Accuracy of Customized Abutment Data Superimposition According to the Extent of the Scanning Area

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Purpose: To evaluate the accuracy of superimposition of customized abutment library data onto scanned abutment data according to the extent of the scanning area. Materials and Methods: A patient model was fabricated using a 3D printer (Probo, DIO Implant), and a customized abutment was fabricated using a four-axis milling machine (ARUM 4X-100, Doowon). The customized abutment library data were generated using a laboratory scanner (E3, 3Shape) for superimposition after intraoral scanning. A cone-shaped structure was embedded into the library data at the center of the connection part. The customized abutment was placed on the model, and the model was scanned using a laboratory scanner to produce reference data. Three different test group datasets were generated using the intraoral scanner and computer-aided design software: (1) fully scanned customized abutment; (2) insufficiently scanned proximal surface; and (3) insufficiently scanned margin, assuming challenging intraoral conditions. The library data were superimposed onto each test group; thereafter, the distance and angle between the reference and test group data were analyzed by using the embedded cone. Statistical analysis was performed using one-way analysis of variance followed by post hoc Tukey test for multiple comparisons. Results: There were no statistically significant differences between the mean distance or angle of the test group data (with three different scanning areas) and the reference data. Conclusion: The superimposition technique can be used clinically, not only when the scan is complete, but also when the proximal surfaces and margin of the customized abutment have been scanned incompletely.


Generally, fixed implant prostheses are fabricated through an implant-level or abutment-level impression. Intraoral scanners, as well as a conventional silicone material, have been widely used for abutment-level impressions.1 When recording an impression at the implant level, the abutment and final prosthesis can be fabricated at the same time; however, after using an abutment and provisional prosthesis for a certain period of time, the impression can be recorded at the abutment level to fabricate the final prosthesis. It has been reported that axial displacement may occur in implant prostheses because of tightening torque and cyclic loading.2,3 There may also be rotational errors between the abutment and implant owing to the low tolerance of the implant-abutment connection.4 Therefore, if the final prosthesis...
is fabricated after taking an impression at the implant level, the occlusion may change after functional loading. To prevent this, use of the provisional prosthesis for a particular time period is recommended; thereafter, the impression should be recorded at the abutment level to design the final prosthesis. Vertical and rotational errors of the abutment could be minimized by this procedure. However, when using an intraoral scanner, the deep and narrow areas—such as the proximal surfaces of abutments—are difficult to scan accurately. In addition, it is difficult to obtain an accurate impression of an abutment with a subgingival margin without using gingival retraction, which may cause gingival bleeding, damage, or recession.

Cho et al reported a novel method of fabricating an implant prosthesis by superimposing the prescanned abutment library data, which is scanned extraorally, onto the intraoral scan data. The abutment is scanned using an intraoral scanner without gingival retraction, and the library scans are flawlessly superimposed sequentially. In this way, an implant prosthesis can be fabricated using the customized abutment data while preserving the integrity of the marginal and proximal surfaces. However, guidelines outlining the minimum extent of the intraoral abutment scanning area required for the accuracy of superimposition are lacking.

Therefore, this study aimed to evaluate the accuracy of superimposition of customized abutment library data onto the scanned data according to different extents of intraoral scanning areas. The null hypothesis was that the accuracy of superimposition is significantly different depending on the extent of the intraoral scanning area.

**MATERIALS AND METHODS**

Figure 1 shows the flowchart of the study design. The model with an edentulous site at the mandibular left first molar was fabricated using a 3D printer (Probo, DIO Implant), and a lab analog (FAW300, Osstem Implant) was placed on the edentulous site of the model. Thereafter, a customized abutment was fabricated using computer-aided design (CAD) software (exocad, Align Technology) and a four-axis milling machine (ARUM 4X-100, Doowon) (Fig 2).

The customized abutment was prescanned using a laboratory scanner (E3, 3Shape) to generate the library data before it was placed onto the model. A cone with a diameter of 0.5 mm and a height of 0.5 mm was produced in the CAD software (Meshmixer, Autodesk), and the library data were finalized by adding the cone to the center of the platform of the customized abutment library data. The cone provided a single 3D point at the apex and an axial line from the abutment base perpendicular to the base of the cone (Fig 3). The apex
and the axial line were used to evaluate the accuracy of the superimposition.

The reference data were prepared as follows: The customized abutment was placed and tightened on the model with a tightening torque of 15 Ncm, which was followed by scanning the model with the customized abutment using the laboratory scanner. Thereafter, the library data were superimposed onto the scanned data.

Fig 3 Preparation of the (a) customized abutment library data. A cone, including the (b) apex and a perpendicular line (axial line) to evaluate the accuracy of customized abutment superimposition, was embedded.

Fig 4 Preparation of test groups. (a) F group: superimposition of the library data on the fully scanned abutment surface data. (b) P group: superimposition of the library data on the insufficiently scanned proximal surface data. (c) M group: superimposition of the library data on the insufficiently scanned margin data.
In the first group, the customized abutment on the model was fully scanned using an intraoral scanner (TRIOS 3, 3Shape), and the library data were superimposed onto the scanned data (F group).

In the second group, insufficient scanning was assumed on the proximal area, considering the deep and narrow conditions in the interproximal regions. The customized abutment was fully scanned; thereafter, the mesial and distal surfaces of the abutment were intentionally deleted identically using a rectangular shape with the size of 2.75 mm × 1.5 mm, followed by library data superimposition (P group).

The last group assumed an insufficient scanning of the marginal area considering the subgingival margins. The abutment was fully scanned, a 1-mm–thick band was deleted intentionally from the margin, and the library data were superimposed (M group).

In each test group, the scanning and superimposition were performed 10 times repeatedly. Finally, 30 scanned datasets (n = 10 per group) were prepared (Fig 4).

The test group data and reference data were superimposed using best-fit alignment based on the teeth adjacent to the abutment with an inspection software (GOM Inspect). The error of distance and angle of the customized abutment between the reference and test group data were measured by embedding the cone on the abutment (Fig 5).

Statistical analysis was conducted using SPSS Statistics version 22 software (IBM). Kolmogorov-Smirnov test was performed to assess the normality of data. Subsequently, the data were analyzed using one-way analysis of variance followed by Tukey post hoc test for multiple comparisons. The level of statistical significance for both tests was set at \( P < .05 \).

RESULTS

The mean and SD for distance and angle between the test groups and reference data are shown in detail in Table 1.

There were no statistically significant differences between the mean of the distance or angle among the three groups (F, P, and M) (\( P > .05 \)).

DISCUSSION

This study aimed to evaluate the accuracy of superimposition of prescanned library data onto intraoral customized abutment scan data, even when a surface is not clearly scanned on inaccessible interproximal surfaces or subgingival margins of the customized abutment.

The prescanned customized abutment library data superimposed accurately onto both incomplete (missing proximal surface or subgingival margin) and complete scan data. As a result, the null hypothesis was rejected.
With the superimposition technique, it was easy to obtain clear scan data to fabricate the implant prosthesis, even when the proximal surfaces or subgingival margins were not scanned accurately. Ender et al reported that the distance error of the intraoral scanner while scanning a quadrant in a dental arch was 21 to 49 µm. In another study, Gimenez-Gonzalez et al reported that the angle error of the intraoral scanner in a quadrant scan was 0.16 degrees to 0.4 degrees.

In the present study, the means of the distance and angle errors were within or below the error range of the intraoral scanners mentioned above. Therefore, it appears that the mean distance and angle errors were caused due to the intrinsic error of the scanning process. Within the limitations of this study, the results suggest that insufficient scanning of the customized abutment on the proximal areas or margins does not affect the accuracy of superimposition of the library data. Additional studies are required to reveal the minimum scan range for assuring the accuracy of the superimposition technique in relation to a clinical condition.

According to the results of this study, clinicians may scan the abutment prior to intraoral placement. Extraoral scanning of abutments is a straightforward technique, since there are no obstacles during the scanning. All surfaces, including the margins and proximal areas of the abutment, can be clearly scanned as library data. After the library data are obtained, the abutment can be placed intraorally, and the prescanned library data can be utilized by the superimposing technique.

In many intraoral scanners, the filling of incomplete areas or holes is automatically performed where the scan data are insufficient. These automatically filled surfaces may not represent the actual surface accurately, which might cause error during superimposition. Therefore, it would be preferable for this automatic feature to be suppressed until the library data are superimposed onto the scanned data. Further studies to determine whether this function affects the accuracy of the superimposition are warranted.

**CONCLUSIONS**

The superimposition technique can be used clinically to fabricate implant prostheses since the error of the technique is within the range of scanning errors not only when the scan is complete, but also when the proximal surfaces and margins of the customized abutment are scanned incompletely.

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