ACCURACY OF TWO IMPRESSION TECHNIQUES WITH ANGULATED IMPLANTS

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Statement of problem. Accurate recording of implant locations is required so that definitive restorations are properly supported and do not place additional stress on the implants. Angulated implants may result in inaccurate impressions, and the impression technique may affect the accuracy of the definitive cast.

Purpose. The purpose of this study was to determine the effect the combined interaction of impression technique, implant angulation, and implant number has on the accuracy of implant definitive casts.

Material and methods. One definitive stone cast was fabricated for each of 6 experimental groups and 1 control group. All 7 definitive casts had 3 implants arranged in a triangular pattern creating a plane. In the 6 experimental groups, the center implant was perpendicular to the plane of the cast while the outer implants had 5, 10, or 15 degrees convergence towards or divergence away from the center implant. The control definitive cast had all 3 implants parallel to each another and perpendicular to the plane of the cast. Five open tray and 5 closed tray addition silicone impressions were made of each definitive cast. Impressions were poured with type IV dental stone, and a fine tip measuring stylus was used to record multiple axis (X-Y-Z) coordinates on the top surface of the implant hex and on the cast base. Computer software was used to align the data sets and vector calculations determined the difference in degrees between the implant angles in the definitive cast and the duplicate casts. Statistical analysis used repeated-measures ANOVA (α=.05) with post-hoc tests of significant interactions.

Results. The angle errors for the closed and open tray impression techniques did not differ significantly (P=.22). Implant angulations and implant numbers differed in average angle errors but not in any easily interpreted pattern (P<.001). The combined interaction of impression technique, implant angulation, and implant number had no effect on the accuracy of the duplicate casts compared to the definitive casts (P=.19).

Conclusions. The average angle errors for the closed and open tray impression techniques did not differ significantly. There was no interpretable pattern of average angle errors in terms of implant angulation and implant number. The magnitude of distortion was similar for all combinations of impression technique, implant angulation, and implant number. (J Prosthet Dent 2007; 97: 349-356)

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Reproducing the intraoral relationship of implants through impression procedures is the first step in achieving an accurate, passively fitting prosthesis. The critical aspect is to record the 3-dimensional orientation of the implant as it occurs intraorally, rather than reproducing fine surface detail. Imprecise superstructure fit results in mechanical and biologic consequences that disrupt the function of dental implants. Mechanical complications include loosening, bending, and fracture of the prosthetic or implant components. Biologic complications from loading above physiologic tolerance levels often result in breakdown of the osseointegrated interface between the implant and the surrounding bone. Loss of integration and loss of the implant is a potential outcome of either problem.

The difference between implant prosthodontics and conventional fixed prosthodontics is that in the former, it is more critical to record the 3-dimensional position of the implants as they occur intraorally. Natural teeth have a periodontal ligament to compensate for minor inaccuracies of 3-dimensional positioning of the abutments. However, integrated implants are not mobile, therefore, it is important to ensure an accurate relationship on the definitive cast.

The open tray technique involves fastening an impression coping to the implant with a screw that projects through an opening cut in a custom impression tray. The screw is loosened when the material is set and the tray is removed from the mouth with the impression coping retained within the impression. An implant analog is fastened to the impression coping using the same screw.

The open tray technique allows for the impression coping to remain in the impression. This reduces the effect of the implant angulation, the deformation of the impression material upon recovery from the mouth, and removes the concern for replacing the coping back into its respective space in the impression. Disadvantages of this technique are that there are more parts to control when fastening, there may be some rotational movement of the impression coping when securing the implant analog, and blind attachment of the implant analog to the impression coping may result in a misfit of components.

There may be clinical situations which indicate the use of the closed tray technique, such as when the patient has limited interarch space, a tendency to gag, or if it is too difficult to access an implant in the posterior region of the mouth. The closed tray technique uses a single-piece impression coping that remains attached intraorally to the implant once the impression is removed from the mouth. The coping is then removed from the implant, attached to the implant analog, and carefully repositioned with the correct orientation back into the impression.

Supporters of the closed tray technique suggest that it is more reliable as visual fastening of the analog to the coping is more accurate. There is concern that inaccuracies with recovery and subsequent deformation may be encountered with nonparallel implants. Impression copings must also be repositioned exactly into their respective positions in the impression, otherwise, misfits will occur.

Daoudi et al compared the closed tray technique at the implant level with the open tray technique at the abutment level for single tooth implants and found the open tray technique to be superior and more predictable. The closed tray technique had discrepancies in axial rotation and inclination of the analogs. Several authors have reported the superiority of the open tray technique. Carr compared the open and closed tray techniques with a 5 implant mandibular cast where the interabutment divergence angles were all less than 15 degrees. The open tray technique was found to be superior as it provided the most accurate working cast. Carr indicated that the inaccuracy of the closed tray technique may arise from nonparallel implants and the apparent deformation of a stiff impression material such as polyether. In a subsequent paper evaluating a 2 implant situation, 1 parallel to the long axis of the teeth and the other with a 15 degree lingual inclination, Carr reported that both techniques provided comparable results. This is in agreement with 2 other studies.

Separately, Daoudi et al and Liou et al evaluated the ability of different operators to reposition impression coping analog units into an impression and described the technique as unpredictable. Repositioning the implant impression coping back into the impression with the analog attached to it may result in adjusting or remaking the restoration. The copings could not be consistently and accurately repositioned into the impression. Ortorp et al compared the open tray technique using 2 different impression materials to a 3-dimensional photogrammetric technique for recording implant positions. Although all 3 methods studied failed to exactly reproduce the original orientation of the implants, the magnitude of dis-
tortion was similar in all situations.

Techniques to achieve more accurate impressions for patients with multiple dental implants are described in the literature. Most of the research has focused on techniques to improve accuracy with parallel implants.\textsuperscript{1,21,22,24,25,28-30} Carr et al\textsuperscript{16,17,31} evaluated impression methods for nonparallel implants; however, no research was found comparing techniques for implant impressions at varying degrees of divergence or convergence.

The purpose of this study was to measure the accuracy of the closed and open tray impression techniques in vitro, using 7 definitive casts, each with 3 implants at various angulations. The null hypothesis was that the combined interaction of impression technique, implant angulation, and implant number, would have no effect on the accuracy of the duplicate casts compared to the definitive casts.

**MATERIAL AND METHODS**

Coordinates were recorded on the surface of the implant and base of the cast to calculate the difference in the angulation of the implant in the definitive and duplicate casts. One definitive stone cast was fabricated for each of 6 experimental groups and 1 control group. All 7 definitive casts had 3 implants positioned in a triangular pattern to create a plane. The center implant (implant 2) in each of the 6 experimental groups was perpendicular to the plane of the cast, while the implants on either side (implants 1 and 3) had 5, 10, or 15 degrees convergence towards or divergence away from the center implant. The control definitive cast had all 3 implants positioned parallel to each other and perpendicular to the plane of the cast (Figs. 1 through 3).

To create the definitive casts, type IV dental stone (GC Fujirock EP; GC Europe N.V., Leuven, Belgium) was vacuum spatulated using a mechanical spatulator (Whip Mix Combina-
tion Unit; Whip Mix Corp, Louisville, Ky) and poured into a preformed mold and allowed to set. The casts were held in a vertical milling machine (Alliant Vertical Milling Machine; Alliant, Cincinnati, Ohio), and the holes were plunge cut to match the depth and diameter of the implant analogs. The differing angle holes were cut with a precision angle block placed in the vice under the casts. Regular diameter implant lab analogs (3i Implant Innovations, Palm Beach Gardens, Fla) were substituted in the definitive casts for implants due to cost and were secured with cyanoacrylate (910 Metal Bonding General Purpose; Perma-bond, Pottstown, Pa). Seven definitive casts were labeled and prepared for impression procedures. All procedures were completed by the same operator and intraoperator error was measured.

Seventy custom trays were made, allowing 5 open tray and 5 closed tray impressions for each of the 7 definitive casts. The trays were made from a visible light-polymerizing material (Triad TruTray; Dentsply Intl, York, Pa) and polymerized (Triad 2000 Visible Light Curing Unit; Dentsply Intl) for a total of 6 minutes. The trays were trimmed and perforated for added retention of the impression material. The custom open tray had a 3 opening design to accommodate the guide pins for any of the definitive casts.

Two-piece square open tray impression copings (Fig. 2) and twist lock closed tray impression copings (both of 3i Implant Innovations) with a 3 groove orientation (Fig. 3) were used to transfer the position and angulation of the implant. Either 3 open tray or 3 closed tray impression copings were placed on the 3 implants in the definitive cast to engage the hex and were hand tightened.

The custom trays were painted with vinyl polysiloxane adhesive (VPS Tray Adhesive; 3M ESPE, St. Paul, Minn) and allowed to dry for 15 minutes. The custom trays were filled with heavy body vinyl polysiloxane impression material while the regular body vinyl polysiloxane impression material (Imprint II Garant; 3M ESPE) was syringed around the impression copings on the definitive cast. The custom trays were seated on the definitive cast, and any excess material from the open tray windows was removed with a finger swipe to expose the guide pins.

The impression material was allowed to polymerize for 10 minutes prior to separation. For the open tray technique, the guide pins were loosened with a hex driver and removed, the tray was separated from the definitive cast, and the impression copings remained locked in the impression. The guide pins were placed back into the square open tray impression copings from the top, while an implant analog was connected to the hex on the bottom, and the guide pins were tightened with the driver.

Closed tray impression copings remained on the definitive cast after the impression material had polymerized when the tray was removed. These impression copings were removed one at a time from the definitive cast and attached to an implant analog. The combined impression coping analog unit was inserted into the impression by firmly pushing it into place to full depth and slightly rotating clockwise to feel for the antivotational resistance. This tactile feel indicated that the 3 grooves on the coping were locked into place and that the implant orientation was accurately transferred.

Impressions were inspected and repeated when any inaccuracies were found such as air voids, impression material between the analog-impression coping interface, impression material separation from the custom tray, or nonhomogenous mix of the 2 viscosities of impression material. Special care was taken to ensure that all components were properly oriented and completely seated. Type IV dental stone (GC Fujirock EP; GC Europe N.V.) was prepared according to the manufacturer’s instructions. The impressions were boxed and filled to form a base height of 2-3 centimeters.

Casts were separated from the impressions after allowing the stone to set for 1 hour, followed by trimming and labeling to prepare for measurements.

One at a time, all 7 definitive casts and all 70 duplicate casts were secured to a mounting plate with a clamp. A fine tip measuring stylus (FaroArm Silver; Faro Technologies, Lake Mary, Fla) with a single point accuracy of 76 µm was used to record 3-dimensional coordinates on the implant analog and base of the cast (Fig. 4). While wearing x2.5 magnification, the operator manually positioned the stylus on the top flat surface of the hex to capture 6 points near each apex and 3 points on the base at widely separated points. Measurement of these 21 points was repeated 5 times for a total of 105 measurements per cast (Fig. 5). The coordinates for each cast were recorded in a spreadsheet (Excel, Microsoft Office 2003; Microsoft, Redmond, Wash).

In order to make comparisons between the definitive and duplicate casts, an alignment was done to have all the casts in the same coordinate system. Each duplicate cast was aligned to the appropriate definitive cast using a least square fitting algorithm (Cumulus Version 0.7, 2003 Regents of the University of Minnesota; Twin Cities, Minnesota Dental Research Center for Biomaterials and Biomechanics, Minneapolis, Minn). For each of the 18 points on the definitive cast implants, the corresponding closest point on the duplicate cast implants was identified. The duplicate cast was rotated and translated in 3-dimensions to minimize the distance between corresponding points. The duplicate cast orientation corresponding to the minimum distance represented the optimal alignment with the definitive cast.

Coordinates for the aligned duplicate casts were exported to a spreadsheet (Excel; Microsoft Office 2003; Microsoft) where vector algebra was used to calculate a vector parallel to the long axis of each implant. Since a
plane is defined by 3 points that are not in a straight line, recording 6 points on the top flat surface of the hex allowed for the formation of 2 triangles by connecting alternating points. Using the coordinates of the equilateral triangles, a vector parallel to the long axis of the implant was calculated for each cast. Angular differences between corresponding definitive and duplicate cast implant vectors were calculated in degrees. Intraoperator measurement error was calculated using the replicate angle measures of individual implants relative to the respective cast base. These angles were analyzed using a mixed linear model with fixed effects for impression technique, implant angulation, implant number and their interactions, and variance components corresponding to subjects and measurements.

The primary analysis used was a repeated measures (split-plot) analysis of variance (ANOVA) (α=.05). The dependent variable was the angle (degrees) between the long axis of the implants in the definitive and duplicate casts, and a ‘subject’ was a duplicate cast. The between-subject (whole-plot) fixed effects were impression technique, implant angulation, and their interaction. The within-subject (split-plot) fixed effects were implant number and its interactions with impression technique and implant angulation. Combinations of the 7 implant angles, 5 casts produced from both the closed tray and open tray impression techniques, and the 3 implants in each cast, made up the 210 angle error measurements. The analysis used the MIXED procedure in the statistical software (SAS Version 8; SAS Institute, Cary, NC) with the restricted maximum likelihood estimation method and the slice option for post-hoc tests of interactions.

RESULTS

Intraoperator measurement error for a single angle measurement was determined for measurements of the angle of a given implant relative to the perpendicular of the plane of the cast. The standard deviation of this measurement error was estimated to be 0.7 degrees, using the 5 replicate measurements of a given implant angle. Table I summarizes the ANOVA results. The main effect for impression technique was not statistically significant (P=.22); nor were the interactions of impression technique with either the implant angulation (P=.47), implant number (P=.33), or both the implant angulation and implant number (P=.19).

Statistically significant results were found for the main effect for implant angulation (P<.01) and implant number (P<.001), as well as the interaction of implant angulation and implant number (P<.001). Comparing the implant angulations, with a separate test for each implant number, the implant angulations differ significantly using a Bonferroni-adjusted significance threshold (P<.05/3=.017) for implants 1 (P<.001) and 3 (P<.01) but not for implant 2 (P=.02) (Table II). For implant 1, 5 degrees divergence differs from all other implant angulations except 5 degree convergence, while no other pairs of implant angulations differ. For implant 3, 10

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degrees convergence differs from 5 degrees divergence, 15 degrees convergence, and 10 degrees divergence, but no other pairs of implant angulations differ. If instead the implant numbers are compared with a separate test for each implant angulation, the implant numbers differ significantly using a Bonferroni-adjusted significance threshold (P<.05/7=.007) for 5 degrees divergence, parallel, and 15 degrees convergence (Table III). For the parallel and 15 degrees convergence, implant 3 had significantly larger angle errors than either implants 1 or 2, which did not differ from each other.

For 5 degrees divergence, implant 1 had larger angle error than implant 2, but no other pairs of implants differed. Interpreted either way, these interaction results show no interpretable pattern.

### Table I. Repeated-measures analysis of variance

<table>
<thead>
<tr>
<th>Effect</th>
<th>Numerator Degrees of Freedom</th>
<th>Denominator Degrees of Freedom</th>
<th>F Statistic</th>
<th>P Value</th>
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### Table II. Tests comparing 7 implant angulations separately for each implant number

<table>
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<th>Implant Number</th>
<th>Numerator Degrees of Freedom</th>
<th>Denominator Degrees of Freedom</th>
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<th>P Value</th>
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<tr>
<td>Implant 1</td>
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<td>Implant 2</td>
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<td>2.67</td>
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<td>Implant 3</td>
<td>6</td>
<td>112</td>
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<td>.01</td>
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**DISCUSSION**

The data support acceptance of the null hypothesis as the combined interaction of impression technique, implant angulation, and implant number, had no effect on the accuracy of the duplicate casts compared to the definitive casts ($P = .19$) (Table I). Although there was a significant interaction of implant angulation and implant number ($P < .001$), the average angle errors have no interpretable pattern in either implant angulation or implant number.

Errors may be introduced during any of the several steps required, such as dimensional changes in the materials, inaccurate repositioning of impression copings, and improper connection of components. The clinical significance of distortion of this magnitude is unknown. The results of this study are limited to 3 implants and may not be relevant for impressions that have higher or lower numbers of implants.

One assumption made during this study was that the top surface of the hex was flat and that it was perpendicular to the long axis of the implant analog. This is important as the vector calculated for the implant angulation was based on the plane of the hex. The other was that although 18 of the 21 points recorded were on metal components that would not wear during impression procedures, the other 3 points were recorded from the stone base. The assumption was made that the stone would not wear significantly over the course of 10 impressions from each definitive cast.

The intraoperator measurement error of 0.7 degrees can be accounted for almost entirely by the precision of the measuring stylus (FaroArm Silver; Faro Technologies) as it may not be sensitive enough to detect differences between the variables. In order to decrease the error and find a statistical difference, a higher precision instrument would be required. A positioning device for the measuring stylus would not likely reduce the error as exact positioning was not critical as long as it contacted the top surface of the hex which was the reference plane for the angulation of the implant.

The results of this study are not in agreement with several studies which reported the superiority of the open tray technique. The ultimate clinical objective should be to fabricate an implant superstructure that imparts no stress to the implants when fully seated. Future research is needed to make further refinements to the impression and laboratory procedures, to determine the amount of discrepancy tolerable physiologically and mechanically, and to clinically analyze failures and complications in implant treatment. Whether or not two thirds of a degree in angle error is clinically relevant may be answered by further studies which should evaluate the fit of frameworks on these casts using either an electron microscope or strain gauges. An electron microscope could be used to evaluate the fit of the framework by measuring the size of the gap between the abutment and the implant. Strain could be measured and then correlated to misfit or time to failure in the prosthesis. Developing a method to test strain clinically would be a valuable objective tool for clinicians to evaluate framework fit.

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<th>Implant Angulation</th>
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<th>Denominator Degrees of Freedom</th>
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<th>$P$ Value</th>
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<td>112</td>
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<td>5 degrees divergence</td>
<td>2</td>
<td>112</td>
<td>5.45</td>
<td>.005</td>
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<td>Parallel</td>
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<td>112</td>
<td>5.52</td>
<td>.005</td>
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<td>112</td>
<td>1.24</td>
<td>.29</td>
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<td>112</td>
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<td>&lt;.0001</td>
</tr>
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</table>
CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The combined interaction of impression technique, implant angulation, and implant number, had no effect on the accuracy of the duplicate casts compared to the definitive casts (P=.19).

2. The average angle errors for the open tray technique were not significantly different from the average angle errors for the closed tray technique (P=.22).

3. There were significant differences when isolating the main effect for implant angulation (P<.01) and implant number (P=.001), as well as the combined interaction of implant angulation and implant number (P<.001). The interaction results had no interpretable pattern.

4. The interaction of impression technique with either the implant angulation (P=.47) or the implant number (P=.33) was not significant.

REFERENCES


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