**Trueness of the Combined Intra- and Extraoral Scanning Technique for Transferring Subgingival Contours from Provisional Restorations to Definitive Restorations**

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**Purpose:** To compare the morphologic trueness of provisional and definitive restorations constructed with conventional custom impression techniques to those constructed with intra- and extraoral scanning (IEOS), which can digitally transfer the subgingival morphology of the provisional restoration to the definitive restoration. **Materials and Methods:** Provisional restorations were fabricated on typodonts in which implants were placed. In the conventional method, a customized impression coping was produced by using polymethyl methacrylate resin to transfer the subgingival contour of the provisional restoration. Impressions were taken with silicone impression material, and definitive restorations were made by CAM. The IEOS technique was performed as previously reported. In brief, three individually scanned stereolithography (STL) files were superimposed in CAD software to transfer the morphology of the provisional restoration to the definitive restoration. Definitive restorations were then made by CAM. The provisional and definitive restorations were both scanned by IOS. Scanned data files were superimposed with morphometry software, and the distortions were measured. Student t test was used for statistical analysis. **Results:** The subgingival morphologies of definitive restorations prepared by the conventional method showed significant negative distortions compared to definitive restorations prepared by the IEOS technique. **Conclusion:** The IEOS technique can more accurately transfer the subgingival contour of provisional restorations to definitive restorations compared to the conventional customized impression coping technique. *Int J Prosthodont* 2023;36:308–314. doi: 10.11607/ijp.7030

In the field of digital dentistry, the development of intraoral scanning (IOS) has led to its use in daily practice. An advantage of IOS is the ability to avoid the use of impression materials when taking impressions. This change enables clinicians to prevent displacement caused by shrinkage of the impression material and the hardening expansion of gypsum when the cast is made. The use of IOS reduces the necessary time to take impressions and also reduces patient discomfort when impressions...
are taken. Furthermore, similar reproducibility to conventional impression material can be achieved by using IOS. In addition, digitization of the patient's intraoral information eliminates the need for storage of gypsum casts and preserves space for data storage. In these respects, the use of IOS is effective for management of digital data practices.

To maintain long-term implant stability, the shapes of subgingival contours of the restorations and the intaglio surface of the pontic should be considered with respect to cleanability. In implant treatment, esthetics—including crown shape and soft tissue shape—are also important. When taking definitive impressions for definitive restorations, the subgingival soft tissue changes immediately after the removal of the provisional restorations. To transfer the adjusted subgingival contours of provisional restorations to definitive restorations, the conventional method is to take definitive impressions with the aid of a duplicate custom impression coping from provisional restorations. When impressions are taken by IOS, the custom impression coping cannot be applied. Therefore, the current method for taking impressions of subgingival soft tissue is scanning immediately after the removal of provisional restorations to minimize soft tissue changes. However, when this approach is used, the customized subgingival contours cannot be accurately transferred from provisional restorations to definitive restorations. Notably, the intra- and extraoral scanning (IEOS) technique has been proposed to address this problem by using an IOS to scan the provisional restoration both intraorally and extraorally. By superimposing the resulting stereolithography (STL) data, the morphology of subgingival contours and the intaglio surface of the pontic can be transferred from provisional restorations to definitive restorations.

The purpose of this study was to compare the morphologic trueness of subgingival contours and the intaglio surface of the pontic between provisional and definitive restorations constructed with the IEOS vs conventional custom impression techniques. The first null hypothesis of this study was that the IEOS technique would be less reproducible than the conventional method in terms of definitive restorations of single-crown casts. The second null hypothesis was that the IEOS technique would be less reproducible than the conventional method in terms of definitive restorations of three-unit fixed dental prosthesis (FDP) casts.

MATERIALS AND METHODS

A typodont with artificial gingiva attached (P9-IMP6-1, Nissin) was used in single-crown casts, while a typodont with artificial gingiva attached (P9-X.1133, Nissin) was used in three-unit FDP casts. An implant (Ø 4.1 mm Bone Level Implant, Straumann) was embedded in the edentulous ridge of the mandibular right first premolar region for single-crown casts. Two identical implants were embedded in the edentulous ridges of the mandibular left lateral incisor and first premolar regions for three-unit FDP restoration casts. Provisional restorations of one single-crown cast and one three-unit FDP cast were made on the typodont (Fig 1). Teeth were waxed...
up on the typodont in combination with their appropriate morphologies.

Thereafter, the morphologies were obtained using laboratory putty (Blue Eco, Detax) and prepared by using a temporary coping (RC Temporary Abutment, Straumann), an implant analog (RC Implant Analog, Straumann), and immediate polymerization resin (Provinice, Shofu). For the single-crown cast and the three-unit FDP cast in the conventional method, a customized impression coping was produced by using polymethyl methacrylate resin (Pattern Resin, GC) placed on impression coping (RC Impression Post, Straumann). To prevent distortion during impression procedures, verification jigs were used in the three-unit FDP restoration group. A casted Co-Cr alloy ring and pattern resin were used to connect the two customized impression copings.

For the conventional method, impressions were taken with silicone impression material (Panasil, Kettenbach Dental) using an open-tray method (Tray Resin, Shofu). The working cast was made with gypsum (New Fujirock, GC) and silicone gum (Softtissue Moulage, Kerr Dental) (Model 1). A scan body (Cares RC Mono Scanbody, Straumann) was attached to this cast (Model 2). In addition, form reference casts of the provisional restorations (Gypsum, New Plastone, GC) were used as reference casts of the gingival margin (Model 3). Thereafter, the three casts (Models 1 to 3) were scanned with a lab scanner (Cares D7 Plus, Straumann).

The definitive restorations (Ti/TAN, Straumann) were designed with CAD software (Cares Visual, Straumann), then made by CAM (Fig 2). The CAD design process steps were designed by a single user, who was an experienced dental technician. The restorations were fabricated in the Straumann factory; detailed information is confidential and thus unavailable from the company. Completed definitive restorations were measured in an as-milled state.

The workflow of fabricating definitive restorations with the IEOS technique was performed in accordance with a previous report. In the single-crown cast and the three-unit FDP cast, the provisional restorations were first scanned intraorally (Data 1; Fig 3a). The scan bodies were then placed on the implant and scanned (Data 2; Fig 3b), while the provisional restorations were also scanned extraorally to record the entire morphology (Data 3; Fig 3c). The three STL data files (Data 1–3) were imported and superimposed in CAD software (Cares Visual, Straumann), enabling restoration fabrication (Fig 4). As with the conventional method, definitive restorations made with the IEOS technique were made by CAM (Straumann) and measured in an as-milled state (Fig 5).

Both conventional and IEOS processes up to this point were repeated five times; definitive restorations of the single-crown cast and the three-unit FDP cast were each produced by the conventional method and IEOS technique (sample size: n = 5). The fabricated single-crown and three-unit FDP restorations, as well as the original provisional restorations, were then scanned extraorally by IOS (TRIOS 3, 3Shape). The restorations were shielded from sunlight; only fluorescent light was used during the scan procedure. A thin layer of alumina powder (Scan Powder, Quest) was applied to reduce light reflection that could negatively affect the scanning process. A trained researcher (K.S.) recorded all scans in accordance with each manufacturer’s instructions. After scanning
had been performed, the original 3D format file was converted to the STL format and exported. To compare the resulting STL data, the submucosal morphologies of definitive and provisional restorations were measured with morphometry software (PolyWorks Inspector, InnovMetric). The STL data of provisional and definitive restorations were superimposed in the software; all restorations were connected to the implant analog (RC Implant Analog, Straumann) at the same angle, and the implant analog was used as a reference point for STL data. The distortions and differences between superimposed STL layers were then measured by using the “cross-section” function of the software; the peak value of distortion in each cross-section was measured.

In the single-crown casts, the morphologic differences of subgingival contours were measured from the data obtained by superimposed provisional and definitive restorations (Fig 6). Cross-sections of mesiodistal and buccolingual directions, as shown in Fig 7, were created by software; maximum distortions in subgingival contours were measured at four locations on the cross-sections (mesial, distal, buccal, and lingual). The mean values of morphologic differences were calculated for the five definitive restorations measured. In the three-unit FDP casts,
the morphologic differences of the intaglio surface of the pontic were measured from the data obtained by superimposing provisional and definitive restorations (Fig 8). In the three-unit FDP restoration casts, three cross-sections were made quarterly based on the mesiodistal width of the pontic. The three cross-sections selected were mesial, central, and distal; the largest distortion was recorded in each cross-section (Fig 9). The mean values of morphologic differences were calculated for the five definitive restorations measured. Student t test analysis was used for statistical analysis of all data (sample size n = 5 in each group). All statistical analyses were performed using R software (R version 3.6.3, The R Foundation); differences with \( P < .01 \) were considered statistically significant.

**RESULTS**

The single-crown cast measurements showed that the subgingival contours of definitive restorations produced by the conventional method exhibited a mean morphologic difference of 169.7 ± 22 μm (range: 147.8 to 198.6 μm) compared to the subgingival contours of provisional restorations. The subgingival contours of definitive restorations produced by the IEOS technique exhibited a mean morphologic difference of 107.1 ± 14 μm (range: 93.6 to 124.6 μm) compared to the subgingival contours of provisional restorations. Statistical analysis revealed a significant difference in subgingival morphology between definitive restorations prepared by the conventional method and those prepared by the IEOS technique \( (P = .002964; \) Fig 10).

The three-unit FDP cast measurements showed that the intaglio surface of the pontic of definitive restorations produced by the conventional method exhibited a mean morphologic difference of 315.8 ± 14 μm (range: 307 to 331.8 μm) compared to the intaglio surface of the
pontic of provisional restorations. The intaglio surface of the pontic of definitive restorations produced by the IEOS technique exhibited a mean morphologic difference of 160.3 ± 37 μm (range: 125 to 199.4 μm) compared to the intaglio surface of the pontic of provisional restorations. Statistical analysis revealed a significant difference in subgingival morphology between definitive restorations prepared by the conventional method and those prepared by the IEOS technique (P = .002496; Fig 11).

**DISCUSSION**

In the present study, IOS and morphometry software were used to compare subgingival contours between definitive and provisional restorations. The definitive restorations were fabricated with both the conventional impression method and the IEOS technique; the measured distortions were statistically analyzed with Student t test. The first null hypothesis of the present study was that in single-crown restoration casts, compared to subgingival contours around implants in provisional restorations, the definitive restorations made with the IEOS technique would exhibit less reproducibility than restorations made with the conventional impression method; this null hypothesis was rejected. The second null hypothesis was that in three-unit FDP casts, definitive restorations made with the IEOS technique would have lower reproducibility around the intaglio surface compared to restorations made by using the conventional impression method; this hypothesis was also rejected.

In the present study, the subgingival contours of definitive restorations made with the conventional impression method showed greater distortion compared to the restorations made with the IEOS technique. There may have been a shift during clinical and laboratory procedures, such as distortion when the impression material was removed, expansion of gypsum during hardening, and/or shrinkage of pattern resin. In particular, there was noticeable contraction of the subgingival contour; this might have been caused by the polymerization shrinkage of polymethyl methacrylate resin during fabrication of the custom impression copings.26 The brush method for the use of polymethyl methacrylate resin has been widely adopted in daily clinical practice.27 However, the residual, unreacted monomer might continue to polymerize and cause distortion.27 The use of IOS can eliminate the deformation that occurs when taking impressions and making casts.2,3 Furthermore, the working time can be shortened by omission of the need to wait for polymerization of the polymethyl methacrylate resin and production of the gypsum working cast that have been necessary thus far.

When taking impressions with IOS, the current method for taking impressions of subgingival soft tissue is scanning immediately after the removal of provisional restorations to minimize soft tissue changes.24 However, when this approach is used, the mucosal morphology changes after removal of the provisional restoration, and the mucosal morphology cannot be accurately scanned.15 By using the IEOS technique, regardless of whether mucosal morphology changes after the removal of provisional restorations, the submucosal morphology can be transferred from provisional restorations to
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definitive restorations. Thus, this study revealed that the IEOS technique can produce definitive restorations with higher reproducibility compared to those produced by the conventional method. Therefore, the IEOS technique may be more useful than the conventional method because it can eliminate potential errors that occur when the custom impression coping technique is used. Clinically, modification of provisional restorations and adjustment of surrounding mucosa is commonly performed. But there is no evidence-based consensus for the “ideal” morphology for the clinical outcome. Further study should be considered for that aspect as well. There are some drawbacks for this method. One of them is the initial time and effort of the dentists/dental technicians to become familiar with the machine. The other is that this study was carried out using only a specific setting of one CAD/CAM machine, which means these data are not universal for any other system. Further development of digital dentistry would address these problems.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. In implant-supported single-crown restorations, the subgingival contours of the provisional crown could be transferred to definitive restorations more accurately with the IEOS technique than with the conventional custom coping impression method.

2. In implant-supported three-unit FDP restorations, the intaglio surface of the pontic could be transferred to definitive restorations more accurately with the IEOS technique than with the conventional custom coping and verification jig impression method.

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