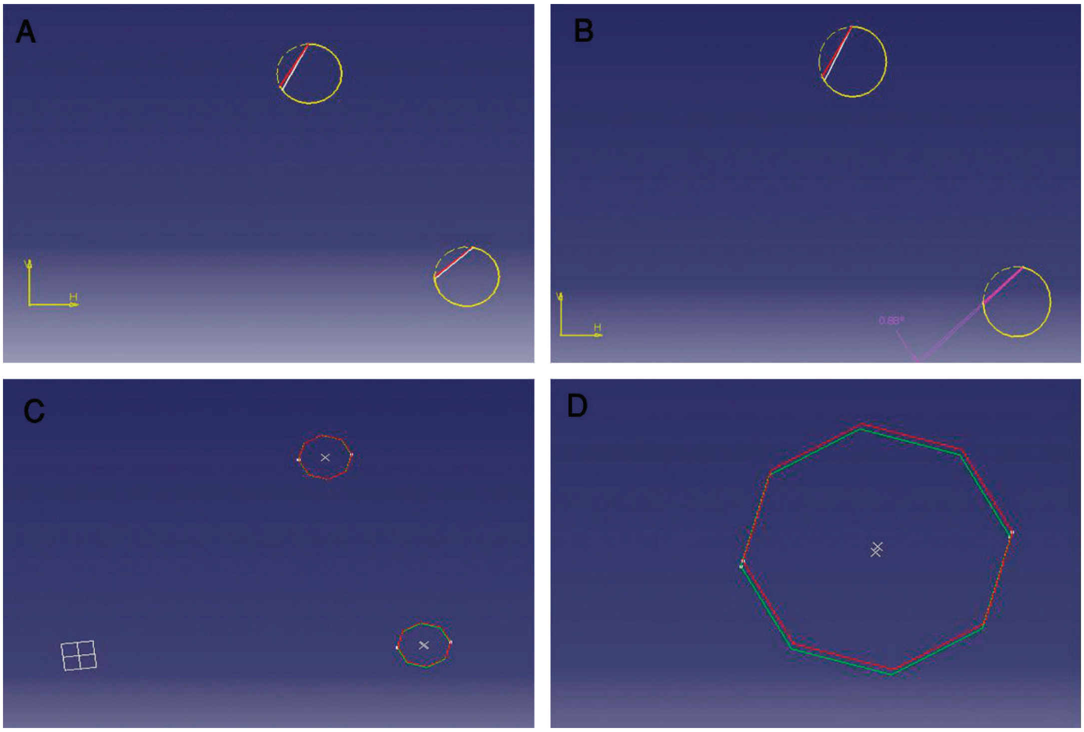

FIGURE 2. Schematic drawings of the measurements. The red drawing indicates baseline measurements on the reference model. The green and yellow lines show measurements of the casts of implant and abutment level groups, respectively, superimposed on the original diagrams. (A and B) Abutment level measurements. (C and D) Implant level measurements.

linear and angular measurements performed on the dentoforms were repeated for all working casts. Data obtained from the readings were recorded. Edge-to-edge marginal discrepancies were also recorded using a profile projector (Nikon Profile Projector Model V-12, Nikon Corp, Tokyo, Japan) with 0.001 mm accuracy. All casts were secured to a universal movable surveyor table (Ney, Hartford, Conn), and 3-dimensional status was adjusted so that the horizontal reference plane of the profile projector was consistent with the plane connecting the highest points of 2 implants. This procedure allowed for reproducible 3-dimensional positioning of all 21 experimental casts. Measurements were taken at 4 points for each implant, and the mean level was recorded.

Statistical analysis

With the Statistical Package for the Social Sciences (SPSS) version 16 (SPSS Inc, Chicago, Ill), an appropriate statistical test was applied for each comparison. Normal distribution plots showed a skewed distribution of some variables; after statistical adaptation tests (Kolmogorov-Smirnov) were run for each comparison, the application of nonparametric tests was indicated. The Wilcoxon rank sum test (Mann-Whitney *U* test) at a confidence level of 95% was used to determine the significance of differences between the 2 groups. When several groups were considered together, nonparametric analysis of variance (ANOVA) according to Kruskal-Wallis was used. For variables with normal distribution (Δx, Δz, $\Delta \theta$, and Δr), 1-way ANOVA and post hoc Tukey were applied. A significance level of $P = .05$ was used.

RESULTS

Three groups, each with 7 casts, were prepared, for a total of 21 casts. The mean and standard deviation of each measurement (Δx, Δy, Δz, $\Delta \theta$, and marginal discrep-

Table

Mean ± SD of 3-dimensional (x, y, z) displacement (mm), angular displacement (grad), and first and second marginal discrepancies (mm) in every impression technique group*

Measurement	Abutment Level		Implant Level (open tray)		Implant Level (closed tray)	
	Mean	SD	Mean	SD	Mean	SD
Δx	0.163	0.162	0.137	0.102	0.141	0.098
Δy	0.010	0.012	0.049	0.082	0.028	0.061
Δz	0.189	0.098	0.223	0.193	0.152	0.125
Δr†	0.268	0.160	0.264	0.186	0.234	0.131
$\Delta\theta$	4.747[d,f]	0.894	1.330[d]	0.608	1.330[f]	0.608
Marginal discrepancy	0.103[a]	0.066	0.014[b]	0.005	0.072[c]	0.027

*Identical letters indicate that values are significantly different at $P = .05$.
†$\Delta r^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$.

ancy) in experimental groups can be seen in the Table. Δr was calculated using the equation $\Delta r^2 = \Delta x^2 + \Delta y^2 + \Delta Z^2$, which expresses the 3-dimensional linear displacement of overall components. With comparison of different impression methods, including abutment level and implant level (closed tray and open tray), no significant difference was noted among the following measurements: Δx, Δy, Δz, and Δr ($P > .05$). Two implant level impression technique groups (open and closed tray) had significantly lower angular displacement ($\Delta\theta$) in comparison with the abutment level impression technique group ($P < .001$), although no significant marginal discrepancy differences were noted among groups.

Discussion

In light of various options available for impression making, an understanding of which method offers the most precise result is needed. A variety of factors have an influence on the precision of each impression technique, including flawless manipulation of impression materials, the materials used for impression making, the materials used for pouring dental stone, and appropriate timing of cast fabrications.[12–15,13,23] In this study, a single material was used, and all previously mentioned parameters were used to assess the accuracy of each impression technique. Properties of polyether, including great tear resistance, improved accuracy, excellent dimensional stability, and reproduction of details, suggest that it is a favorable material for implant impressions.[24] Although several reports advocate use of the implant level impression technique as a method to improve the esthetics of the restoration, reduce the number of treatment visits, or compensate for malpositioned implants,[12,13,15] some dentists prefer to place abutments and then make the impression in the same manner that an impression is made for natural teeth. This latter impression technique necessitates recording of positions and dimensions, rather than the implant level impression method (with machined components), which requires only recording of the implant head position. Both of these factors suggest that displacement of impression coping was likely to have less of an effect than in abutment level impressions.

Other factors that appear to play an important role in the accuracy of the abutment level impression technique in many implant systems are tactile sensation and the snap mechanism that indicates proper seating. It is likely that in some cases, the dentist does not feel the snap and improperly assumes that the transfer coping is properly seated. Moreover, Implantium impression copings, similar to many other implant systems, use a plastic impression coping that costs less and exhibits greater laboratory variance and poor fit as the result of irregularities. Less retentive components are present and can be compared with metal impression copings. Although these results are not in agreement with those of Daoudi's study, in which the author concluded that abutment level impression technique produced less inaccuracy, his study design and materials were different. Daoudi attributed these results to differences between picking the impression coping up and repositioning the coping in the impression. However, the impression coping shape of that study was different; also, abutment level and implant level copings were metallic rather than plastic. Moreover, Daoudi compared the pickup impression technique (abutment level) with the repositioning impression technique (implant level) and did not evaluate 2 pickup (direct) impression techniques at implant and abutment levels.[12]

Displacements occurred in the direction of each axis (x, y, and z) and Δr; no statistically significant difference was noted among methods ($P > .05$). However, with regard to another measured value, angular displacement ($\Delta\theta$), a significant difference was seen between implant level and abutment level methods ($P < .001$). These rotational errors should be noted carefully in single restorations because any rotation will affect the position of the final restoration that will be made to fit this malpositioned laboratory analog.[12] Most plastic impression copings have an external ledge that helps the clinician orient them on the abutment correctly. It may be difficult to find this slight ledge, and despite inaccuracy in seating the impression coping, it can be forced into place. It is believed that rotation of about 3 degrees for the transfer coping technique might not result in a clinical problem, given the tolerances commonly incorporated into the cylinders used for buildup of the final restoration or equivalent internal relief to allow room for the cement.[12,25] Greater machining error and machining tolerance, as defined by Ma et al,[26] of plastic impression copings may be one of the reasons for exhibiting less accuracy. Ma reported that measured tolerances ranged from 22 μm to 100 μm. Despite the fact that the machining tolerance was not measured separately in this study, it must be assumed that a significant amount of the discrepancy might have originated from machining tolerance.

Results of this study show that the abutment level impression method had comparable marginal discrepancy with other techniques. The prosthetic restoration for this study was a 3-unit FPD fabricated using burn-out caps recommended by the company, which has no antirotational design. Therefore, although the mean value of rotational error in this study was more than 3 degrees in the abutment level group, this had no significant effect on marginal discrepancy. Although these discrepancies were not statistically different, it seems that with increased numbers of implants and the combination of errors in x-, y-, and z-coordinates with rotational error, marginal discrepancies would increase.[27]

Multiple methods and materials were employed to assess marginal discrepancy, thus making it difficult for investigators to compare these quantities.[2,28] It is of interest that throughout this investigation, an exact reproduction of implant position was never accomplished. Clinically, this indicates that accurate fit of a superstructure may be unachievable on definitive casts from any impression technique, and laboratory procedures currently in use make use of the terms *precision* and *fit* completely subject to clinical evaluation by the clinician.

Additional studies are needed to determine the amount of discrepancy produced by a different alteration in the shape (length, width, indentation depth, number, etc.) of impression copings. Also, results of this study are limited to 2 parallel implants and may not be relevant for impressions that have different numbers of tilted implants and implants that sit away from each other.

Conclusion

Within the limitations of this study, it can be concluded that the impression technique has an effect on impression accuracy, and the implant level technique produced greater accuracy in representing the 3-dimensional positions of implants in impressions made with polyether impression material. Results of this study reveal that although a significant difference ($P < .001$) in angular displacement ($\Delta\theta$) was found between implant level and abutment level impression methods, no statistically significant difference ($P > .05$) in Δy, Δx, Δz, Δr, and marginal discrepancy was noted between the 2 methods. These results can help the clinician to select the better impression technique.

Abbreviations

ADA: American Dental Association
ANOVA: analysis of variance
CMM: coordinate measuring machine
FPD: fixed partial denture

Note

The authors claim to have no financial interest in any company nor in any of the products mentioned in this article.

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