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CAD-CAM Hollow Obturator Prosthesis: A Technical Report

Amal Alfaraj, BDS, MSD,[1] Fang-Yu Su, DMD,[2] & Wei-Shao Lin, DDS, FACP, PhD[1]

[1]Department of Prosthodontics, Indiana University School of Dentistry, Indianapolis, Indiana, USA
[2]Department of Restorative Dentistry, Temple University Kornberg School of Dentistry, Philadelphia, Pennsylvania, USA

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Correspondence
Dr. Wei-Shao Lin, Department of Prosthodontics, Indiana University School of Dentistry, 1121 W. Michigan St, DS-S406, Indianapolis, IN 46202-5186, USA.
Email: weislin@iu.edu

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Abstract

An obturator with a hollow bulb can decrease the overall weight of the prosthesis, stress on the underlying tissues, and patient discomfort. Although many techniques and materials have been proposed in the literature for hollowing the obturator prosthesis, they are often time consuming and technique sensitive. This proposed technique used an open-source software program to hollow a digital design of a solid obturator base from a commercially available software in one single convenient step. The hollowing process allowed precise control of prosthesis thickness at the hollow space area for desirable hermetic seal and prosthesis strength.

The maxilla plays an essential role in mastication, deglutition, and phonation.[1] The presence of congenital malformations or acquired defects such as oral cancers or trauma in the maxilla requires partial or complete maxillectomy, leaving the patient with an oronasal defect that impacts normal function.[2] Such patients require prosthetic rehabilitation to restore their function and improve their quality of life.[1] The maxillary-palatal defect can be restored with the maxillofacial prosthesis, also known as an obturator.[3] To improve the seal and retention of the obturator, the prosthesis is extended into the defect.[4,5] The obturator provides functional and psychological support for the patient, affording patients with improved speech and swallowing functions.[6,7]

One primary limitation of the maxillary obturator prosthesis is its weight.[8] Restoration of significant oronasal defects require more extension of the prosthesis that makes the prosthesis heavier.[5] A heavier prosthesis applies continuous stress on the underlying tissues and causes discomfort to the patient.[5,8] In patients with large-size defects, gravity acts as a dislodging factor that affects the stability and retention of the prosthesis.[5,8] An obturator with a hollow bulb can reduce the weight of the prosthesis. A previous study showed that hollow design reduced the weight of the obturator prostheses up to 33% depending on the size of the defect.[5] However, fabricating an obturator with a hollow bulb with conventional approaches is time consuming and technique sensitive. An obturator with an open part and a hollow bulb could be fabricated separately and joined with autopolymerizing resins or silicones. However, inadequate adhesion at the joint may disrupt the seal and allow moisture to enter the obturator, weakening the integrity of the prosthesis.[7,8] Alternatively, different materials such as sugar, ice, or wax can be used as matrices inside the bulb to maintain its hollow nature during processing and these materials are removed from the prosthesis after processing.[9,10]

Computer-aided design and computer-aided manufacturing (CAD-CAM) technologies allow the digital designing and manufacturing of removable dental prostheses including maxillofacial prostheses.[8,11,12] This technical report aims to describe a digital laboratory workflow to fabricate an obturator with a hollow bulb using an open-source software program and additive manufacturing technology.

Technique

1. Make a definitive impression of the edentulous maxilla and the opposing prosthesis and create definitive casts (Fig 1). Fabricate record bases and occlusal rims to articulate the definitive casts. Scan the definitive casts and maxillomandibular relationship using a dental laboratory scanner (E4; 3Shape A/S, Copenhagen, Denmark) and import the digital files in a commercial CAD software (Dental Designer, 3Shape A/S, Copenhagen, Denmark) (Fig 2).
2. Design the maxillary obturator in the CAD software program (Fig 3) and export the obturator base file in the standard tessellation language (STL) file format. Import the STL file into an open-source CAD software (Meshmixer v11.0.544; Autodesk, San Rafael, CA) (Fig 4a and 4b).

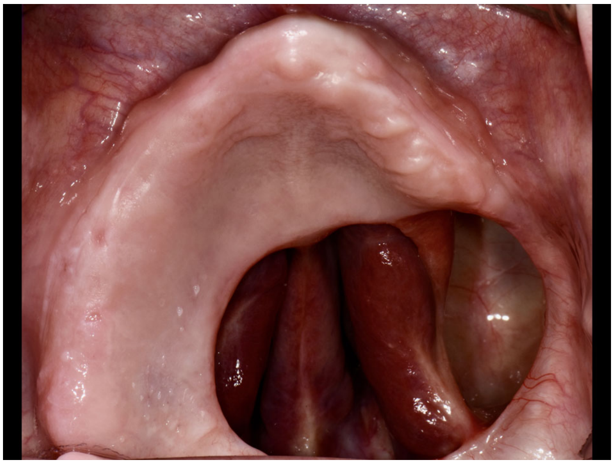

Figure 1 Intraoral view of maxilla and maxillary defect.

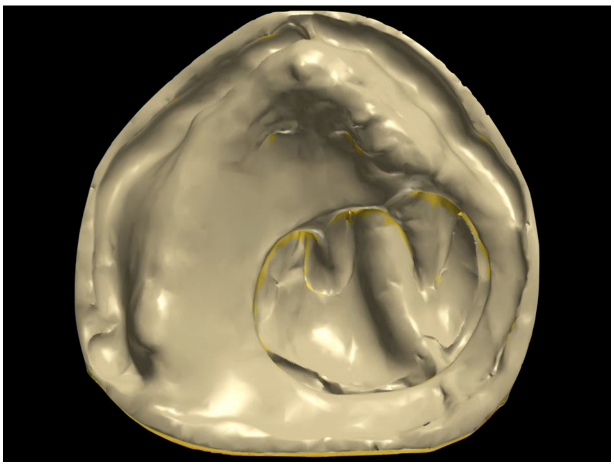

Figure 2 Digitized definitive maxillary cast.

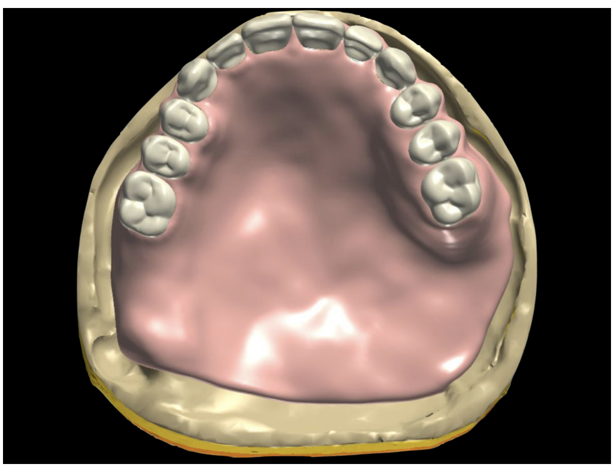

Figure 3 Digital design of maxillary obturator.

3. Hollow the bulb part by using the "Hollow" function in the "Edit" tab. Select appropriate thickness for the border forming the hollow bulb (Offset Distance: 3 mm, Solid Accuracy: 150, Mesh Density: 150, Holes Per Hollow: 2, Hole Radius: 2 mm, Hole Taper: 0 mm). Increase the offset distance to decrease the size and extension of the hollow portion when necessary (Fig 5a). Use the "Generate Holes" function and place 2 vent holes at the cameo surface over the hollow space to prevent hydraulic and air pressure during additive manufacturing (Fig 5b). Export the obturator base with a hollow bulb in an STL file format.
4. Manufacture the obturator base additively with the light-polymerizing denture base resin (Lucitone Digital Print; Dentsply Sirona, Charlotte, NC) and a 3D-printer (M1; Carbon Inc, Redwood City, CA) (Fig 6a).
5. Seal the vent holes with gingiva-colored light-polymerizing resin (anaxgum; anaxdent North America, Ardmore, OK).
6. Apply the conditioning agent (Lucitone Digital Fuse, 3D Tooth Conditioning Agent; Dentsply Sirona, Charlotte, NC) on the denture teeth (SR Vivodent DCL; Ivoclar Vivadent, Amherst, NY) and lute the denture teeth to the 3D-printed obturator base with light-polymerizing resin (Lucitone Digital Fuse, 3D Denture Bonding Resin; Dentsply Sirona, Charlotte, NC) (Fig 6b).
7. Finish and polish the obturator prosthesis for the trial insertion and delivery (Fig 6c).

Discussion

This technical report describes a digital laboratory workflow to fabricate a 3D-printed obturator prosthesis with a hollow bulb to decrease the weight of the prosthesis. This technique results in a 24% weight reduction of the hollow obturator base when compared with the solid one (Fig 7a). Many traditional methods have been introduced to fabricate an obturator with a hollow bulb, such as using different materials inside the bulb during processing or processing the obturator in separate segments.[7–10] These techniques may not be able to maintain the even thickness of the hollow space and achieve a uniform prosthesis thickness for the obturator. It may also be challenging to remove materials inside the bulb after processing through the small holes drilled in the prosthesis. Although CAD-CAM technologies allow for the digital designing and manufacturing of obturator prostheses, there is currently no effective way to hollow the solid obturator base in commercially available dental digital design software.

This proposed technique used a free open-source software program (Meshmixer v11.0.544) to conveniently convert a solid obturator base from a commercially available software into a hollow design. The conversion process utilized the existing "Hollow" function in the open-source software program and was completed in a single step. This digital design process allowed precise control of even prosthesis thickness at the hollow space area (3 mm prosthesis thickness was used in this report) (Fig 7b). A recent preliminary in vitro study showed that 2 mm prosthesis thickness is suitable for a hollow obturator, in terms of hermeticity and durability.[13] Although

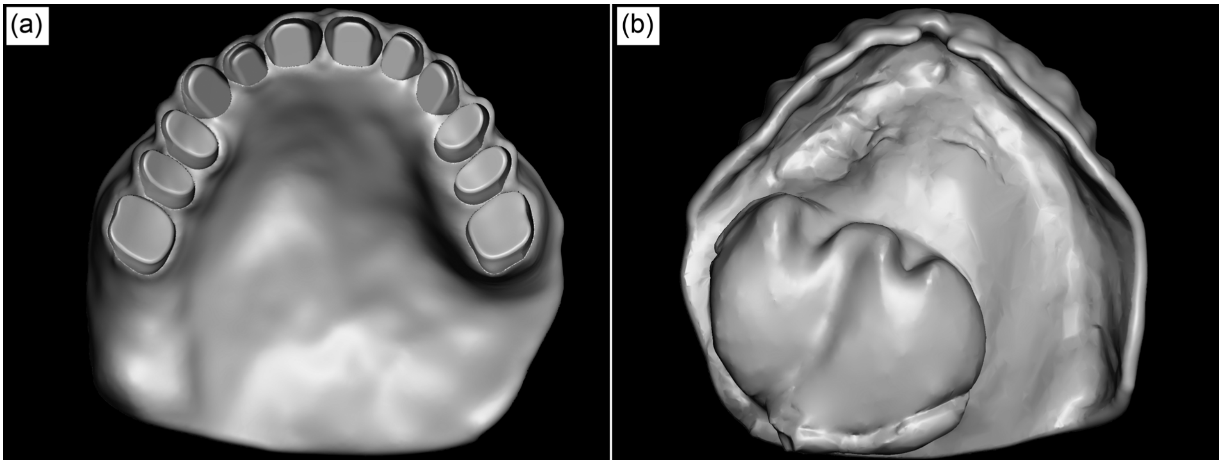

Figure 4 Maxillary obturator base file. (a) Cameo surface; (b) intaglio surface.

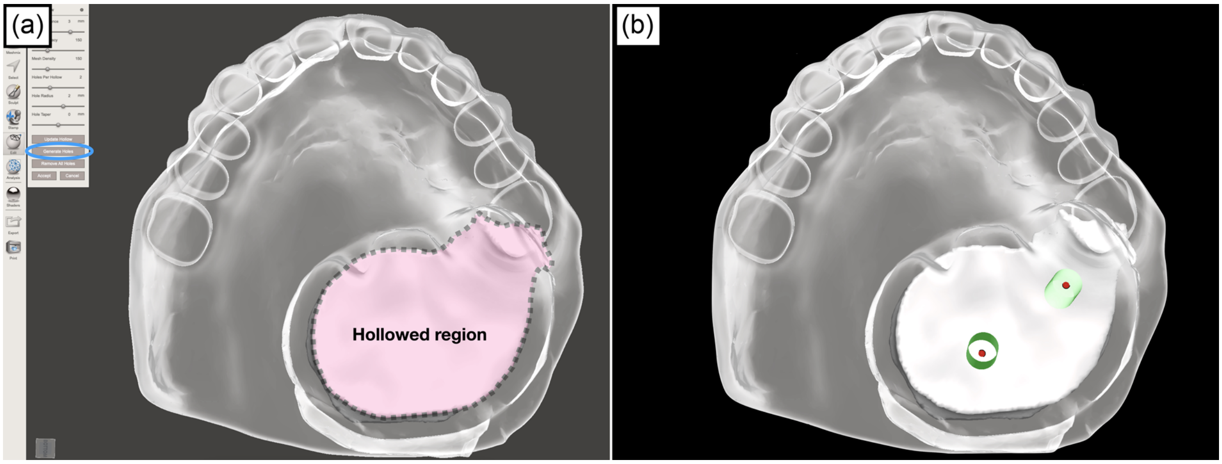

Figure 5 (a) Hollowed obturator base. Pink color highlights hollowed region, and blue color depicts "Generate Holes" function to create vent holes; (b) two vent holes placed on cameo surface of obturator base.

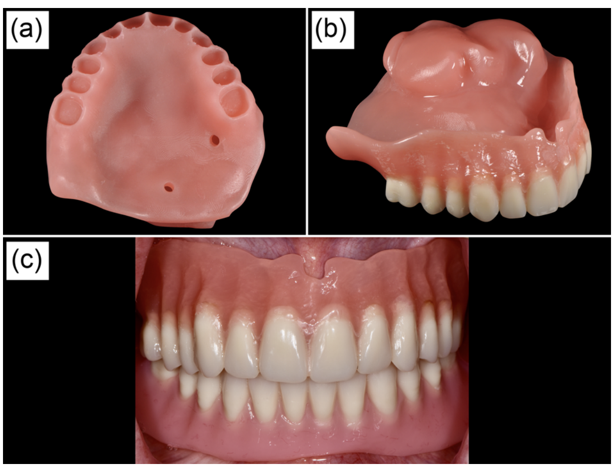

Figure 6 (a) 3D-printed obturator base with vent holes; (b) denture teeth luted with 3D-printed obturator base; (c) definitive CAD-CAM hollow obturator in situ.

CAD-CAM prostheses can be either milled or 3D-printed, the milling technology may not be suitable for manufacturing an obturator prosthesis base. The complexity of the prosthesis intaglio surface morphology, presence of heavy undercuts, and height of the prosthesis exceeding the dimension of available acrylic blocks are all challenges in milling an obturator prosthesis base.[14] A 3D printer was used to manufacture the hollow obturator base in this report, and a recent study showed excellent accuracy of 3D-printed obturator bases (comparable to compression molded ones) using the same printer.[14]

A previous report also described the use of the same open-source CAD software (Meshmixer; Autodesk, San Rafael, CA) to hollow an obturator bulb. However, no vent holes were designed in the previous report, and the obturator prosthesis was 3D-printed with support structures remaining within the bulb.[15] The support structures added additional weight to the overall obturator prosthesis. A different 3D printer (M1; Carbon Inc, Redwood City, CA) was used in the current report, and no support structures were used inside the hollow obturator bulb. Furthermore, no vent holes were designed in the previous

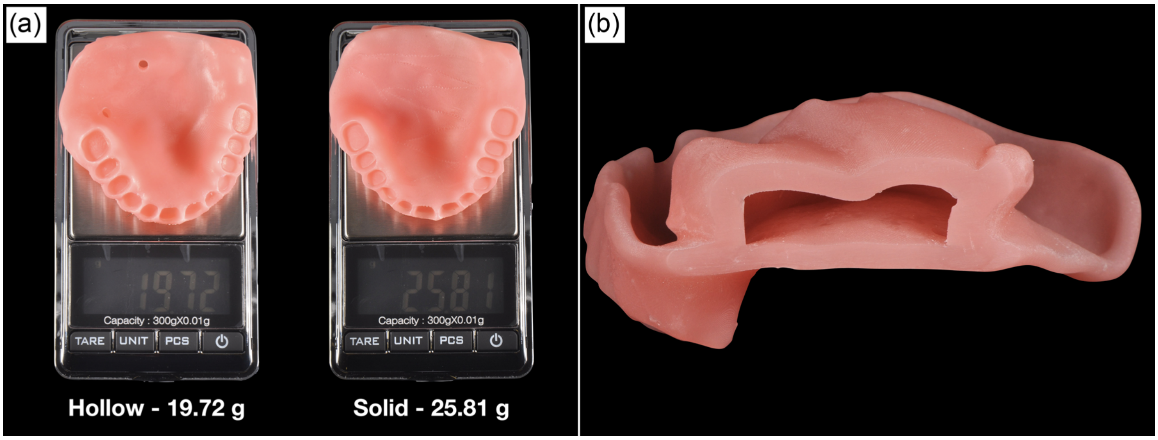

Figure 7 (a) Weight difference between hollow (19.72 g) and solid (25.81 g) obturator bases; (b) cross-sectioned view of hollow bulb in CAD-CAM obturator base with even prosthesis thickness.

report, and it was not possible to eliminate any residual light-polymerizing resin enclosed inside the hollow obturator bulb. Light-polymerizing resin and air can get trapped inside a hollow object during the printing process which may lead to deformation or discoloration.[16] In this present report, two vent holes were designed to allow resin and air to escape during 3D printing, and isopropyl alcohol to flow through the hollow part during the cleaning process.[17] Gingiva-colored light-polymerizing resin was used to seal the vent holes in this report, however, water leakage into the bulb could be a potential complication. A long-term clinical study should be considered to investigate the stability of 3D-printed hollow obturators. Different 3D printing technologies, materials, and printing strategies can also be studied in the future to explore the possibility of eliminating the use of vent holes and to minimize the opportunity of water leakage and fluid accumulation.

Conclusions

This report described a digital workflow using an open-source software program to hollow a digital design of a solid obturator base from a commercially available software. Additive manufacturing technology was used to manufacture an obturator with a hollow bulb.

Conflict Of Interest

The authors declare no conflict of interest.

References

1. Wang F, Huang W, Zhang C, et al: Functional outcome and quality of life after a maxillectomy: a comparison between an implant supported obturator and implant supported fixed prostheses in a free vascularized flap. Clin Oral Implants Res 2017;28:137-143
2. Deng H, Sambrook PJ, Logan RM: The treatment of oral cancer: an overview for dental professionals. Aust Dent J 2011;56:244-252
3. The glossary of prosthodontic terms. J Prosthet Dent2005;94:10-92
4. Tasopoulos T, Chatziemmanouil D, Karaiskou G, et al: Fabrication of a 3D-printed interim obturator prosthesis: a contemporary approach. J Prosthet Dent 2019;121:960-963
5. Wu YL, Schaaf NG: Comparison of weight reduction in different designs of solid and hollow obturator prostheses. J Prosthet Dent 1989;62:214-217
6. Desjardins RP: Early rehabilitative management of the maxillectomy patient. J Prosthet Dent 1977;38:311-318
7. Shimizu H, Yoshida K, Mori N, et al: An alternative procedure for fabricating a hollow interim obturator for a partial maxillectomy patient. J Prosthodont 2009;18:276-278
8. Koyama S, Kato H, Harata T, et al: A workflow for fabricating a hollow obturator by using 3D digital technologies. J Prosthet Dent 2020;123:648-652
9. Matalon V, LaFuente H: A simplified method for making a hollow obturator. J Prosthet Dent 1976;36:580-582
10. Patil PG, Patil SP: A hollow definitive obturator fabrication technique for management of partial maxillectomy. J Adv Prosthodont 2012;4:248-253
11. Strub JR, Rekow ED, Witkowski S: Computer-aided design and fabrication of dental restorations: current systems and future possibilities. J Am Dent Assoc 2006;137:1289-1296
12. Pillai S, Upadhyay A, Khayambashi P, et al: Dental 3D-printing: transferring art from the laboratories to the clinics. Polymers (Basel) 2021;13:157
13. Koyama S, Sato N, Mito T, et al: Hermeticity of a hollow obturator model using CAD and rapid prototyping technologies. J Prosthet Dent 2020;124:123-127
14. Alfaraj A, Yang CC, Levon JA, et al: The trueness of obturator prosthesis base manufactured by conventional and 3D printing techniques. J Prosthodont 2022;31:221-227
15. Jamayet NB, Farook TH, Al-Oulabi A, et al: Digital workflow and virtual validation of a 3D-printed definitive hollow obturator for a large palatal defect. J Prosthet Dent 2021; https://doi.org/10.1016/j.prosdent.2021.08.021
16. i.Materialise. How to hollow out your 3D model: https://imaterialise.helpjuice.com/design-printing/how-to-hollow-out-your-3d-model.
17. Formlabs. How to hollow out 3D models with Meshmixer to save material and time. https://formlabs.com/blog/how-to-hollow-out-3d-models/