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DENTAL TECHNIQUE

Facially generated and additively manufactured baseplate and occlusion rim for treatment planning a complete-arch rehabilitation: A dental technique

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ABSTRACT

Computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have been successfully integrated into the digital workflow to treat completely edentulous patients. However, the digital design and manufacturing technique of the baseplate and occlusion rims have not yet been developed into the digital workflow. This article describes a novel digital workflow using extraoral digitizing procedures, open-source CAD software, and additive manufacturing technologies to obtain a 3D patient. This virtual patient can then be used to plan treatment for a completely edentulous patient, with which the maxillary baseplate and occlusion rims are digitally designed. The workflow allows the digital determination of tooth exposure at rest, the dental midline, the location of the canines, and the determination of the occlusal plane related to the Camper plane. The digital determination of these parameters increases the predictability of the treatment, reducing laboratory and clinician time and costs. (J Prosthet Dent 2019;121:741-5)

An esthetic complete-mouth rehabilitation of completely edentulous patients can be challenging.[1-3] Comprehensive diagnosis, treatment planning, and treatment sequence are essential for the long-term success of a dental rehabilitation. In addition, complex rehabilitations should be guided by facial references.[4-6] Conventionally, this has been achieved with diagnostic casts mounted on a semiadjustable articulator supplemented with radiographic analysis and extraoral and intraoral digital images. This approach provides 2D information, which can then be improved with 3D digitalization of the patient's face.

Computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have revolutionized dentistry by improving predictability.[7-9] The CAD-CAM workflow involves 3 fundamental steps: data acquisition, data processing, and the manufacturing process.[9-16] Cone beam computed tomography (CBCT) scans,[17] facial scans,[18] and intraoral scans[19-21] may be made to virtualize the patient by reliable superimposition of the standard tessellation language (STL) files with CAD software.[22-24] The 3D patient provides information regarding the relationship between hard and soft tissue profiles, resulting in optimal esthetic outcomes,[25] and is an improvement on the conventional approach.

The 3D patient and CAD-CAM procedures have been integrated successfully to treat completely edentulous

Figure 1. Extraoral digitizing procedures. Frontal view of 3D facial scan.

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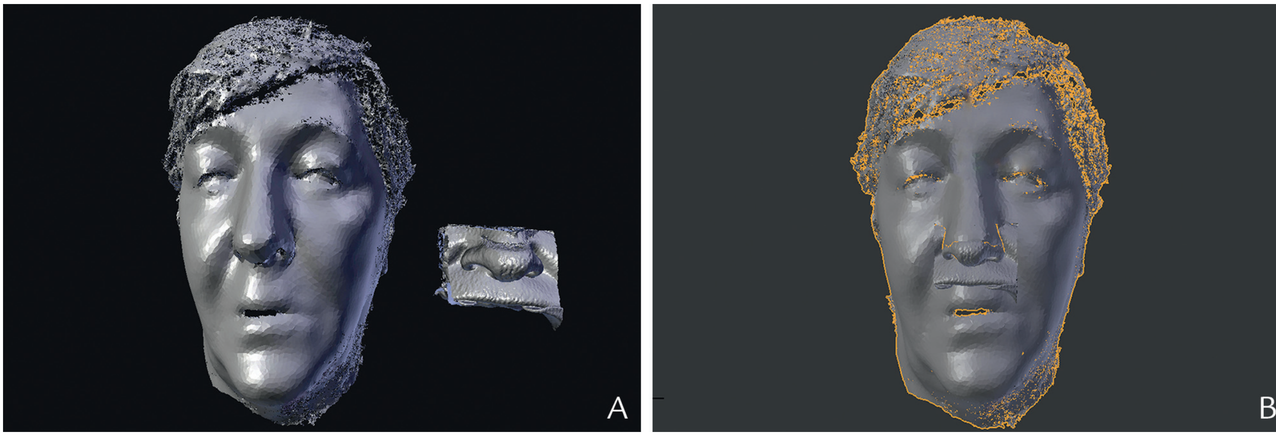

Figure 2. A, STL file of extraoral digitalization of patient's face and STL file obtained from CBCT of patient imported into 3D CAD software. B, Best fit alignment obtained using ICP algorithm of software. CAD, computer-aided design; CBCT, cone beam computed tomography; ICP, iterative closest point; STL, standard tessellation language.

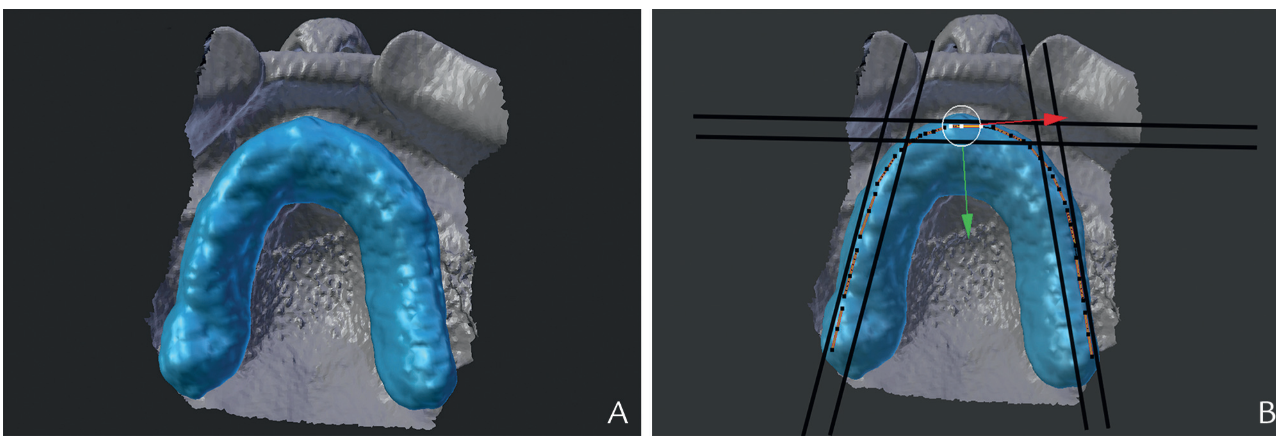

Figure 3. Occlusal view of digital maxilla imported into CAD software. A, Intaglio surface delimitation of maxillary digital baseplate and determination of homogeneous thickness of 2 mm for maxillary digital baseplate. B, Delimitation of rim above digital baseplate. CAD, computer-aided design.

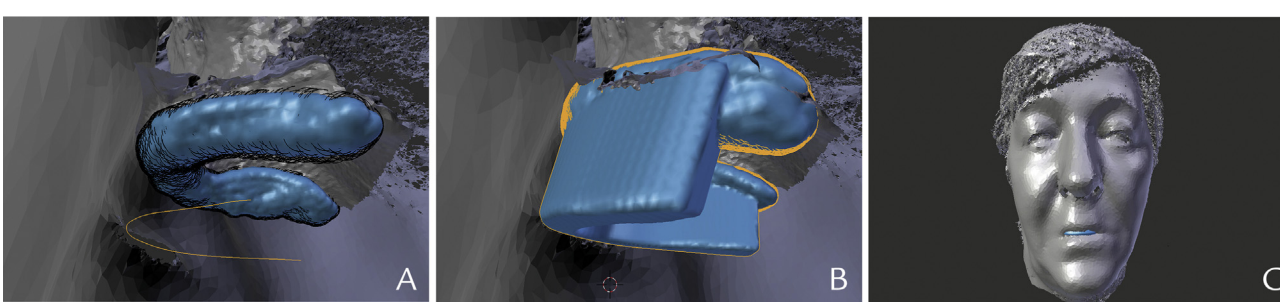

Figure 4. A, Occlusal curve delimitation beyond upper lip. B, Tentative design of maxillary baseplate and rim. C, Frontal view of maxillary baseplate and rim and superimposed with the facial scan.

patients.[26-30] However, the integration of digitally designed and additively manufactured baseplates and occlusion rims has not been reported as part of the sequence of treatment of these patients. The purpose of this article was to describe a novel protocol where facial digitizing procedures,[31] open-source CAD software, and additive manufacturing technologies were used to virtualize a patient and digitally design and additively fabricate a baseplate and occlusion rim as an initial step in the treatment planning of a completely edentulous patient.

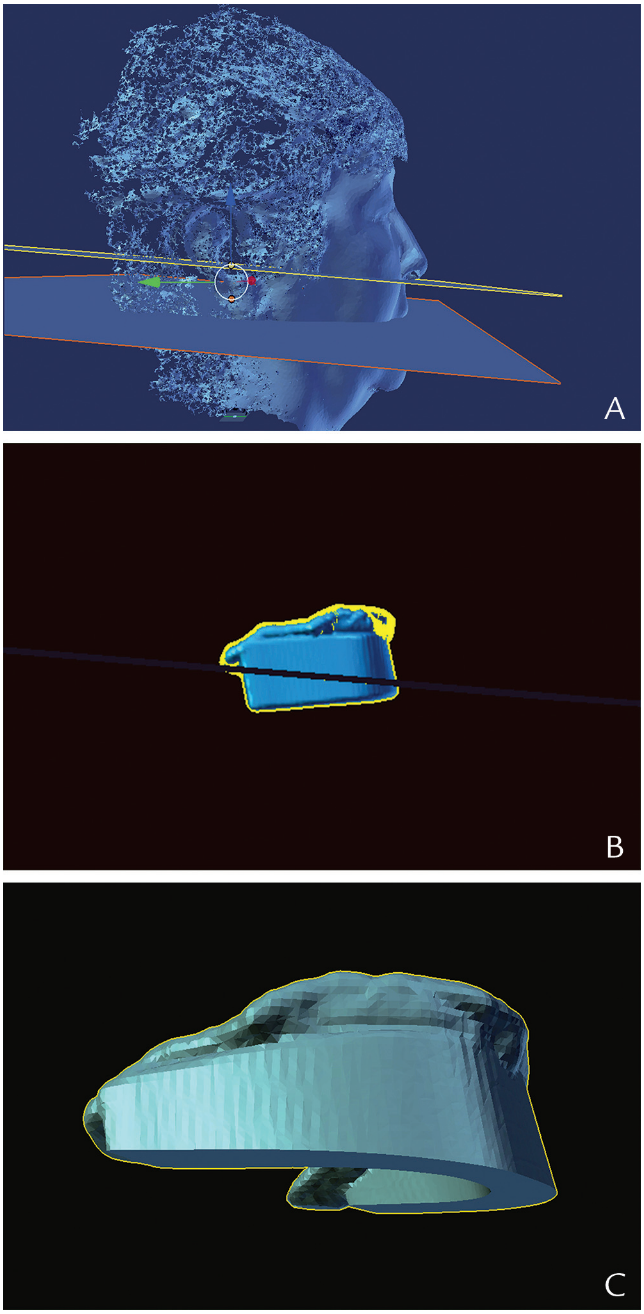

Figure 5. A, Camper plane determined on CAD software. B, Maxillary rim digitally trimmed parallel to marked Camper plane. C, Design of definitive maxillary rim and baseplate facially generated. CAD, computer-aided design.

TECHNIQUE

A patient with an edentulous maxilla is used to illustrate this technique. The following technique was used to obtain a virtual patient for designing and manufacturing the maxillary baseplate and occlusion rim to determine esthetics and occlusal and functional parameters.

1. Make 30 to 40 photographs from ear to ear to digitize the patient's face by using a digital camera (Canon EOS 700D; Canon) and use reverse engineering software (Agisoft PhotoScan; Agisoft LLC) to obtain the patient's facial scan in the rest position. Store the extraoral digitized scans of the patient's face as an STL file (Fig. 1).
2. Make a CBCT scan of the lower third of the patient's face with the teeth out of occlusion (Planmeca ProMax 3D; Planmeca). Export the Digital Imaging and Communications in Medicine (DICOM) files obtained and convert them into an STL file with soft tissue sensitivity.
3. Import both the STL files (step 1 and step 2) to 3D software (Blender v277a; The Blender Foundation). Superimpose the patient's CBCT scan on the facial scan by using common facial points as references to relate the patient's face (soft tissues) to the maxilla (hard tissues). Use the iterative closest point algorithm of the software to align them. Select a minimum of 3 common points in both the STL files to obtain the best alignment of the meshes (Fig. 2).
4. Design the intaglio surface of the digital baseplate for the digital occlusion rim and its border extensions 1.5 mm beyond the maximum contour of the alveolar ridge (Fig. 3A). Use the tools of the 3D software to obtain the definitive baseplate with a uniform thickness of 2 mm and an intaglio space of 0.3 mm (Fig. 3B).
5. Select the specific tools of the 3D software (Blender v277a; The Blender Foundation) to draw reference lines from an occlusal view as guidance for the design of the occlusion rim; 2 lines passed through the center of the baseplate at the posterior region and 1 line horizontally over the interincisal papilla. Duplicate these reference lines and move to the buccal side to obtain the limits of the occlusion rim (Fig. 3C).
6. Draw a curve touching the outermost reference lines of the design from an occlusal view (Fig. 3C).

Figure 6. 3D-printed baseplate and rim after support structure removal.

Figure 7. Clinical evaluation of additively manufactured maxillary rim and baseplate. A, Tooth visibility of 1 mm at rest. B, Exaggerated smile. C, Verification of the occlusal plane related to Camper plane.

Duplicate the curve and move it 3 to 4 mm in a coronal direction beyond the lips of the facial scan at the rest position (Fig. 4A).

7. Use the CAD software (Blender v277a; The Blender Foundation) to generate the maxillary digital rim above the digital baseplate. The occlusion rim is generated automatically, considering the angulation and distance between both the previously designed curves (Fig. 4B).
8. Create a plane in the 3D software to establish the Camper plane in the facial scan from a lateral view. Duplicate it and move toward the occlusion rim in relation to the desired tooth display at rest. The maxillary digital occlusion rim is trimmed parallel to the Camper plane, and its length is determined using the rest position scan as a reference, leaving the desired display at rest (Fig. 5).
9. Send the STL file of the generated baseplate and occlusion rim to the dental laboratory for fabrication using a 3D printer (Form 2; Resolution XY:150 μm and Z:100 μm, Formlabs) and white photopolymer resin (Try-in; NextDent) (Fig. 6). Once printed, immerse the object in an isopropyl bath for no more than 4 minutes and complete the polymerization using a UV polymerization machine (405 nm, 60 minutes, 36W) (Eurolight; Mestra). Finally, remove the supporting structures.
10. Evaluate the maxillary occlusion rim for the esthetic and functional parameters designed in the CAD software, including tooth display at the rest position, smile line, lip line, and Camper plane (Fig. 7). Then, verify those parameters in the patient's mouth with the 3D-printed esthetic diagnostic template (Fig. 8).

DISCUSSION

The feasibility to virtualize a patient and to digitally design and additively manufacture occlusion rims was confirmed. Coachman et al,[28] Bassam et al,[29] and Harris et al[30] demonstrated how to integrate 3D facial information into the digital workflow to rehabilitate patients with edentulism. However, they did not describe the CAD-CAM occlusion rim phase to determine esthetic and functional parameters.

Figure 8. Patient's smile with 3D-printed esthetic diagnostic template designed from additive manufactured baseplate and rim.

Two digital procedures are incorporated into the described technique: the digitizing of the patient's face through photogrammetry and the design and 3D printing of the occlusion rim. The facial scan could have been made with a specialized facial scanner, but a photogrammetry approach could have been applied too. For that, only a digital camera and reverse engineering software are required.[31] Schwindling and Stober[32] reported a protocol in which the baseplates and occlusion rims were digitally designed and milled from polymethyl methacrylate. However, their protocol needs specific devices to record the maxillomandibular relation and the occlusal plane. Also, the rims were milled instead of being 3D printed. The latter is less time-consuming and less expensive than milling. Digital techniques provide advantages over conventional procedures, such as the digital determination of tooth display at rest and the occlusal plane of the occlusion rim related to the patient's Camper plane calculated with the CAD software. Once the learning curve has been overcome, the superimposition process of the STL files and the CAD design of the baseplate and rim phase should take no more than 25 minutes. This approach allows affordable clinical and laboratory procedures to determine the esthetic and functional parameters in edentulous patients, saving time and cost. To the authors' knowledge, this is the first article to apply the virtual patient concept to design an additive manufactured baseplate and occlusion rim with open-source software, completing the digital workflow to treat edentulous patients.

SUMMARY

This article describes a step-by-step digital workflow using digital photographs, CBCT imaging, and open-source software to make a virtual representation of the patient's face. The 3D patient was then used to digitally design and fabricate a 3D-printed baseplate and occlusion rim in office.

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