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DENTAL TECHNIQUE

A vat-polymerized 3-dimensionally printed dual-material occlusal device: A dental technique

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ABSTRACT

A technique to additively manufacture an occlusal device by using a completely digital workflow is described. Using a computer-aided design program, information captured with an intraoral scanner was used to additively manufacture a dual-material occlusal device by using a vat-polymerization printer. This technique allows for the combination of 2 different materials, resulting in an occlusal device with a resilient intaglio and a hard resin exterior surface. Advantages of the resulting occlusal device compared with a single-material device include improved patient acceptance and comfort, better fit, and minimal adjustments to ensure fit. (J Prosthet Dent 2020;■:■-■)

The conventional technique for fabricating occlusal devices has been using single-layered or dual-layered acrylic resin materials.[1-4] Vat-polymerization additive manufacturing (AM) technologies are becoming popular for manufacturing dental devices, including occlusal devices, from biocompatible photosensitive resins based on acrylic esters.[5-12]

Studies that evaluated the mechanical properties of photosensitive resins for AM occlusal devices are sparse[7-10] but have reported that AM materials for occlusal devices have similar properties to those of conventional materials.[7,10] Typically, vat-polymerization printers have been used to process one dental material at a time. However, the present article describes a technique for manufacturing an occlusal device by combining 2 different photosensitive resins with a vat-polymerization 3-dimensional (3D) printer. This technique allows the intaglio surface of an occlusal device to be fabricated with a resilient material and the exterior surface with a hard resin material.

TECHNIQUE

This digital workflow includes the clinical and laboratory procedures needed to AM a dual-material occlusal device with data captured from an intraoral scanner and a digital design from a dental computer-aided design (CAD) software program.

1. During the first clinical appointment, obtain an intraoral digital scan of the maxillary and mandibular arches by using an intraoral scanner (TRIOS 4; 3Shape A/S) as per the manufacturer's recommended scanning protocol. Select a room with no windows with a luminosity of 1000 lux, making sure the dental chair light is kept off during the scanning procedure.[13-15]
2. Fabricate an anterior device with composite resin to guide the patient into centric relation position (Fig. 1). With the anterior device in position, acquire the occlusal relation scans at the determined occlusal opening. Export the standard tessellation language (STL_1) file.
3. Import STL_1 file into a dental CAD software program (Dental System; 3Shape A/S) to design the

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Figure 1. Fabrication occlusal anterior device for interocclusal record.

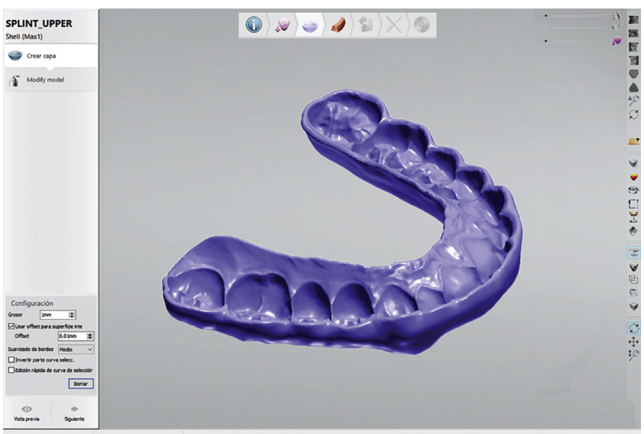

Figure 2. Virtual design of occlusal device.

occlusal device (Fig. 2). On completion of the design, export the STL file (STL_2).

4. Import STL_2 into a slicer software program (ChiTuBox; CBD-Tech). Position the occlusal device in the 3D build platform with 0-degree print orientation. Generate the corresponding attachment layer and the support structures necessary to ensure a successful printing process. Slice the STL_2 with a layer thickness of 100 µm.
5. Review the total number of layers and divide the sliced images obtained into 2 folders, F1 and F2. In the F1folder, place the layers corresponding with the first layer up to the layer corresponding with the intaglio of the occlusal surfaces of the teeth (Fig. 3A). Place the remaining layers in the F2 folder (Fig. 3B). Use a 3D printer (Bean; Kudo 3D) to manufacture the occlusal device to allow customization of the 3D printing workflow (Table 1). Calibrate the printer in accordance with the manufacturer's recommendations.
6. Import the files stored in the F1 folder into the 3D printing software program (Bean Web-based software; Kudo 3D) and select a rigid resin material (NextDent Ortho Clear; 3D Systems) designated for AM intraoral occlusal devices. Shake the resin before use for 5 minutes. Select the appropriate printing parameters for the selected resin material (Fig. 4).
7. Once printed, remove the rigid clear polymer (NextDent Ortho Clear; 3D systems) from the resin container of the printer. Next, place a new vat with a resilient resin material (NextDent Ortho IBT; 3D systems), making sure to shake the material for 5 minutes. Change the corresponding printing parameters for the newly selected resin material (Table 2).

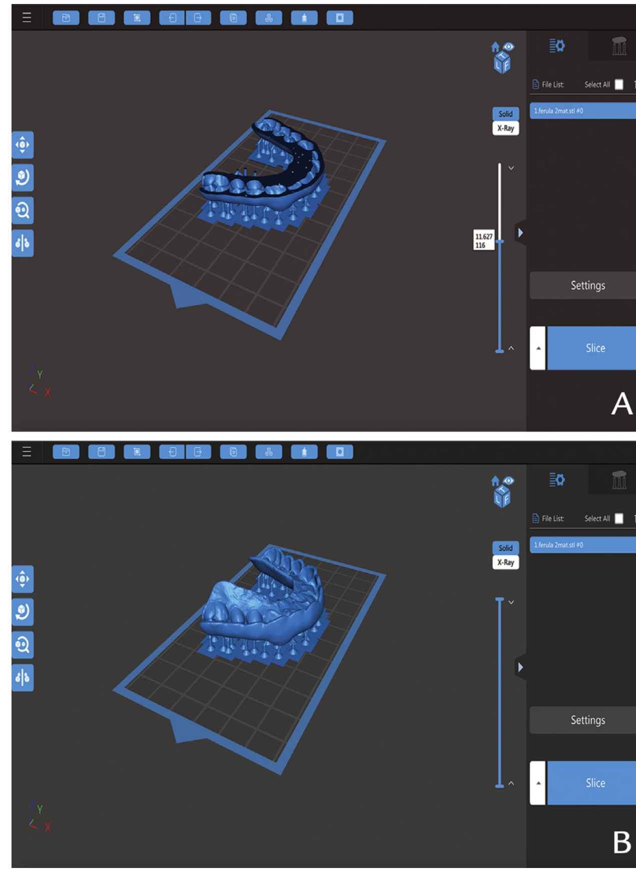

Figure 3. Slicing of digital occlusal device design. A, From layer 1 to layer 116. B, From layer 117 to layer 197.

Table 1. Features of 3D printer used (Bean; Kudo 3D)

Technology	Vat-polymerization stereolithography (SLA)
Light source	Liquid crystal display (LCD)
LCD pixel resolution	2560×1440
Light source power	High
Wavelength	405 nm
XY resolution	47 µm
Min/Max layer thickness	10-100 µm
Printing volume	121×68×160

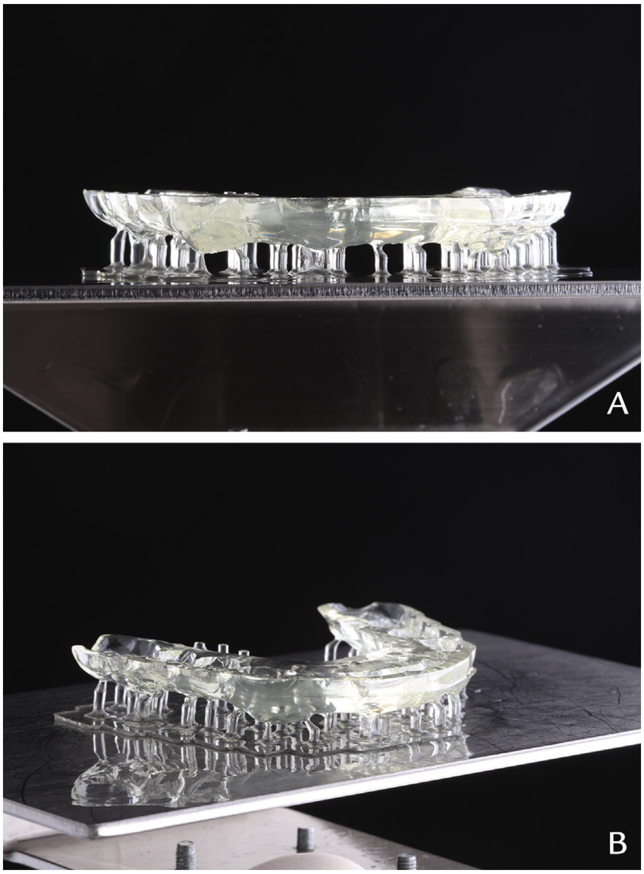

Figure 4. Additively manufactured occlusal device from layer 1 to 116 using hard resin (NextDent Orto Clear; 3D systems). A, Frontal view. B, Lateral view.

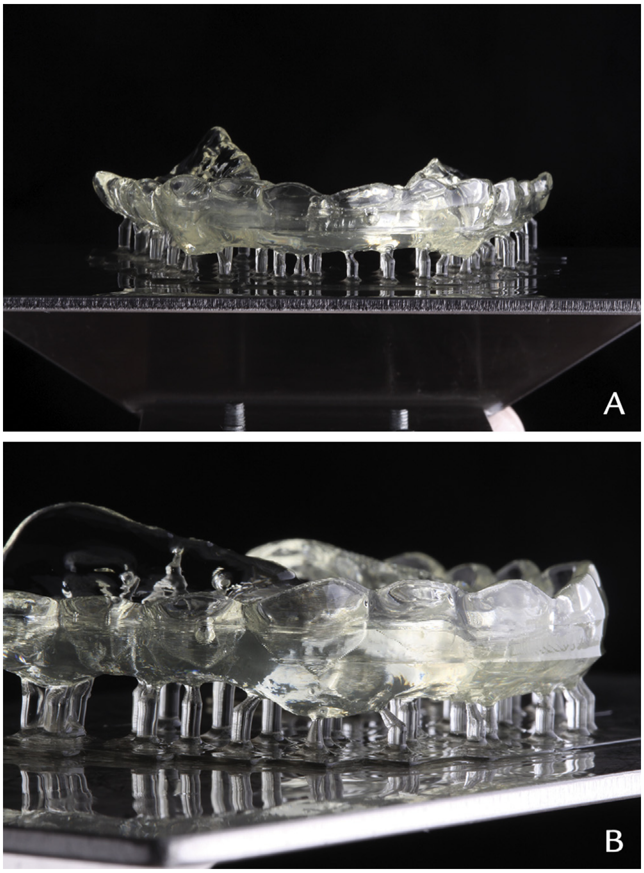

Figure 5. Additively manufactured occlusal device from layer 117 to 197 from resilient resin (NextDent Orto IBT; 3D systems). A, Frontal view. B, Lateral view.

8. Use the 3D printing software to lower the build platform to the corresponding position of the last layer of F1. Import images from the F2 folder into the 3D printer software (Bean Web-based software; Kudo 3D) and continue the printing process (Fig. 5).
9. Remove the occlusal device from the build platform and perform the postprocessing procedures recommended by the manufacturer. Submerge the device in a container with 99% isopropyl alcohol for 3 minutes, followed by a second bath with clean isopropyl alcohol solvent for 2 minutes. Subsequently, rinse the device with water and let it dry for 2 minutes. Place it inside a ultraviolet-polymerization machine (LC-3D Print Box; NextDent) for 10 minutes. Remove the supporting structures with a cutting device. Polish the external surface using an abrasive paper (sequence of roughness 220, 500, and 1200), followed by polishing paste (Universal Polishing Paste; Ivoclar Vivadent AG) (Fig. 6).
10. During the second clinical appointment, verify the fit of the occlusal device. Evaluate the occlusal contacts with an articulation film (Arti-Fol BK 28, 012 mm; Bausch GmbH & Co) and adjust as needed (Fig. 7).

Table 2. Mechanical properties of biocompatible resins used to manufacture dual material occlusal device

Characteristics	Intaglio Material of Occlusal Device	Exterior Material of Occlusal Device
Material selection	NextDent Ortho clear; 3D systems	NextDent Ortho IBT; 3D systems
Shore A Hardness	85	NA
Elongation break	17%	NA
Ultimate flexural strength	NA	>50 MPa
Flexural modulus	NA	>1300 MPa

NA, not available. Information provided by manufacturer.

DISCUSSION

Soft, hard, and a combination of both materials for occlusal devices manufactured using conventional methods have been evaluated in the dental literature.[16-20] While soft appliances seems more comfortable to the patient, there is no agreement on the most beneficial design.[16-20] However, most AM protocols

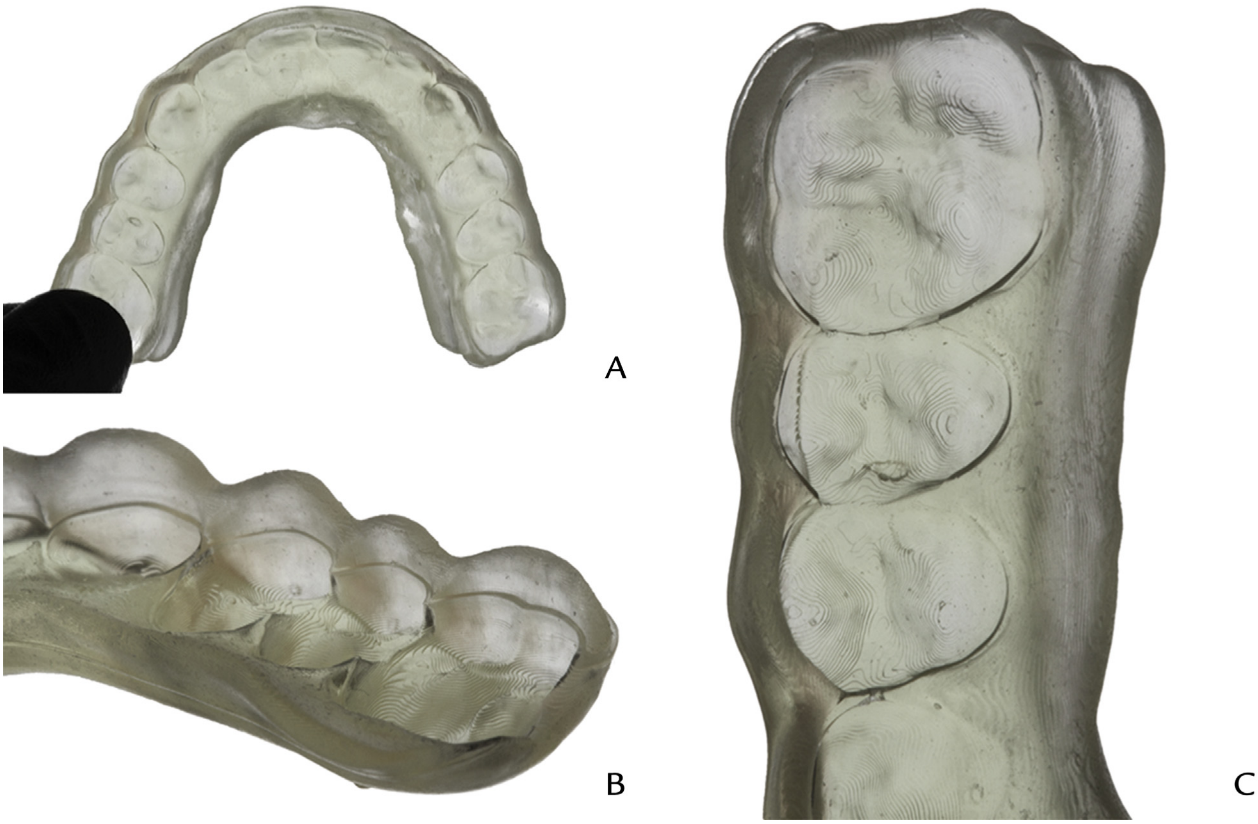

Figure 6. Completed additively manufactured occlusal device. A, Intaglio surface. B, Interface of resilient and rigid materials. C, Resilient material located on intaglio of dual-material occlusal device.

implemented in dentistry are focused on fabricating 3D-printed objects in a single material. The technique described in this article allows for the fabrication of a dual-material occlusal device by using a vat-polymerization 3D printer. In addition to being more comfortable to wear, the resilient intaglio material may improve the distribution of occlusal forces and increase patient acceptance and compliance. Furthermore, using a resilient intaglio surface can facilitate the delivery appointment by minimizing the number of adjustments needed to obtain appropriate fit of the occlusal appliance, as the resilient material may compensate for manufacturing errors. However, studies are recommended to evaluate the clinical fit and clinical performance of AM dual-material occlusal devices.

This technique can only be performed with a 0-degree build angulation to enable the interchange of the resin in the printer. This technique allows the fabrication of a dual-material device in the same printing procedure. Vasques and Laganá[11] compared the fit of occlusal appliances made of rigid material with a layer thickness of 100 μm and manufactured by using a vat-polymerization printer with 3 build orientations (0, 30, and 90 degrees). The authors concluded that the best build orientation to ensure proper fit was 0 degrees. Revilla-León et al[21] also reported that the manufacturing of silicone indexes at 0-degree angulation had the least surface roughness by using a vat-polymerization printer with a resilient material at a layer thickness of 50 μm.

Salmi et al[7] described a workflow to manufacture an occlusal device by using a vat-polymerization printer with a rigid material. Patients receiving the AM occlusal device reported it to be excessively tight at every use.[7] Determining the retention of the digital occlusal device design by using CAD software programs is not a straightforward process. Although CAD software programs are able to determine the undercut areas in relation to the elected path of insertion, the extension and tooth offset of the design is defined by the technician and is based on their expertise. These nonstandardized parameters could result in a device with deficient or excessive retention. The dual-material 3D-printing process described in this article could facilitate retention and patient comfort. Studies are recommended to assess the interface behavior of both rigid and resilient materials and the clinical performance of such AM devices.

Figure 7. Vat-polymerized dual-material occlusal device inserted. A, Right lateral excursive movement. B, Centric occlusion. C, Left lateral excursive movement.

SUMMARY

The digital workflow described to additively manufacture an occlusal device by using a vat-polymerization 3D printer allowed the combination of 2 different materials, resulting in an occlusal device with the intaglio surface fabricated with a resilient material, whereas the exterior surface was fabricated using a hard resin material. Intended advantages of the described technique included better distribution of the occlusal forces, increased patient comfort, minimal adjustments on the intaglio surface to ensure fit, and the need for a skilled dental laboratory technician.

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