Accuracy of Impression Techniques for Dental Implants Placed in Five Different Orientations

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**Purpose:** The purpose of this study was to evaluate the impression accuracy of two implants placed in different orientations and compare the impression accuracy obtained with the dual-arch impression technique using hybrid impression copings and the conventional open-tray impression technique. **Materials and Methods:** Five mandibular dentiform models were prepared by placing implants in the second premolar and second molar regions in the following different orientations: parallel to each other; 15-degree mesiodistal angulation; 30-degree mesiodistal angulation; 15-degree buccolingual angulation; and 30-degree buccolingual angulation. After making 10 impressions for each model with the open-tray impression technique and dual-arch impression technique with hybrid impression copings, cast models were fabricated for each impression (n = 10). Scan bodies were mounted on the five dentiform models and the fabricated 100 cast models were scanned using a desktop scanner. The three-dimensional deviation of the scan bodies on the cast models was calculated and compared to the reference data from the dentiform models. A two-way analysis of variance was conducted (α = .05). **Results:** The root mean square deviation values obtained from the implants placed with 30-degree mesiodistal angulation were 93.05 ± 6.21 µm with the open-tray impression technique and 104.01 ± 8.89 µm with the dual-arch impression technique, which were the largest deviation values for both techniques (P < .001). Compared to the open-tray impression technique, the dual-arch impression technique with the hybrid impression copings showed significantly lower accuracy when the angulation between the implants was 15 degrees mesiodistally (P < .001), 30 degrees mesiodistally (P = .016), or 30 degrees buccolingually (P < .001). However, there was no significant difference between the accuracy of the two impression techniques for parallel implants (P = .74). **Conclusion:** When the two implants were inclined 30 degrees mesiodistally, both implant impression techniques showed the largest deviation and the dual-arch impression technique showed lower accuracy compared to the conventional open-tray impression technique. Parallel placement of implants may improve impression accuracy and enable use of the dual-arch impression technique. *Int J Oral Maxillofac Implants* 2022;37:997–1002. doi: 10.11607/jomi.9441

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A passive fit between an implant and its superstructure is essential to minimize biologic and mechanical complications.1–4 Obtaining a passive fit requires accuracy of the implant impression, which is reportedly influenced by the impression material,5,6 impression technique,7–9 implant location,10 and implant angulation.7,9,11,12 In general, it is advantageous to place multiple implants parallel to each other; however, implant orientation is also dependent on the clinical situation.

A previous study reported that large differences in the angulation of implants resulted in inaccurate implant impressions.7 Another study showed that the inaccuracy of implant impression increased significantly when the angle between the two implants was more than 20 degrees.11 The impact of implant orientation on impression accuracy may vary for newly developed impression techniques and materials.

Another factor that influences the accuracy of impressions is the impression acquisition technique. Conventional techniques for implant-level impressions include the open-tray and closed-tray impression techniques. Several studies have reported that the open-tray impression technique yielded more accurate results than the closed-tray impression technique.7,8,13,14 However, the open-tray impression technique requires the
preparation of an open tray apart from a sufficient vertical space to tighten the guide pin of the pick-up coping. For these reasons, closed-tray impressions are preferred over open-tray impressions in certain clinical situations. However, both impression techniques cannot be applied as a dual-arch impression technique because of the height of the pick-up and transfer impression copings.

A recently developed hybrid impression coping method, also known as bite impression coping, provides the convenience of both closed-tray and dual-arch impression techniques for implant impression. Since the dual-arch impression technique can make the antagonist and bite impression at the same time, it can reduce the clinical time required for impression-making. However, studies on the accuracy of implant impressions made with the dual-arch impression technique using hybrid impression copings in various clinical situations are scarce. Thus, the purpose of this study was to compare the accuracy of impressions of differently oriented implants, obtained with the dual-arch impression technique using hybrid impression copings and the conventional open-tray impression technique. The null hypothesis was that there is no difference in the impression accuracy of implants placed in multiple different orientations and that there is no difference between the impression accuracy provided by the open-tray and dual-arch impression techniques.

**MATERIALS AND METHODS**

Five partially edentulous acrylic resin dentiform models (Dental Model, M. Tech Korea Co) were prepared, in which two implants were placed in different directions in the mandibular second premolar and second molar regions (Fig 1). Surgical guides were designed by scanning the dentiform models with a desktop scanner (Identica T500, Medit Inc) to place the implants in the correct direction and angulation. Two bone-level internal connection implants (IS-Ill active, Neobiotect Co) were placed 3 mm subgingival in each model. In the first model, two implants were placed perpendicular to the dentiform model and parallel to each other (parallel group). In the second model, the distal implant was placed with a 15-degree mesiodistal angulation between each other (MD15 group). In the third model, in addition to the 15 degrees mesial tilt of the distal implant, the mesial implant was placed with a 15-degree distal tilt, such that the two implants were placed at a mesiodistal angle of 30 degrees (MD30 group). In the fourth model, the distal implant was placed with a 15-degree lingual tilt (BL15 group). In the fifth model, in addition to the 15-degree lingual tilt of the distal implant, the mesial implant was tilted 15 degrees buccally, such that the two implants were placed at a buccolingual angle of 30 degrees (BL30 group). The test groups were further divided according to the impression technique used: open-tray and dual-arch impression techniques using hybrid impression copings (IS Pick Cap Impression Body and Cap, Neobiotech). Thus, a total of 10 groups were created (Table 1).

For the open-tray impression groups, individual trays were fabricated with a light-curing acrylic resin (Triad TruTray VLC, Dentsply). Two sheets of baseplate wax were applied to each dentiform model to provide identical space for the impression material. Pick-up impression copings (IS Hex Pick-up Impression Coping, Neobiotech) were hand-screwed to the implants (Fig 2a). The inner surface of each tray was coated with an adhesive (VPS Tray Adhesive, Kerr). Light-body
Polyvinyl siloxane (PVS) impression material (Charm-Flex Light-Premium, Dentkist) was loaded onto the copings and spread thinly by air blowing. Simultaneously, a heavy-body PVS impression material (CharmFlex Heavy, Dentkist) was placed in the tray. After setting of the impression material, the impression was removed from the model (Fig 2b). Ten impressions were made for each group (n = 10). Complete-arch master casts were fabricated in a conventional manner using a simulated gum material (GumQuick, DreveDentamid GmbH) and type IV dental stone (Heraeus Kulzer).

For the dual-arch impression groups, hybrid impression copings (IS Pick Cap Impression Body and Cap, IS Pick Cap Impression Screw, Neobiotech) were used for making impressions. Considering the interocclusal distance and soft tissue thickness of the dentiform model, hybrid impression copings with a gingival height of 3 mm were selected and connected to the implants. Then, hybrid impression coping caps were mounted on each hybrid impression coping (Fig 3a). Impressions were made using plastic dual-arch partial trays (Triple Tray, Premier Dental Products) and the same impression material used for the open-tray impression groups. The model was fully occluded during the setting of impression material (Fig 3b). Ten dual-arch impressions were made for each group (n = 10). After removal of the impression from the dentiform model, the hybrid impression copings were unscrewed from the model and connected to implant analogs. The hybrid impression coping–analog complexes were reinserted into each impression coping cap on the impression body, and the partial-arch master casts were fabricated with the same conventional method used for the open-tray impression groups.

The implant scan bodies (IS Oral Scan Body, Neobiotech) were connected to the implants of the dentiform models and scanned using a desktop scanner (Identica T500, Medit Inc) to create reference scan data. Three-dimensional (3D) scans were also performed for all fabricated 100 master casts in the same manner. Unnecessary scan data except for the scan bodies were removed before exporting the data into the Standard Tessellation Language (STL) file format.
The 3D deviation analysis was conducted using 3D inspection software (Geomagic Control X, Geomagic). The scan data obtained from the dentiform model was set as the reference data, and initial alignment and best-fit alignment were performed using the experimental scan data (Fig 4). Then, the resulting root mean square error (RMS) values were used to show the amount of deviation in terms of trueness according to ISO 20896-1. RMS values were calculated using the following formula:

$$\text{RMS} = \sqrt{\frac{\sum_{n=1}^{N} (X_{1,n} - X_{2,n})^2}{N}}$$

where $X_{1,n}$ is the value of the measurement of point n on the reference scan data, $X_{2,n}$ is the value of the measurement of point n on the experimental scan data, and N denotes the total number of corresponding points. Furthermore, the amount of displacement along each of the x, y, and z coordinates was analyzed to identify the direction of the displacement. The reference scan data and the experimental scan data were aligned with respect to the mesial scan body using the partial data align feature in the “align between measured data” function. Subsequently, a virtual circle was drawn according to the top surface of the distal scan body, and the x, y, and z coordinates of the center point of the circle were obtained. The direction and displacement of the distal implant with respect to the mesial implant were calculated by subtracting each coordinate value of the reference scan data from the experimental scan data. The x, y, and z directions represent the lingual, distal, and occlusal directions, respectively.

The data were statistically analyzed using the SPSS software (SPSS Statistics version 25.0, SPSS Inc). The Kolmogorov-Smirnov test showed the normality of the data. Two-way analysis of variance (ANOVA) was performed to determine the effects of implant angulation and impression methods on the RMS values. The level of significance was set at .05. A post hoc power analysis was also performed to confirm the power of the sample.

RESULTS

The two-way ANOVA test showed that the deviation values varied significantly according to the implant orientation ($P < .001$; post hoc power = 1.000) and impression techniques ($P < .001$; post hoc power = 0.999). A significant interaction was also revealed between the implant orientations and evaluated impression techniques ($P = .015$; post hoc power = 0.817). The mean ± standard deviation of the RMS values in the order of the parallel, MD15, MD30, BL15, and BL30 groups was 51.89 ± 10.35, 48.76 ± 11.98, 93.05 ± 6.21, 51.66 ± 6.06, and 39.44 ± 6.59 µm for the open-tray impression groups and 50.42 ± 11.76, 65.74 ± 15.97, 104.01 ± 8.89, 58.76 ± 9.77, and 57.91 ± 7.70 µm for the dual-arch impression groups (Fig 5). When the deviation values were compared according to the impression techniques, in the MD15, MD30, and BL30 groups the deviation values were significantly higher for the dual-arch impression groups than those using the conventional open-tray impression groups ($P < .001$ for MD15 and BL30; $P = .016$ for MD30). For both impression techniques, the MD30 group showed the largest deviation values ($P < .001$ for both impression techniques). Among the open-tray impression groups, the values for groups other than MD30 were not significantly different from each other ($P > .05$). Among the dual-arch impression groups, the MD15 group showed greater deviation than the parallel group ($P = .009$) (Fig 5).

Table 2 shows the displacement values of the experimental distal scan body when the reference and
experimental scan data were aligned based on the scan body of the mesial implant. In the MD30 group, in which a significantly large RMS deviation was observed, displacements of $0.03 \pm 0.19$ mm lingually, $0.27 \pm 0.06$ mm distally, and $0.19 \pm 0.04$ mm apically were observed in the open-tray impression group. In the dual-arch impression groups, the distal scan body was displaced by $0.14 \pm 0.18$ mm in the lingual direction, $0.24 \pm 0.05$ mm in the distal direction, and $0.2 \pm 0.04$ mm in the apical direction.

### DISCUSSION

The accuracy of the implant impressions was compared according to the implant orientations and impression techniques. The orientation of the implants and the impression technique had a significant effect on the accuracy of the impression; thus, the null hypothesis of this study was rejected. The measured deviation values, except for the dual-arch impression technique in the MD30 group, were within the clinically acceptable range of 100 µm.\(^{15,16}\)

First compared was the accuracy of impressions obtained from models with different implant orientations using the same impression technique. In the present study, the 3D deviation values of the scan bodies were significantly greater when the implants were inclined 30 degrees mesiodistally. This result corresponds with the findings of Rutkunas et al\(^{7}\) and Jang et al,\(^{11}\) who reported that the accuracy of the impression decreased as the angulation between the implants increased. A review of papers published between 1990 and November 2012 reported that implant angulations of 20 to 25 degrees negatively affected multi-unit implant impression accuracy.\(^{9}\)

In this study, when the angle between implants was 15 degrees mesiodistally or buccolingually, the accuracy of the open-tray impression technique was not different than when the implants were placed parallel to each other. Jang et al\(^{11}\) also reported that the accuracy of the open-tray impression technique was not affected until the angle between implants was 15 degrees, but decreased when this angulation exceeded 20 degrees.\(^{11}\)

Another study evaluated the impression accuracy of a hybrid impression coping, which had a similar concept as that of the hybrid copings used in the present study.\(^{12}\) The study reported that when pick-up impression copings or hybrid impression copings were used, there was no significant difference in impression accuracy when the implants were tilted 15 degrees mesiodistally or buccolingually compared to when they were parallel.\(^{12}\) Further, in this study, the deviation was larger when the two implants were inclined 30 degrees mesiodistally than when they were inclined 30 degrees buccolingually. This difference might be attributed to the placement of the implants at the distant positions of the second premolar and second molar and their mesiodistal inclination toward each other rather than in the opposite direction. Further research on this topic is needed.

Second, the accuracy of impressions was compared according to the impression technique used for the same implant orientations. When the implants were angulated 15 degrees and 30 degrees mesiodistally or 30 degrees buccolingually, the dual-arch impression technique using the hybrid impression copings showed larger deviation values than the open-tray impression technique. Thus, this hybrid impression coping method using a pick-up cap for a relatively short transfer impression coping was considered to increase inaccuracy when making impressions of excessively inclined implants.

In addition, this inaccuracy can be weighted by the low accuracy of the dual-arch impression using a heavy-body PVS material and plastic tray. Cox et al\(^{17}\) showed that the plastic dual-arch tray loaded with heavy-viscosity PVS had worse accuracy than other dual-arch protocols using putty material or metal tray. Larson et al\(^{18}\) also reported that the accuracy of dual-arch impressions was reduced when the trays were flexed. This simple dual-arch impression technique is useful in clinical practice as it reduces the time required to make an antagonist impression and bite registration. However, as mentioned above, there is concern about the accuracy when using disposable plastic trays. Additionally, in a distal free-end case similar to

### Table 2 Displacement Value (mm) in the xyz Coordinate System of the Distal Implant with Respect to the Reference when Aligned with the Mesial Implant

<table>
<thead>
<tr>
<th>Reference when Aligned with the Mesial Implant</th>
<th>Open-tray impression</th>
<th>Dual-arch impression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>Parallel</td>
<td>–0.41 ± 0.26</td>
<td>0.14 ± 0.06</td>
</tr>
<tr>
<td>MD15</td>
<td>–0.07 ± 0.24</td>
<td>0.16 ± 0.09</td>
</tr>
<tr>
<td>MD30</td>
<td>0.03 ± 0.19</td>
<td>0.27 ± 0.06</td>
</tr>
<tr>
<td>BL15</td>
<td>–0.27 ± 0.43</td>
<td>0.1 ± 0.12</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD. The data represent the displacement value of the top of the scan body on the distal implant. xyz coordinates = x for lingual direction, y for distal direction, z for occlusal direction.
the simulated models in this study, the obtained intermaxillary relationship can easily be inaccurate owing to the limited number of included teeth and the lack of a posterior vertical stop between arches.19

On the other hand, in the present study, no significant difference was found between the two impression techniques when the implants were placed parallel to each other and when they were placed with a 15-degree buccolingual tilt. This result is consistent with that of a study by Lee et al.,20 which reported no significant difference in the impression accuracy of two parallel implants between the open-tray and the dual-arch impression techniques. Therefore, when the implants are placed parallel to each other with a posterior vertical stop, it would be effective to use the time-saving dual-arch impression technique with hybrid impression copings.

This study has several limitations. All scans in this study were made using a desktop scanner (Identica T500, Medit Inc) with an error of 7 μm; therefore, the error may be larger than that in other studies using a coordinate measuring machine with an error of 1 μm.21–23 Further, this study was performed in vitro. Clinically, the accuracy of the PVS impression body may be affected by the presence of saliva.24 Also, when using a disposable plastic tray for the dual-arch impression technique, the shape of the mandible and maxilla and the size and position of the tongue may affect impression accuracy.19,25 Therefore, it is necessary to confirm the results of this study through further clinical studies.

CONCLUSIONS

Within the limitations of this in vitro study, the implant orientation and impression techniques significantly affected impression accuracy in terms of trueness. The dual-arch impression technique with hybrid impression copings showed similar accuracy to that of the conventional open-tray impression technique when the two implants were parallel; however, it showed significantly lower accuracy when the mesiodistal or buccolingual angulation between the implants was 30 degrees. Further, for both open-tray and dual-arch impression techniques, the largest deviation was observed when the two implants were placed with a mesiodistal inclination of 30 degrees toward each other. Considering impression accuracy, it would be advantageous to use the simple dual-arch impression technique using hybrid impression copings only when the implants are placed parallel to each other.

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REFERENCES