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DENTAL TECHNIQUE

Four-dimensional digital prediction of the esthetic outcome and digital implementation for rehabilitation in the esthetic zone

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ABSTRACT

A technique for 4-dimensional (4D) digital prediction of the outcome of esthetic dentistry for a virtual patient is presented. Static 3D images (which incorporate predicted precise dentition and facial soft tissue in different smiling positions) can be converted into dynamic 3D images by using 3D intraoral imaging, 3D face imaging, and various computer software programs. This strategy can improve the visual perception and quality of esthetic prediction. In addition, the predicted esthetic outcome can be implemented by replicating the contour and shape of digital wax patterns in the definitive ceramic restorations. (J Prosthet Dent 2020;123:557-63)

When teeth in the esthetic zone (the visible area seen in an exaggerated smile) are restored, careful preoperative analysis and prediction of the outcome are important to meet patient expectations.[1-7] Diagnostic waxing, trial restorations, interim prostheses, and digital smile design (DSD) can be used as esthetic previews.[1,3-5,8-13] These methods enhance treatment predictability, but they may not completely predict the esthetic outcome.

Recently, digital approaches for 3-dimensional (3D) prediction of esthetic outcome and digital design processes with or without patient involvement have been reported.[14-16] However, limitations remain, the most important being that only static images can be displayed during smiling.[14,17-20] Four-dimensional facial imaging, integrated with virtually restored teeth, should improve the accuracy and visual perception of esthetic prediction by adding the time sequence to the 3D domain.[19]

A digital workflow for the 4D prediction of esthetic outcome was developed by combining 3D intraoral imaging, 3D face imaging, and software. In addition, the predicted outcome can be implemented. This workflow can simulate postoperative effects during different smile positions dynamically while taking into account the desired position and contour of esthetic restorations.

TECHNIQUE

The treatment consisted of the restoration of defective and discolored anterior teeth caused by fluorosis.

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1. Obtain 2D intraoral digital photographs and 3D digital dental casts. Make intraoral digital photographs by using a single-lens reflex camera (EOS 70D; Canon Inc) (Fig. 1A). Scan the maxillary and mandibular dentitions with the gingival tissues and the buccal sides of dentitions with the teeth in the maximum intercuspal position by using an intraoral scanner (TRIOS; 3Shape) to obtain 3D digital diagnostic casts with the occlusal relationship (Fig. 1B). Export the 3D digital images as a standard tessellation language (STL) file.
2. Make digital face scans with a 3D face scanner (FaceSCAN3D; 3D-Shape GmbH). Scan the face with the teeth in the maximum intercuspal position by using cheek retractors (Fig. 2A). Scan the face in successive positions from closed lips to exaggerated smile to obtain 3D facial images of the overall dynamic smiling process (Fig. 2B). Export the 3D face images as geometry definition (OBJ) format files.
3. Import all 3D facial images into reverse-engineering software (Geomagic Studio 2012; 3D Systems). Use the "N-point Alignment" command to align the 3D facial images according to the anatomic landmarks that remain static during the different scanning positions: inner canthi, outer canthi, pupils, nasal root point, and tip of the nose (Fig. 3A, left). Use the "Deviation" command to examine the accuracy of alignment of the 3D facial images by generating color-coded mapping (Fig. 3A, right).
4. Import the digital dentition casts into Geomagic Studio software. Project the 2D intraoral photographs onto the 3D intraoral dentition casts to construct a 3D colorized digital dental cast. Use the "N-point Alignment" command to align the digital dental casts with the facial image in which the dentitions are displayed with cheek retractors (Fig. 3B). Conceal the dentition portion from all 3D facial images. Consequently, the preoperative 3D images are constructed with display of colored precise dentitions and facial soft tissue in the smiling position (Fig. 3C). The 3D facial image is set as the fixed image so that the dentition cast is registered simultaneously to all the 3D facial images because these have been previously registered. Export the 3D image as a 3D modeling (WRP) format file.
5. Design the virtual esthetic restorations on the digital casts in dental computer-aided design (CAD) software (Dental System; 3Shape) according to esthetic principles (Fig. 4). Export the intended 3D diagnostic waxing as an STL format file.
6. After importing the designed digital diagnostic waxing into Geomagic Studio software, use the "Best-fit Alignment" command to align the designed digital diagnostic waxing with the original cast by registering the posterior teeth, the 3D images of which have not been modified during the virtual design. Project the intraoral digital photographs onto the designed digital diagnostic waxing pattern after merging with the color of the shade guide. Consequently, the 3D prediction of the esthetic outcome in a virtual patient has been accomplished (Fig. 5). Export as a WRP format file.
7. Using the same coordinate system and display scale, display each facial image with intended esthetic restorations during the smiling process separately and make a screenshot of each of them from the application display (Fig. 6).
8. Convert the sequential screenshot images (which are in the same direction and scale from the closed-lip position to the exaggerated-smiling position) into dynamic images by using video-editing software (iMovie; Apple Corp) (Fig. 7, Supplemental Videos 1, 2, available online). As a result, a 4D digital prediction of the esthetic outcome is fabricated in the virtual patient.

Figure 1. Preoperative frontal view in maximum intercuspal position. A, Intraoral digital photograph. B, Digital diagnostic cast.

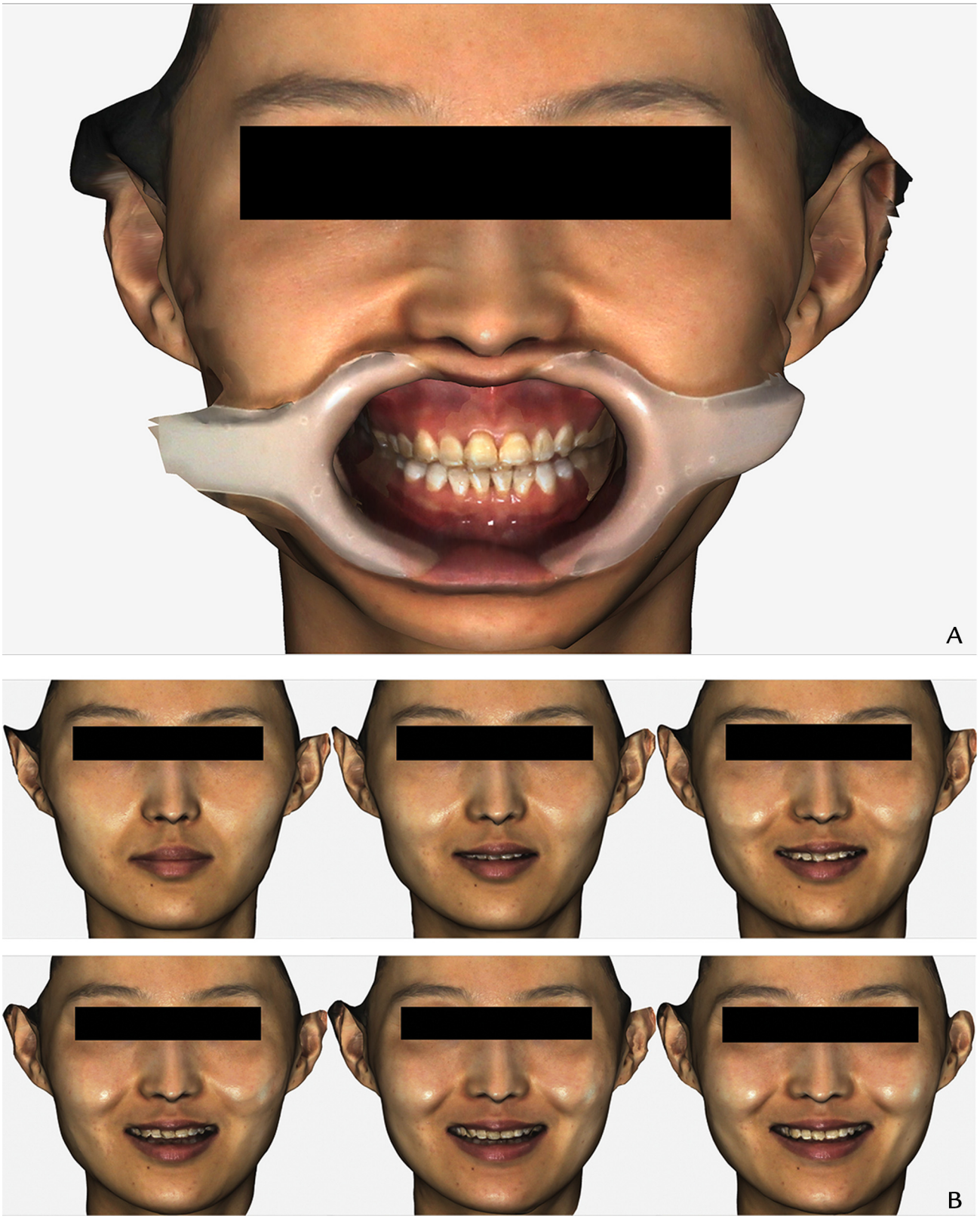

Figure 2. Three-dimensional face scans. A, Teeth in maximum intercuspal position with cheek retractors. B, Smiling process.

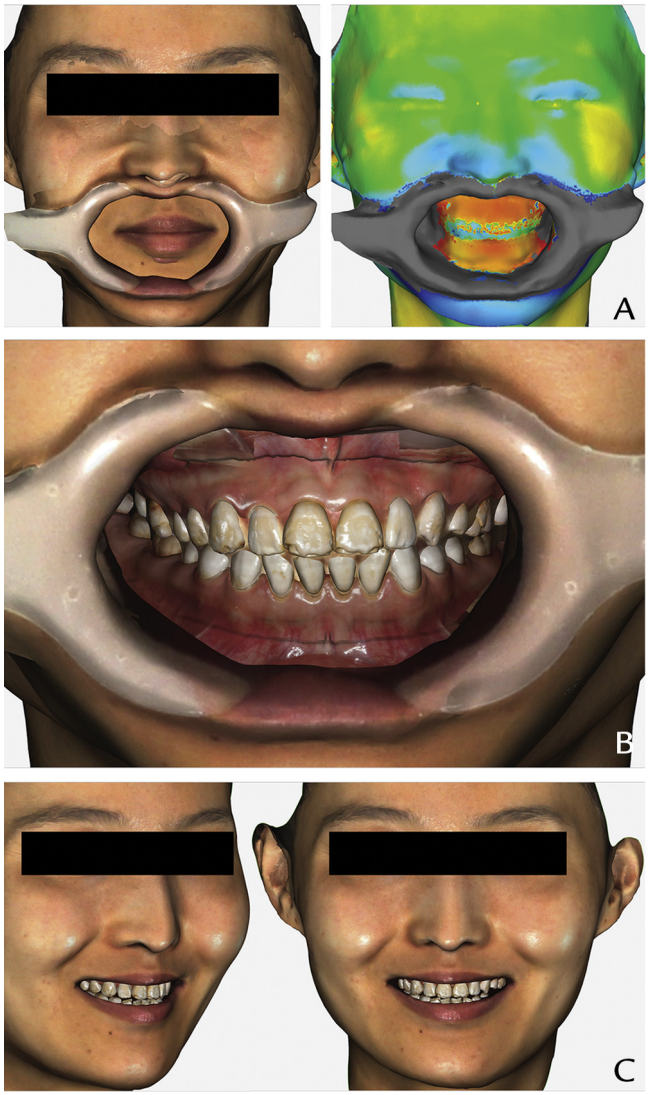

Figure 3. A, Alignment of 3D digital facial images. B, Colorized digital dental cast aligned to 3D facial images. C, Preoperative 3D face of virtual patient with exaggerated smile, shown from frontal and lateral 45-degree frontal view. 3D, three-dimensional.

9. Show the 4D esthetic prediction to the patient and invite decision-making of the definitive esthetic design. Fabricate the diagnostic resin dental cast by using the 3D printing technique from a patient-approved digital diagnostic waxing (Fig. 8).
10. Fabricate silicone indexes (Express XT Putty Soft; 3M ESPE) by using the diagnostic resin dental cast. These will be used for a preparation index and also for the fabrication of trial restorations. After tooth preparation, scan the prepared teeth to obtain the digital preparation cast. In the dental CAD software, copy the shape of the diagnostic waxing to the shape of the definitive prosthesis. Subsequently, mill the restorations by using ceramic blocks (IPS e.max CAD; Ivoclar Vivadent AG).

Figure 4. Custom design of virtual esthetic restorations on digital cast.

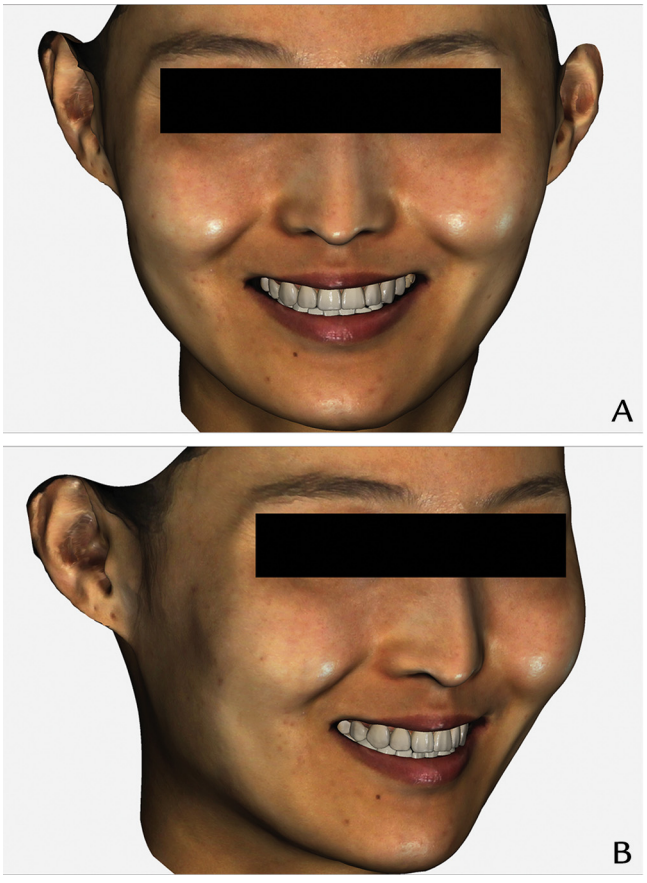

Figure 5. Three-dimensional prediction of esthetic outcome in virtual patient. A, Frontal view. B, Lateral 45-degree frontal view.

Deliver the restorations in the same manner as that seen in the virtual patient after evaluation and cementation (Fig. 9).

DISCUSSION

The presented digital technique promotes the visual perception and prediction quality of esthetic dentistry.

Figure 6. Screenshots from application display of facial images with intended restoration in virtual patient. A, Frontal view. B, Lateral 45-degree frontal view.

Figure 7. Four-dimensional prediction of esthetic outcome in virtual patient.

Figure 9. After treatment. A, Intraoral view of teeth in maximum intercuspal position. B, Frontal view of smiling face.

This strategy can facilitate dentist–patient–technician communication and, subsequently, transfer the digitally designed shape of restorations to the definitive ceramic restorations. The authors are unaware of a previous report of this technique for predicting esthetic outcome, which integrates an intended diagnostic cast into the overall dynamic smiling process.

Figure 8. Three-dimensional-printed diagnostic resin dental cast.

Previous methods used to predict esthetic outcome have had disadvantages. Diagnostic waxing does not show the effects of the lips. Sometimes, tooth preparation is needed before a trial restoration is possible. The transfer of the predicted tooth anatomy to the definitive restorations depends on the expertise of the dental technician, particularly for 2D digital methods, such as DSD,[4] which may lack precision.[15] A static smiling position is used for 3D digital methods.[14-16]

Dynamic 3D images can be used to overcome the limitations associated with a static smiling position.[14,19] Rather than using 3D smiling images (which are static in 1 facial expression), the present technique can greatly improve the realistic state of the dynamic smiling process and provide a satisfactory preview for clinical applications. Four-dimensional prediction of the esthetic outcome offers an efficient way for communicating with patients, dental technicians, and other dentists throughout the course of the treatment. Demonstrating the intended results and planned treatments dynamically and making appropriate adjustments according to patient feedback can ensure the patient is motivated.[1,4,8] Ultimately, such 4D digital prediction of esthetic outcome with the patient-incorporated design can be transferred to the definitive ceramic restorations by fabricating and copying the 3D-printing dental cast from an approved digital diagnostic waxing or by copying the contour of digital diagnostic waxing directly.

Additional software was used in this approach because current dental CAD software is not equipped to import 3D and 4D images. Although this technique requires more time than conventional techniques, it makes the entire treatment more predictable and efficient. In addition, the special software needed for this approach could be developed to make the technique more efficient and convenient. Research is needed to confirm the practicability and predictability of this technique.

SUMMARY

The technique described is applied for 4D prediction of the outcome of esthetic dentistry. The use of this technique could improve the simulation effect and visual reality of esthetic prediction before treatment.

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