

Technical Note

Fabrication of Metal-Reinforced Complete Dentures Using the CAD-CAM Technique

Xing-Yu Piao , June-Sung Shim  and Ji-Man Park * 

Department of Prosthodontics, College of Dentistry, Yonsei University, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea; 18625049725@163.com (X.-Y.P.); jfshim@yuhs.ac (J.-S.S.)

* Correspondence: jimarn@gmail.com

Abstract: The digital manufacture of complete dentures would greatly simplify the workflow; however, the metal-reinforced complete dentures production method has not been well established. This article describes a technique of fabricating metal-reinforced complete dentures in a milling machine using the geometry guide, a negative impression of the occlusal surface of the metal-reinforced complete denture designed using the computer-aided design software. The geometry guide supports and stabilizes the artificial teeth and metal framework in the correct position in the surrounding resin. Fabrication of metal-reinforced dental prosthesis using the digital technique is possible with this method.

Keywords: CAD-CAM; geometry guide; dental prosthesis; metal substructure



Citation: Piao, X.-Y.; Shim, J.-S.; Park, J.-M. Fabrication of Metal-Reinforced Complete Dentures Using the CAD-CAM Technique. *Appl. Sci.* **2021**, *11*, 7369. <https://doi.org/10.3390/app11167369>

Academic Editor: Anming Hu

Received: 5 July 2021

Accepted: 29 July 2021

Published: 11 August 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

With the wide applications of digital technology in dentistry, research to establish a completely digital workflow for the fabrication of complete dentures has been underway since 1994 [1]. Currently, complete dentures are being fabricated using computer-aided design and computer-aided manufacturing (CAD-CAM) via milling or rapid prototyping methods. The clinical feasibility of these dentures has been proven [2–5]. Additionally, various advantages have been reported, such as better fit, retention, easy reproduction, and decreased manipulation [6,7]. However, fabricating metal-reinforced complete dentures using the digital technique is different, as these dentures are fabricated using at least two other materials.

Metal-reinforced complete dentures are associated with improved retention, reduced probability of fracture, and greater patient satisfaction in terms of comfort and pronunciation compared to conventional resin-based complete dentures [8]. Metal denture bases, fabricated using selective laser melting, milling, stereolithography apparatus, or digital light processing techniques, have been found to be feasible for clinical use [9,10]. Digital fabrication of metal-reinforced complete denture bases using the current technology is difficult.

To overcome this limitation, considerable research has been conducted. Oh et al. [11] introduced a method to combine the digital technique and conventional flask procedure to fabricate a removable partial denture. Moreover, Park et al. [12] fabricated a digital denture by bonding the functional cusps of artificial teeth manufactured using a 3D metal printer with the resin denture base. Nevertheless, a fully digital workflow for the fabrication of metal-reinforced complete dentures, preserving the basic structure, has not been developed. Hence, in this technical article, we report a novel method to add a metal framework structure to the complete denture milling procedure. A geometry guide, an indentation for the complete denture, was designed to determine and replicate the correct positions of the artificial teeth and metal framework.

2. Materials and Methods

2.1. Technical Note: Designing Process on the CAD Software

1. Digitize the master casts and the occlusal relation record by scanning using a desktop scanner (T500; Medit, Seoul, Korea);
2. Design the metal frameworks with the attachments and complete dentures for both arches separately in the CAD software (Exocad DentalCAD 2.4 Plovdiv; Exocad GmbH, Darmstadt, Germany) using the acquired data;
3. Replace the denture base with the corresponding tissue surface of the dental cast in the CAD software (Meshmixer; Autodesk, Inc., San Rafael, CA, USA) in the imported standard tessellation language (STL) files. Combine the denture and designed metal framework (Figure 1);

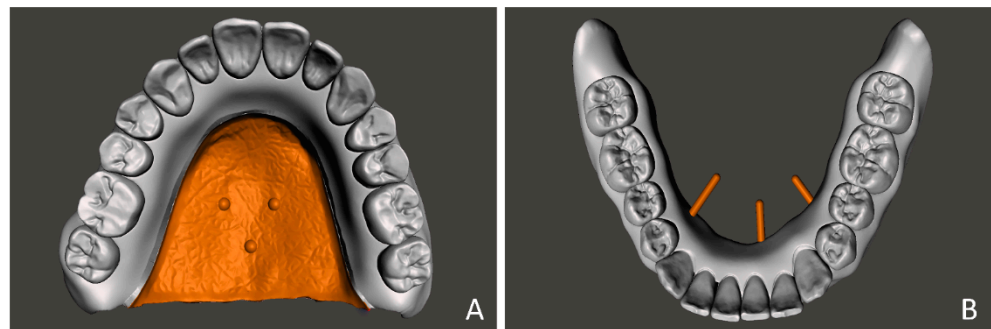


Figure 1. Design of metal-reinforced complete dentures. Yellow portion represents the metal framework with the attachments. (A) Maxillary denture. (B) Mandibular denture.

4. Extrude the metal portion by 1 mm and export the modified metal-reinforced complete denture data;
5. Design the geometry guide for the metal-reinforced complete dentures using the “Boolean command” in the CAD software (Meshmixer; Autodesk, Inc., San Rafael, CA, USA) that contains the negative impression of a part of the metal-reinforced complete dentures (Figure 2);

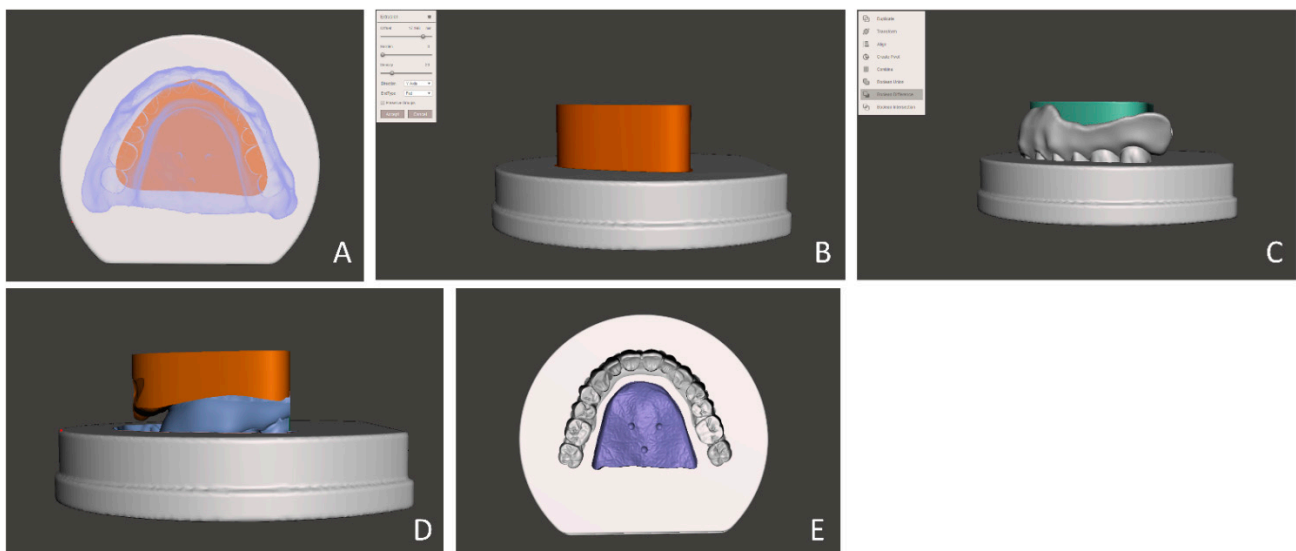


Figure 2. Design process for the primary geometry guide of the maxillary denture. (A) Selecting the region covering the metal base and artificial teeth on a base structure. (B) Extruding the selected area in a vertical direction. (C) Applying “Boolean Difference” command between the base structure and denture to eliminate the area occupied by the denture. (D) Discarding the upper structure after the command is performed. (E) Inspecting the primary geometry guide.

- Modify the geometry guide design by discarding the labial, mesial, and distal surfaces of the teeth sockets (Figure 3). Export the STL file of the geometry guide.

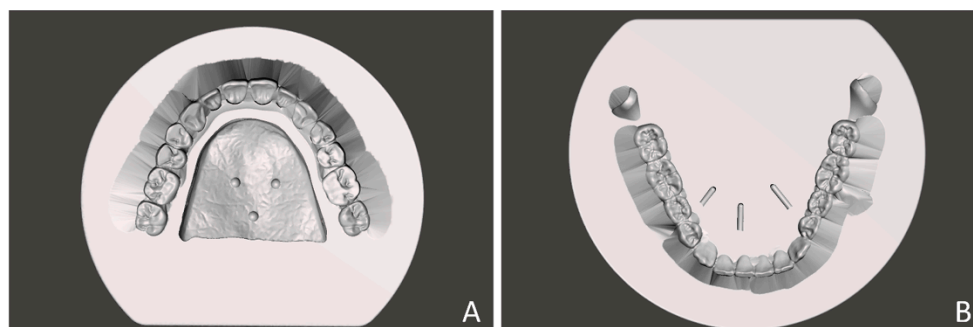


Figure 3. Design of the geometry guides. (A) Maxillary geometry guide. (B) Mandibular geometry guide.

2.2. Technical Note: Fabrication of Dental Prosthesis

- Mill the artificial teeth from a double cross-linked resin disk (SR Vivodent CAD; Ivoclar Vivadent AG, Schaan, Liechtenstein). Fabricate the metal framework using the lost-wax casting technique after milling the wax pattern (Mazic Wax; VERICOM Co., Ltd., Chuncheon, Korea);
- Mill the geometry guide from the gypsum poured on the metal holder attached to the milling machine. Mill the designs in a milling machine (Rainbow Mill-Zr 2nd; Dentium Co., Ltd., Seoul, Korea) after calculating the toolpath;
- Bond the artificial teeth and the metal framework to the geometry guide (Figure 4);

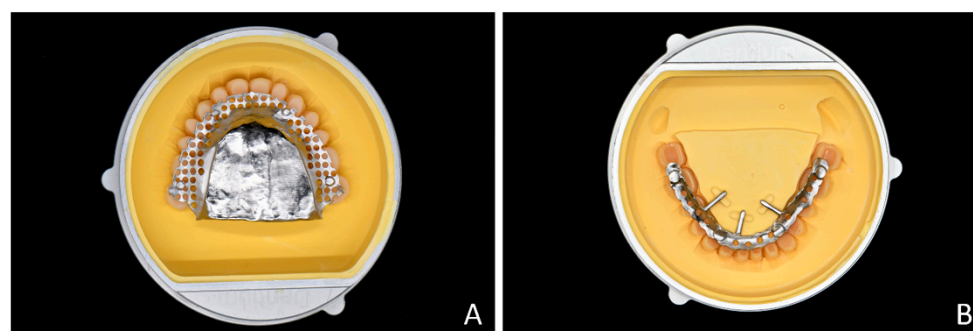


Figure 4. Artificial teeth and metal framework bonded to the geometry guide within the metal holder. (A) Maxillary structure. (B) Mandibular structure.

- Pour autopolymerizing resin (Retec PRESS LT; Retec Kunststofftechnik GmbH, Rosbach, Germany) to fill the space above the geometry guide. Cure the resin using a dental polymerization unit (Palamat elite; Kulzer GmbH, Hanau, Germany) as per the manufacturer's instructions;
- Set the metal holder that contains the geometry guide, artificial teeth, and metal framework in the milling machine. Mill the denture according to the acquired modified denture data, in which the metal portion is extruded by 1 mm (Figure 5);
- Remove the attachments, gypsum, and resin covering the metal base. Finish the prosthesis by polishing (Figure 6).

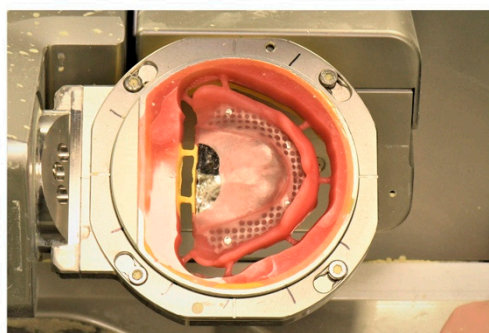


Figure 5. Fabrication of metal-reinforced complete denture extruded by 1 mm.



Figure 6. Final prosthesis after polishing. (A) Maxillary denture. (B) Mandibular denture. (C) Intraoral photograph.

3. Discussion

In this technique, the denture base designed in the CAD software was first replaced with the corresponding tissue surface of the dental cast to obtain an ideal denture border and enhance the retention and stability of the denture [13]. The geometry guide, specially designed through this technique, functions as a connector to maintain parts of the denture in the correct position. To maintain a stable position, three hemispheres were attached to the maxillary flat metal base and three bars were attached to the mandibular metal framework. The customized design of the artificial teeth ensures ideal teeth arrangement and interocclusal relationship as per individual requirements. In addition, milling individual teeth from a double cross-linked resin block according to the CAD data provides adequate esthetics and accuracy.

Oh et al. [11] utilized the CAD-CAM technique to mill the denture base and artificial teeth from a wax disk. After the placement of the wax structure and metal framework, conventional flasking and injection molding were performed. Thus, the possibility of inevitable errors in these conventional flasking and packing procedures cannot be excluded. However, in our technique, unexpected errors can be eliminated as the conventional manual procedures were replaced by the geometry guide and subtractive milling process. Additionally, polymerization shrinkage of the base resin will not affect the fit of the denture, as the resin is cured before the milling procedure [7,14].

The limitation of this method is that additional efforts are required compared to the commonly used commercial techniques, due to the lack of automatic function in the CAD software for replacing the palatal part of the denture base with the metal base. To protect the milling burs from breakage while in contact with the metal base, the corresponding region should be extruded by 1 mm while designing. Thin remnant parts of pink resin and gypsum should be removed after the milling process.

With the geometry guide providing support and stability for all components in the right position, this technique can be applied in edentulous cases. Furthermore, additional clinical studies are needed to comprehensively evaluate the metal-reinforced complete den-

tures fabricated using this method. In addition, research can be conducted for the adaption of this technique in the manufacturing of removable partial dentures and overdentures.

4. Conclusions

This technique enables the fabrication of metal-reinforced complete dentures via the CAD-CAM technique using a specially designed geometry guide. The digital technique offers the possibility of fabricating dental prostheses using more than 2–3 materials.

Author Contributions: Conceptualization, X.-Y.P. and J.-M.P.; methodology, X.-Y.P. and J.-M.P.; software, X.-Y.P.; validation, X.-Y.P., J.-S.S. and J.-M.P.; formal analysis, J.-M.P.; investigation, X.-Y.P.; resources, J.-M.P.; writing—original draft preparation, X.-Y.P.; writing—review and editing, X.-Y.P. and J.-M.P.; visualization, X.-Y.P. and J.-M.P.; supervision, J.-M.P.; project administration, J.-M.P.; and funding acquisition, J.-S.S. and J.-M.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Korea Medical Device Development Fund grant funded by the Korea government, Grant number: 202011A02.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors thank Jeon, J. of the Central Laboratory, Yonsei University for the technical assistance with CAD and laboratory procedures.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Maeda, Y.; Minoura, M.; Tsutsumi, S.; Okada, M.; Nokubi, T. A CAD/CAM system for removable denture. Part I: Fabrication of complete dentures. *Int. J. Prosthodont.* **1994**, *7*, 17–21. [[PubMed](#)]
2. Wang, C.; Shi, Y.F.; Xie, P.J.; Wu, J.H. Accuracy of digital complete dentures: A systematic review of in vitro studies. *J. Prosthet. Dent.* **2021**, *125*, 249–256. [[CrossRef](#)] [[PubMed](#)]
3. Hwang, H.J.; Lee, S.J.; Park, E.J.; Yoon, H.I. Assessment of the trueness and tissue surface adaptation of CAD-CAM maxillary denture bases manufactured using digital light processing. *J. Prosthet. Dent.* **2019**, *121*, 110–117. [[CrossRef](#)] [[PubMed](#)]
4. Yoon, H.I.; Hwang, H.J.; Ohkubo, C.; Han, J.S.; Park, E.J. Evaluation of the trueness and tissue surface adaptation of CAD-CAM mandibular denture bases manufactured using digital light processing. *J. Prosthet. Dent.* **2018**, *120*, 919–926. [[CrossRef](#)] [[PubMed](#)]
5. Yoon, S.N.; Oh, K.C.; Lee, S.J.; Han, J.S.; Yoon, H.I. Tissue surface adaptation of CAD-CAM maxillary and mandibular complete denture bases manufactured by digital light processing: A clinical study. *J. Prosthet. Dent.* **2020**, *124*, 682–689. [[CrossRef](#)] [[PubMed](#)]
6. AlHelal, A.; AlRumaih, H.S.; Kattadiyil, M.T.; Baba, N.Z.; Goodacre, C.J. Comparison of retention between maxillary milled and conventional denture bases: A clinical study. *J. Prosthet. Dent.* **2017**, *117*, 233–238. [[CrossRef](#)] [[PubMed](#)]
7. Bilgin, M.S.; Baytaroglu, E.N.; Erdem, A.; Dilber, E. A review of computer-aided design/computer-aided manufacture techniques for removable denture fabrication. *Eur. J. Dent.* **2016**, *10*, 286–291. [[CrossRef](#)] [[PubMed](#)]
8. Belfiglio, E.J. Using metal bases in making complete dentures. *J. Prosthet. Dent.* **1987**, *58*, 314. [[CrossRef](#)]
9. Ye, Y.; Jiao, T.; Zhu, J.; Sun, J. Adaptation and micro-structure of Co-Cr alloy maxillary complete denture base plates fabricated by selective laser melting technique. *Lasers Med. Sci.* **2018**, *33*, 1025–1030. [[CrossRef](#)] [[PubMed](#)]
10. You, S.G.; You, S.M.; Kang, S.Y.; Bae, S.Y.; Kim, J.H. Evaluation of the adaptation of complete denture metal bases fabricated with dental CAD-CAM systems: An in vitro study. *J. Prosthet. Dent.* **2021**, *125*, 479–485. [[CrossRef](#)] [[PubMed](#)]
11. Oh, K.C.; Jeon, J.; Kim, J.H. Fabrication of a removable partial denture combining conventional and digital techniques. *J. Prosthet. Dent.* **2021**, *125*, 588–591. [[CrossRef](#)] [[PubMed](#)]
12. Park, C.; Kee, W.; Lim, H.P.; Park, S.W. Combining 3D-printed metal and resin for digitally fabricated dentures: A dental technique. *J. Prosthet. Dent.* **2020**, *123*, 389–392. [[CrossRef](#)] [[PubMed](#)]
13. Lee, J.J.; Kim, D.H.; Noh, K. A technique for transferring the contours of a functional impression to the polished surfaces of digitally fabricated removable complete dentures. *J. Prosthet. Dent.* **2020**, *124*, 153–156. [[CrossRef](#)] [[PubMed](#)]
14. Bidra, A.S.; Taylor, T.D.; Agar, J.R. Computer-aided technology for fabricating complete dentures: Systematic review of historical background, current status, and future perspectives. *J. Prosthet. Dent.* **2013**, *109*, 361–366. [[CrossRef](#)]