Digital Gothic Arch Tracing Device with Open-Source Software for CAD/CAM Denture Fabrication

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ABSTRACT
Digital or CAD/CAM workflows and protocols are being increasingly utilized because of their improved efficiency and reproducibility. For the fabrication of complete dentures, digital workflows can reduce treatment time and clinical visits while enhancing the reliability and reproducibility of the laboratory phase and materials. However, establishing centric relation (CR) and vertical dimension of occlusion (VDO) in a reproducible way is still a challenging step for complete denture fabrication in both analog and digital workflows. This clinical report describes a digital workflow utilizing an individualized gothic arch tracing device (GATD) using open-source software for the fabrication of complete dentures. With this workflow, clinicians can offer customized solutions according to patient rehabilitation, with good reproducibility using gothic arch tracing to be implemented in the digital workflow. Int J Prosthodont 2022. doi: 10.11607/ijp.8251

INTRODUCTION
Effective transfer of casts and mandibular movements to articulators is important to the fabrication of complete dentures. A reliable occlusion with an understanding of jaw movements, rest position and centric relation and vertical dimension of occlusion is of great importance.

Recommendations for the recording of centric relation (CR) and appropriate vertical dimension of occlusion (VDO) have included utilization of a central load bearing device (Gothic arch tracing), closest speaking space and rest position and phonetics. While clinicians often utilize multiple methods, the Gothic arch tracing has been used as part of digital workflows for fabrication...
of complete denture\textsuperscript{11-13}. These workflows include computer aided design (CAD) and computer aided manufacturing (CAM) with additive (AM) and subtractive (SM) manufacturing\textsuperscript{11-16}.

AM technology can be cost effective and may be utilized for workflows that do not require high material strength, such as trial dentures and record bases with occlusal rims for jaw relation records\textsuperscript{11,12,14}. This article describes a workflow utilizing an individualized gothic arch tracing device (GATD) with a CAD-CAM workflow using an open-source (Mesh-Mixer) software. The CAM stage has been completed with AM using Digital Light Processing (DLP) technology.

TECHNIQUE

1. Obtain the patient’s informed consent to treatment.

2. Select the treatment workflow or pathway (digital, analog or combination) (Fig. 1, 2)

3. Obtain intraoral impression using alternative methods as;
   a. A digital workflow with an intraoral scanner (Virtuo Vivo; Institut Straumann AG, Basel, Switzerland) to obtain a digital file (STL) or
   b. A combined workflow using stock low temperature edentulous trays (Zest Dental Solutions, Carlsbad, California, USA), border molding and polyvinyl siloxane impression material (Examix NDS Monophase, GC America Inc, Alsip, Illinois, USA) to obtain an analog impression which is then scanned to produce a digital file (STL) (Fig. 3 A, B, C).

4. Import the digital (STL) files into Mesh Mixer Software (Autodesk, California, USA).

5. Align the files in CR at an arbitrary VDO. This process will necessitate chairside adjustment at a later stage (Fig. 4).
6. Design a 2 mm thick record base for each arch to obtain a digital solid file (Fig. 5 A, B).

7. Insert the plate parallel to the mandibular residual ridge (Fig. 5 C).

8. Add pyramidal support on palate area and cylinder shape on top of the pyramidal support to be later modified and act as a “stylus tracing” for the maxillary record base (Fig. 6 A).

Add plate design to act as a “tracing plate” on top of the occlusal rim design combined with the record base of the mandibular arch (Fig. 6 B). Files are obtained for the final designs of both maxillary and mandibular modified base solids (Fig. 6 C).

9. Orientation of the maxillary and mandibular files is reviewed, ensuring the adequate length of the maxillary pin to facilitate reduction adjustments to be made chairside to reach the desired vertical dimension of occlusion for the obtaining of the CR record (Fig. 6 C).

10. Print final STL file(s) using clear resin material (Surgical Guide Clear Resin, Straumann LLC USA, Andover Massachusetts, USA) and a DLP printer (P30 Printer, Straumann USA LLC, Andover Massachusetts, USA) (Fig. 7 A, B, C).

11. The contour and form of the printed baseplates is modified as required using baseplate wax. The cylinder on the maxillary baseplate is shaped to a point and the length adjusted to ensure contact with the mandibular plate at the proposed vertical dimension of occlusion. The tracing is then made (Fig 8 A, B).

12. Use a round bur to make an indentation in the mandibular plate to provide a repeatable locked location for the maxillary pin at the desired VDO and CR. The interocclusal record is then made using PVS bite registration material (ExaBite II NDS, GC America Inc, Alsip, Illinois, USA) (Fig. 8 B, C).
13. After records are obtained, the orientation of the arches can be transferred to CAD software (Dental Systems, 3Shape, Copenhagen, Denmark) (Fig. 9).

14. Trial dentures can then be designed and fabricated using subtractive manufacturing (DWX52 milling unit, Roland DGA, Irvine, California, USA) and Ivotion Denture (Ivoclar Vivadent, Buffalo, New York, USA) (Fig. 10). Subsequent to patient approval and adjustment definitive prostheses can be completed.

DISCUSSION

Denture fabrication utilizing Gothic Arch Tracings was evaluated by Gysi and different variations and concepts have subsequently been studied\textsuperscript{4,8-10}. Gysi’s original design\textsuperscript{1}, places the pin on maxillary rim while the tracing plate is located on the mandibular. Gerber\textsuperscript{4} and El-Aramany\textsuperscript{8} followed the same principles and locations while Trapazano\textsuperscript{9} and Payne\textsuperscript{10} preferred the opposite, with the tracing plate located on the maxillary rim and pin located on the mandibular.

In the digital design workflow presented, it is possible to individualize the pin and plate location and extension of the baseplates according to the clinician’s preference (Table- 1). Commercially available stock trays and gothic arch tracing workflows can be challenging due to size and anatomic limitations (such as presence of tori) and interfering contacts between the maxillary and mandibular baseplates during articulation. A digital workflow allows the stabilized record bases to be located mostly in the anterior area, while capturing the whole arch to facilitate alignment with the GAT records to obtain jaw relations.
There remains however a learning curve in capturing the baseline files to start the design phase, however this workflow is beneficial for application of conventional prosthodontics principles in fabrication of CAD-CAM digital complete dentures. Regardless of workflow chosen the adaptation and stability of the bases is important during the tracing process. The technique presented allows for not only individual base adaptation with improved stability during tracing and jaw movement recordings, but also the possibility of simple modification.

The printer used to present this technique was a DLP technology which has the advantages of cost efficiency and rapid manufacturing. Although other AM technologies such as Stereolithography (SLA) and Continuous Liquid Interface Production (CLIP) or SM method can also be used; DLP provides faster manufacturing compared to other AM and SM methods. Depending on the clinical and laboratory setting; the choice of manufacturing technology, as well as in-house or out-source manufacturing options, can be changed for this technique. This broadens the applicability of this technique in different settings according to clinicians' preferences. By incorporating open-source software and in-house AM, solutions can be customized according to patient rehabilitation with complete dentures with an edentulous state or with present terminal dentition. Different clinical scenarios would be required to apply this technique broadening its clinical benefits and reducing chair time. It allows custom record base and rim fabrication that will reduce the necessity of chair time and improve efficiency as a result. Custom size tracing plate and stylus can be designed and manufactured to overcome challenges for rehabilitation of patients with special needs such as micrognathia, limited VDO and reduced mouth opening. Although the technique might not reduce the number of clinical visits compared to digital denture workflow; it has main advantages of
reduced chair-side adjustments, individualized custom record base design with gothic arch tracing parts as well as ease of adjustments.

**SUMMARY**

This article describes a workflow incorporating an individualized digital gothic arch tracing device applicable for obtaining CR and VDO records in partially or completely edentulous patients, and for the digital design and fabrication of complete dentures. Advantages include the use of free and simple-to-use software which allows the saving and reuse of files after adaptation to other digital formats. Digital technology can also aid the clinician in using conventional methods to obtain more reproducible CR and VDO records.

**REFERENCES**

5. Gysi A. Practical application of research results in denture construction. J Am Dent Assoc. 1929 Feb; 16(2): 199-223


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<td>Digital IOS Impression</td>
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Table- 1. General outline of the workflow sequence.

FIGURE LEGENDS

Figure 1. Photos of maxillary arch initial patient presentation.

Figure 2. Photos of mandibular arch initial patient presentation.

Figure 3 A. Preliminary Intra Oral Scan of Patient’s Maxillary Arch

Figure 3 B. Conventional Impression with customized stock tray with green compound and borders recorded with medium body polyvinyl-siloxane PVS impression material relined with light body.
Figure 3 C. Laboratory Scan of the PVS impression converted in MeshMixer Software to obtain positive digital file.

Figure 4. Alignment of the files in arbitrary VDO

Figure 5 A. Digital solid file for maxillary record base (2 mm thickness)

Figure 5 B. Digital solid file for mandibular record base (2 mm thickness)

Figure 5 C. Inserted plate parallel to the mandibular residual ridge

Figure 6 A, B, C. Individualized Digital GATD design in Mesh Mixer software.

Figure 7 A, B, C. Individualized Digital GATD 3D printed parts.

Figure 8 A. GAT record of centric relation marked on plate with round bur.

Figure 8 B. GAT record of centric relation in correct vertical dimension of occlusion.

Figure 8 C. Centric relation in correct vertical dimension of occlusion with PVS bite registration.

Figure 9. Digital design of complete dentures.

Figure 10. Extra-oral photo at delivery day of digital complete denture.