New Digital Esthetic Rehabilitation Technique with Three-dimensional Augmented Reality: A Case Report

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This case report describes a dynamic digital esthetic rehabilitation procedure that integrates a new three-dimensional augmented reality (3D-AR) technique to treat a patient with multiple missing anterior teeth. The prostheses were designed using computer-aided design (CAD) software and virtually trialed using static and dynamic visualization methods. In the static method, the prostheses were visualized by integrating the CAD model with a 3D face scan of the patient. For the dynamic method, the 3D-AR application was used for real-time tracking and projection of the CAD prostheses in the patient’s mouth. Results of a quick survey on patient satisfaction with the two visualization methods showed that the patient felt more satisfied with the dynamic visualization method because it allowed him to observe the prostheses directly on his face and be more proactive in the treatment process.

Key Words: Augmented reality; Computer-aided design; Esthetic; Rehabilitation

Introduction

Successful dental esthetic rehabilitation requires clinicians to address both clinical concerns and patients’ esthetic demands\textsuperscript{1}. Traditionally, the previsionalization of future prostheses could be achieved by using a physical laboratory-made mock-up or intraoral temporary restoration; however, the fabrication process requires additional work and clinical appointments. For instant previsionalization of the prostheses, a two-dimensional (2D) digital approach, which overlaps idealized artificial teeth images on to facial photographs of the patients, has been introduced\textsuperscript{2,3}. However, this method requires facial photographs taken under ideal light and background conditions that usually require expensive profession-
al cameras and equipment. Moreover, this approach is only partially immersive for patients because it is difficult for a general person to imagine and understand complex professional simile analyses made on 2D photos\(^4\).

To improve patient experience, augmented reality (AR) technology has been integrated into the 2D smile design process\(^4,5\). The use of a 2D-AR smile design has been reported to be an effective tool for enhancing communication in esthetic dentistry by integrating the patient into the decision-making process\(^5\). However, a major limitation of the 2D digital approach is that the proposed design cannot be directly applied to the physical or digital working casts. Even though the 2D design can be transferred with the use of calipers, this approach is still at risk of losing or incorrectly transferring information between the 2D design and three-dimensional (3D) working casts\(^2,6,7\). Therefore, this case report aimed to introduce a dynamic digital esthetic rehabilitation procedure that integrates a new 3D-AR technique to treat a patient with multiple missing anterior teeth.

**Case Report**

A 60-year-old man missing upper central and lateral incisors underwent implant surgery on tooth 12 and 22 areas, and was referred for rehabilitation of the maxillary anterior region from tooth 12 to tooth 22 (Fig. 1). The patient was healthy and taking no current medications. After clinical examination, digital impressions of the patient’s maxilla and mandible were obtained using an intraoral scanner (MEDIT i700; Medit, Seoul, Korea). The digitized dental arches were imported into computer-aided design (CAD) software (Exocad Dental CAD version 2015.03; Exocad GmbH, Darmstadt, Germany), wherein the 3-units fixed prosthesis was designed and saved in standard tessellation language (STL) file format. A virtual trial of the designed prosthesis was performed using static and dynamic visualization methods. A written informed consent was obtained form the patient for the publication of this case report.

For the static virtual trial, the prosthesis was visualized by integrating the CAD model with a 3D face scan of the patient. First, the patient’s face at resting and smiling positions was scanned with a chair-side stereophotogrammetric facial scanner (Ray face; Ray Co., Ltd., Seongnam, Korea) to create 3D facial models. A bite impression was then made with polyvinyl siloxane (Aquasil Ultra Rigid Regular Set; Dentsply Sirona, Philadelphia, PA, USA) using a bite tray attached to an extraoral marker base (Ray face). The patient’s facial images were obtained again using a bite tray and marker base attachment (Fig. 2). The facial and dental scans were saved in the wavefront object (OBJ) file format and imported into the dedicated software (Ray face). Subsequently, dentofacial image integration was conducted based on artificial extraoral markers (Fig. 2)\(^8\).

For the dynamic virtual trial, the 3D-AR application was used for real-time tracking and projection of the CAD prosthesis in the patient’s esthetic zone (Fig. 3). The 3D-AR application used in this case was developed using AR Foundation, ARCore XR Plugin, and ARKit XR Plugin packages in the Unity 3D software.
platform (Unity Software Inc., San Francisco, CA, USA), and it was operated with an Android smart tablet (Galaxy Tab S8; Samsung Electronics, Seoul, Korea). The virtual CAD model of the prosthesis was imported into the 3D-AR application, which was augmented to the patient’s actual oral structure.

Fig. 2. Static virtual trial method. (A) Three-dimensional (3D) facial scan image. (B) 3D facial scan image of the patient wearing the marker-attached bite tray. (C) Superimposition of dental scan with face scan based on artificial extraoral markers. (D) Dentofacial image obtained after the image integration. (E) Previewing of the virtual prostheses on the 3D face scan image of the patient.

Fig. 3. Dynamic virtual trial method. (A) Face detection and three-dimensional face mesh generation. (B) Setting the coordinate points to determine the position of the virtual prostheses on the face mesh. (C) Augmentation of the virtual prostheses to the real oral structure (the prosthesis is adjusted to achieve a good fitting using the “Set position” function of the app).
This dynamic virtual trial consisted of the following steps: face detection, dental landmark determination, virtual prosthesis placement, and tracking. In the face detection step, the patient’s face region was automatically identified, and a corresponding 3D face mesh was generated to track face movement and facial expressions in real-time. Then, three points in the oral region were defined within the face landmarks on the face mesh to place the virtual prosthesis. The virtual prosthesis was augmented to the actual oral structure based on three coordinate points. The initial position of the prosthesis could be adjusted to match the anatomy of the patient. The AR-based virtual prosthesis can follow the patient’s head and lips movement, so that the prosthesis shape and size is adjusted to adapt to the dynamic smile and upper lip curvature more precisely.

After the virtual trials, the prosthesis was modified based on the patient’s preferences, saved, and then used to manufacture the definitive prosthesis. A quick survey on patient satisfaction with the static and dynamic virtual trial methods was conducted after treatment was completed. The patient felt more satisfied with the dynamic previsualization method, as it allowed him to observe the prosthesis directly on his face, and helped him be more confident about the expected prosthesis.

**Discussion**

Recently, a 3D digital esthetic rehabilitation method that uses 3D facial and intraoral scans of patients has attracted a lot of interest, as this approach allows the direct transfer of the proposed design to the digital cast so that the definitive prosthesis can be designed to correspond well with the verified esthetic appearance. However, as the clear appearance of the anterior teeth is essential for the accuracy of dentofacial image matching, an expensive professional face scanner may be required to obtain a high-resolution 3D scan image of the teeth. Although perioral scans or artificial markers could be used to enhance the matching accuracy, it requires additional working processes with significant time and technical skills to manage the dentofacial integration. Moreover, this approach is limited by the static characteristics of the integrated dentofacial images, which cannot cope with the patient’s lip movements during talking or smiling.

The use of AR technology allows a dynamic view of virtual objects in the real-world environment, thus enhancing the interaction and experience of users with virtual objects. Owing to the significant improvement in computer and camera technology, AR can be used in the medical and dental fields with a variety of emerging applications. For preclinical training and dental education, AR technology has been applied to develop students’ psychomotor skills before they engage in real patient treatment. For clinical treatment, AR technology has been employed for implant-guided surgeries. AR technology has been introduced as an effective preoperative planning tool in maxillofacial surgeries. In prosthetic treatment, AR technology has been applied to offer clinicians a dynamic prostheses previsualization concept; however, previous AR applications are limited to the 2D visualization of prosthetic templates.

This study is a clinical report to illustrate the use of a 3D-AR smile design approach for esthetic prosthetic treatment. The 3D-AR approach overcomes the limitations of both static and 2D visualization methods as it provides patients with dynamic 3D images of the prostheses. In the present case report, 3D-AR was applied in the trial phase of the prosthetic treatment process; however, it could also be applied in the mock-up phase to guide the design of prostheses based on the patient’s personal preferences. As the 3D design of the prostheses can be directly transferred to the CAD software, the patient’s approved planned prostheses can be precisely fabricated. Another advantage of this approach is that the 3D-AR...
application is compatible with smart portable devices; thus, it can be used in all general dental clinics without the need for additional expensive face-scan devices or photographic equipment.

The limitations of the 3D-AR tool used in this case report were related to the difficulties in matching and tracking a 3D object in the real environment. This technology is highly sensitive to the lack of sufficiently compatible reference points for correct AR image projection. In the future, further technological evolutions of AR, such as mixed reality technology, could be integrated to provide patients with the opportunity to interact with virtual prostheses to modify their shape, size, and color.

The use of 3D-AR technology for dynamic virtual trials of dental prostheses may enhance patients’ experience in esthetic treatment, improve communication between dental professionals and patients, and enable precise fabrication of prostheses.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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