Title: Digital transfer of the subgingival contour and emergence profile of the provisional restoration to the final bone-anchored fixed restoration
Article category: Technical procedure

Abbreviated title: Digital morphological transfer from implant provisional to final restoration

Key words: Digital transfer, implant fixed restoration, subgingival contour, emergence profile, *in silico* analysis

Abstract

Purpose: This report was written to introduce an attempt at clinical application of our newly developed digital workflow to reproduce the morphology of the subgingival contour and the emergence profile of the provisional restoration within the final bone-anchored fixed restoration, using a bounded unilateral edentulous case.

Methods: This digital workflow involves superimposition of the composite images of two specific types of working casts onto the working cast for the provisional restoration namely, a split cast screwed with a titanium base and a split cast screwed with a provisional restoration and integrating these with the whole intraoral surface image, in which the provisional restoration was present. The final restoration fabricated using this technique could be installed without any clinical problems. The results of *in silico* analysis revealed that the cubic volume ratio of the total discrepancy between the provisional and the final restorations was only 2.4%. Further, sufficient oral hygiene was maintained and the patient was satisfied with the outcome of the treatment.

Conclusions: This technical report suggests that our newly developed digital workflow provided clinical applicability and may enable accurate transfer of the morphology of the

subgingival contour and emergence profile of the provisional to the final bone-anchored fixed restoration.

1. Introduction

It is well accepted that provisional restorations in oral implant treatment play crucial roles in checking the occlusion, esthetics, and cleansability for a certain period of time, before being transferred to the final restoration. This phase of treatment can allow evaluation of the patient's individual adaptability to the morphology of the restoration [1]. Once it is confirmed that the morphology of the fabricated restoration provides satisfactory outcomes, it is desirable to reproduce this morphology, from the provisional restoration to the final restoration. Therefore, several attempts have been implemented to accurately reproduce the shape of the provisional restoration within the final restoration. However, previous manual (analogue) strategies inevitably involve the limitations of complete reproduction of provisional restoration morphology, due to human error or the preferences of dental technicians. In this situation, we conceived that recent developed dental digital technology could surmount this challenge and allow the establishment of novel methods for accurate morphological reproduction.

In clinical situations, a split cast working model is typically employed to fabricate the provisional restoration. To establish a digital work-flow for accurate reproduction of

the restoration morphology, we superimpose two specific types of existing working cast information into the working cast for the provisional restoration, namely two three-dimensional (3D) surface morphologies of a split cast screwed with a titanium base and a split cast screwed with a provisional restoration via an implant replica buried in the split cast [2]. These two digital surface images can be accurately superimposed with reference of the surface morphology of the split cast with the implant replica. The superimposed, composite image of the two 3D digital surfaces can subsequently be integrated to the whole intra oral surface image, in which the provisional restoration is connected, with reference of the tooth crown surface of the provisional restoration. After exporting this image data (containing three-layer surfaces) to the computer-aided design (CAD) software and copying the 3D surface morphology of the provisional restoration into the integrated 3D oral surface image, the final restoration can be fabricated by computer-aided manufacturing (CAM) machinery.

In this article, we report our attempt at clinical application of this technique and digitally analyze the volumetric discrepancy between the provisional and the final restorations, using a bounded unilateral edentulous case.

2. Materials and methods

2.1. Case

The patient was a 56-year old female who had a bounded edentulous space at her right mandibular molar (second premolar: #45, first molar: #46) region. She had already received two implant bodies (ø3.3 × 10.0 mm Brånemark Mk III narrow platform TiUnite at the second premolar region and ø3.75 × 10.0 mm regular platform TiUnite at the first molar region; Nobel Biocare, Kloten, Switzerland) and screw-retained, connected provisional restorations had been installed in this space (Figs. 1 and 2). After the installation, the crown morphology and subgingival contour of these provisional restorations had been adjusted by a dentist and used for 3 months. Since satisfactory function and cleansability had been confirmed, we decided to replace these provisional restorations with final restorations, using the newly developed digital workflow. The patient was informed of the purpose of the study and informed consent was obtained before the study onset.

2.2. Digital workflow to reproduce the provisional restoration morphology

First, the following three aspects of morphological information were digitized using an intraoral scanner (TRIOS2, 3Shape, Copenhagen, Denmark) as 3OXZ data; 1) the intraoral 3D morphology data of the whole mandible with the provisional restoration (#45/46) installed (Fig. 3A); 2) the 3D morphology data of the whole mandibular working cast used for fabrication of the provisional restoration (including a split cast of #45/46 connected with titanium bases [Nobel Biocare] via an implant replica [Nobel Biocare] buried in the split cast) (Fig. 3B); 3) the 3D morphology data of the split cast of #45/#46 connected with the provisional restoration via an implant replica buried in the split cast (Fig. 3C). These three 3OXZ data were converted first to digital imaging and communications in medicine (DCM) format by software (Dental Designer, 3Shape), then converted to stereolithography (STL) format by another software (Exchange, Delcam, Birmingham, UK) and imported to a dental CAD software (exocad, exocad, Darmstadt, Germany). By handling the STL data, the 3D surface image of the whole mandibular working cast, used for fabrication of the provisional restoration, and the 3D surface image of the split cast of #45/46, connected with the provisional restoration (including a split cast

of #45/46 connected with titanium bases), were superimposed by a least mean squares method, with reference to the surface morphology of the split cast (#45/46), onto the implant replica. This enabled the provisional restoration to digitally overlay on the titanium bases (Fig. 4). Then, the intraoral 3D surface image of the whole mandible, with the provisional restoration (#45/46) installed, was overlapped on the integrated working cast image to reflect the form of the soft tissues around the provisional restoration (Fig. 5). Subsequently, this image data, containing three-layer surfaces, was exported back to the CAD design software (Dental Designer, 3Shape). From the final surface morphology, the morphologies of the titanium bases were digitally subtracted, then the final restoration was ground, based on this data, on a zirconia disk (Medium Plus, ADAMANT, Tokyo, Japan) by a 5-axis milling machine (DWX-50, Roland, Hamamatsu, Japan). After the polishing and the final baking of the zirconia using layering porcelain, this crown shape of final restorations and titanium bases was fixed together using an adhesive resin cement (Panavia V5 opaque, Kuraray Noritake Dental Inc., Tokyo, Japan) (Fig. 6).

2.3. In silico comparison of reproducibility between provisional and final restorations

Before installation, volumetric discrepancies in the shape of the final and provisional restorations were measured by *in silico* analysis. The 3D morphologies of the restorations were digitized with a 3D scanner (D810, 3Shape) with accuracy +/- 15 m; images were superposed using an imaging software (Power Shape, Autodesk, San Rafael, CA, USA). Volumetric discrepancy between the final and provisional restorations was determined by the difference in total volume of the geometry of concave and convex portions of the final restoration, relative to the provisional restoration, using the software. The detailed procedure of these measurements is described elsewhere [2] Then, the volume ratio of the total volume of the discrepancy, against the total cubic volume of the provisional restoration, was calculated. The total cubic volume of the provisional restoration was digitally obtained by scanning the 3D image of the provisional restoration, which was connected to an implant replica using a 3D scanner (D810, 3Shape); this DCM image data was converted to STL format by a software (Exchange, Delcam). After that, the cubic volume of the provisional restoration was calculated by making a subtraction of the volume of implant replica. Then, dividing the total volume of discrepancy by total cubic volume, the volume ratio of the total discrepancy was computed.

3. Results

3.1. Difference from conventional methods

A conventional analog strategy comprising a pick-up impression method with a customized impression coping, which reflects the subgingival contour of the provisional restoration, has been utilized when taking impressions for the final restoration [3-5]. By utilizing this procedure, the final restoration, possessing a similar subgingival contour and emergence profile as the provisional restoration, can be manufactured through a conventional analogue technique in the laboratory. However, this procedure is rather complicated, and requires patients to secure an additional visit to the dental office, in order to prepare the customized impression coping. Even with this additional effort, the shape of the final restoration can be substantially different from the provisional one, because of the manual (analogue) procedure that involves some human error, as well as the morphological preferences of the dental technician. In contrast, since the design of the crown morphology is digitally copied and reproduced, our current reproduction procedure does not allow those interferences.

3.2. Effect or performance

Figure 7(A) and 7(B) show the similarity between the final restoration and the provisional restoration. The final restoration was successfully installed without any chairside adjustment. *In silico* analysis revealed that the volumes of the geometry of concave and convex portions of the final restoration, relative to the provisional restoration, were 7.9 mm^3 and 5.8 mm^3, respectively; the total volume discrepancy was 13.7 mm^3 (Fig. 7(C)). Additionally, the volume ratio of the total discrepancy was computed as 2.4%.

Figure 8 indicates the intraoral view of the patient after installation of the final restoration. The patient was maintaining sufficient oral hygiene using the same size of interdental brush (ss size) as utilized when the provisional restoration was installed; no signs of inflammation were observed in the peri-implant tissues. These findings suggest that volumetric discrepancy present in our new digital reproduction procedure did not cause clinical problems. Additionally, since satisfactory function was achieved, the patient was satisfied with the outcome of the treatment.

4. Conclusion

In this technical report, we experienced clinically acceptable accuracy in reproduction of the shape of the provisional restoration within the final restoration, using our newly developed digital workflow. Further, the morphology of the subgingival contour and the emergence profile of the proximal zone of the provisional restoration were accurately transferred to the final restoration. This indicates that our workflow is sufficiently useful in a clinical setting to reproduce the morphology of the provisional restoration within the final bone-anchored fixed restorations, without preparing an additional working cast. In the future, we will investigate the improvement in accuracy, compared with the conventional method, by using appropriate clinical cases.

While this technique has some limitations, it was sufficiently useful in the clinical setting to reproduce the morphology of the subgingival contour and the emergence profile of the bone-anchored final restoration, following verification of the appropriate function and esthetics that was achieved by adjustment of the provisional restoration.

Conflict of interest

The authors declare that there are no conflicts of interest.

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Figure legends

Fig. 1. Panoramic radiographs of patient after installation of implant bodies. Two implant bodies were placed in right side mandibular molar region.

Fig. 2. Intraoral view of patient. Screw-retained, connected provisional restoration was installed in right side mandibular molar region and adjusted, in order to achieve satisfactory oral function and cleansability.

(A), Mandibular occlusal view. (B), Right side lateral view

Fig. 3. Digital images acquired by intraoral scanner to transfer morphology of provisional restoration to final restoration.

(A), intraoral 3D morphology data of whole mandible with provisional restoration (#45/46) installed.

(B), 3D morphology data of whole mandibular working cast used for fabrication of provisional restoration (including split cast of #45/46, connected with titanium bases via implant replica buried in split cast).

(C), 3D morphology data of split cast of #45/#46, connected with provisional restoration via implant replica buried in split cast.

Fig. 4. Images of “3D morphology data of whole mandibular working cast used for fabrication of provisional restoration (including split cast of #45/46, connected with titanium bases)”, and “3D morphology data of split cast of #45/46, connected with provisional restoration via implant replica buried in split cast” (A) were superposed at three-dimensional position (B), by least mean squares method with reference to surface morphology of split cast (#45/46) with implant replica (C).

Fig. 5. Image of “intraoral 3D surface image of whole mandible with provisional restoration (#45/46) installed” was overlapped on image of Fig. 4(B) to reflect formation of soft tissue around provisional restorations (A, B). These two images were superposed by least mean squares method with reference to surface morphology of provisional restoration (C).

Fig. 6. Lateral views of final design of reproduced shape of superstructures on CAD software (A) and final restoration fabricated by our newly developed digital workflow (B).

Fig. 7. (A), Occlusal and (B), lateral views of provisional (right side) and final (left side) restorations of patients. (C), Volumetric discrepancies were calculated using superposed images of scanned data of final and provisional restorations. Total volume difference of convex/concave portions of final restorations, relative to provisional restorations, was 13.7 mm^3.

Fig. 8. Intraoral view of patient after installation of final implant restoration at #45/46 region. (A), Frontal view. (B), Maxillary occlusal view. (C), Mandibular occlusal view. (D) Right side lateral view. (E), Left side lateral view.