

DENTAL TECHNIQUE

CAD-CAM milled dentures: The Geneva protocols for digital dentures



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Initial attempts to fabricate complete dentures (CDs) with computer-aided design and computer-aided manufacturing (CAD-CAM) technology began in the 1990s¹⁻³; since then, there has been an evolution of the techniques and the associated technologies.⁴⁻¹⁰ The infusion of CAD-CAM techniques into CD fabrication methods has led to the evolution of modified and easier clinical protocols,^{11,12} the use of materials with improved properties,¹³⁻¹⁸ better fit and retention of the CDs,¹⁹⁻²⁹ reduction in the chairside and laboratory times,^{12,30-32} and overall reduction in clinical and laboratory costs.³⁰ High patient and clinician satisfaction with CAD-CAM CDs has been reported.³³⁻³⁵

The CAD-CAM clinical protocols used are modified versions of the conventional clinical steps followed during the fabrication of CDs. Although promoted by various manufacturers as being more straightforward and easier, the CAD-CAM protocols require extended time to learn the procedure and to digitize the analog clinical procedures.^{34,36} Elaborate instruments, depending on the manufacturing system, are often required to carry out these novel clinical protocols.

ABSTRACT

This technical report describes 2 workflows for fabricating computer-aided design and computer-aided manufacturing (CAD-CAM) milled complete dentures (CDs). The first technique illustrates a manufacturer-independent workflow using conventional clinical steps and a novel, custom modified tray to successfully fabricate CAD-CAM milled CDs. The second technique highlights a nearly digital workflow for manufacturing a CAD-CAM milled CD and a milled resin interim removable partial denture. (*J Prosthet Dent* 2020;123:27-37)

Despite the numerous advantages, the currently practiced CAD-CAM methods for CDs still have limitations.^{31,37-39} Nevertheless, these protocols are rapidly evolving, and newer alternative protocols incorporating the conventional clinical steps in a manner best suited to satisfying all the required criteria for the successful fabrication of CAD-CAM CDs have been developed.^{11,40} The newer protocols continue to use analog clinical steps that are then digitized to accomplish the prosthesis. Attempts to use optical scans combined with conventional clinical procedures have demonstrated some success⁴¹⁻⁴³; however, a completely digital clinical workflow for the fabrication of CDs has yet to be demonstrated.

The purpose of this technical report was to demonstrate an alternative, manufacturer-independent, clinical workflow that has been routinely used by the Clinic for Gerodontology and Removable Prosthodontics

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Figure 1. Initial situation. A, Completely edentulous maxilla. B, Completely edentulous mandible. C, Measuring anterior height of existing denture.

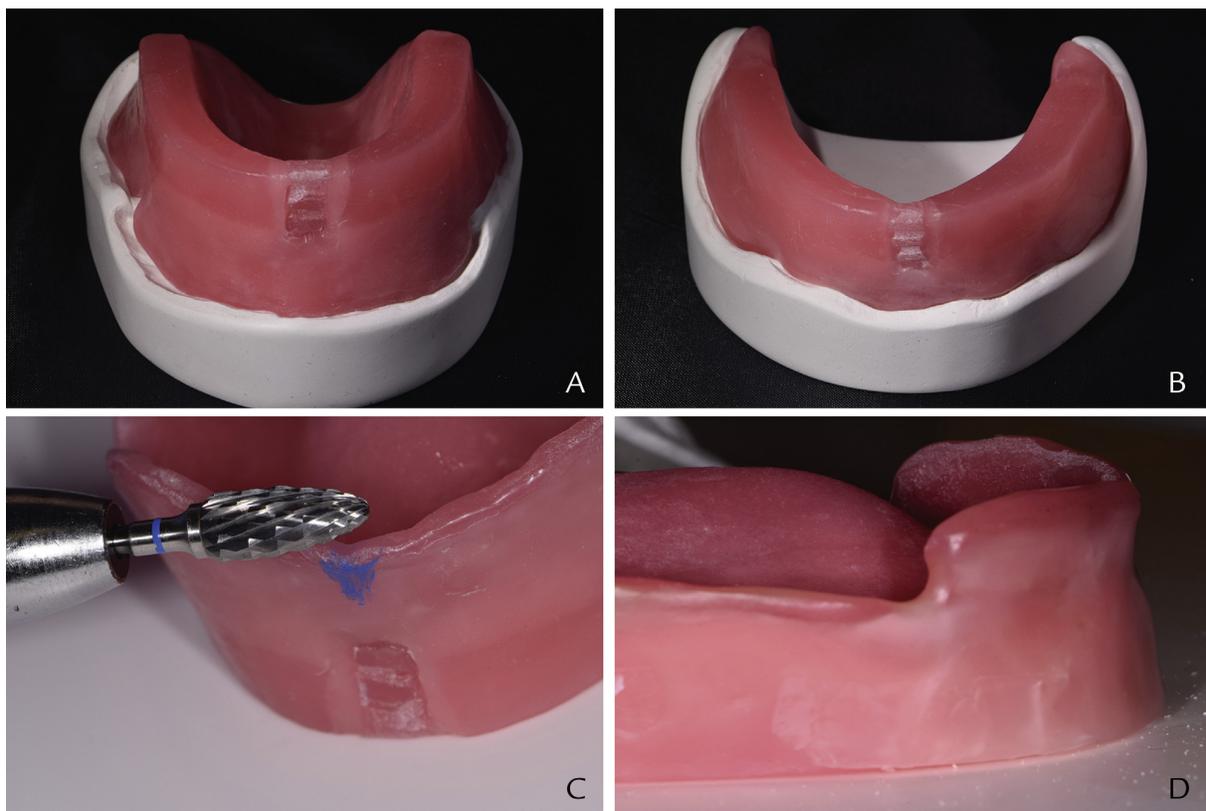


Figure 2. Modified custom trays. A, Maxillary custom tray with occlusal rim and integrated handle. B, Mandibular custom tray with occlusal rim and integrated handle. C, Adjusting custom tray. D, Adding wax over resin tray handle to establish lip support.

at the University of Geneva for manufacturing CAD-CAM milled CDs. This report further aimed to showcase a nearly digital workflow for fabricating a clinically acceptable CAD-CAM fully milled maxillary CD and a fully milled mandibular resin removable partial denture (RPD), without the use of any analog clinical procedures.

TECHNIQUE 1: THE GENEVA PROTOCOL

This manufacturer-independent alternative clinical technique uses a modified clinical protocol to fabricate

maxillary and mandibular CDs in just 3 clinical visits, by using a CAD-CAM milling technique. The various clinical procedures in the respective visits are described below:

Visit 1:

1. Make preliminary impressions using irreversible hydrocolloid impression material (Blueprint; Dentsply Sirona) and stock impression trays (Schreinemakers).
2. Measure the anterior and posterior heights of the existing dentures, if present (Fig. 1), by using

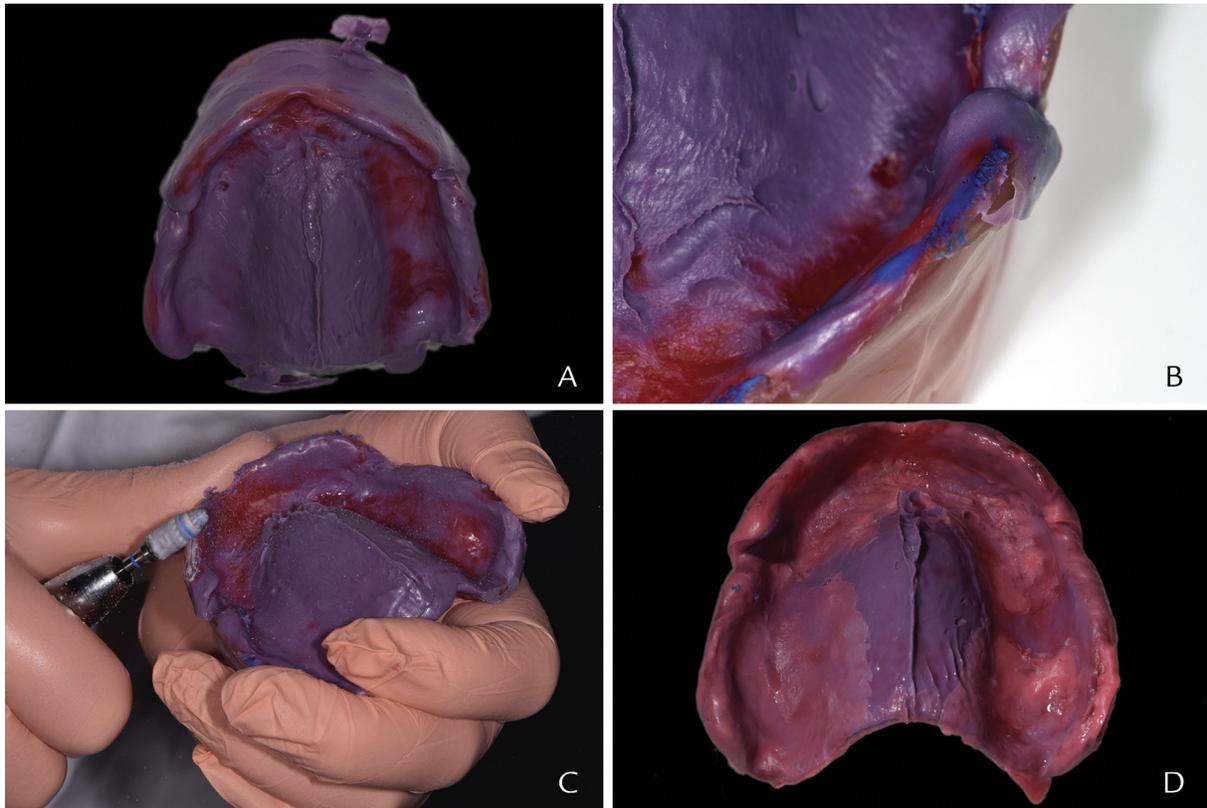


Figure 3. Single-step border molding and definitive impressions. A, Initial single-step border molding for maxilla. B, Tray exposures detected and marked. C, Correcting tray exposures. D, Completed definitive impression of intaglio surface.

calipers (Inox; KNUTH GmbH) or a Gutowsky gauge (Mitutoyo Inc) and the upper lip length by using a Papillameter (AvaDent; Global Dental Science Europe BV).

3. Pour dental stone in casts (Elite; Zhermack S.p.A.) and fabricate modified custom trays by using light-polymerizing polymethylmethacrylate resin (Profibase; VOCO GmbH) with integrated occlusal wax rims (Wax bite rims; Erkodent Erich Kopp GmbH). Position a small tray handle in the anterior part (approximately the width of 2 maxillary central incisors) as seen in [Figure 2A, B](#). Fabricate the wax rims to the measured height of the existing denture and/or the upper lip length.

Visit 2:

4. Verify the fit of the modified custom trays in the mouth and make corrections if necessary ([Fig. 2C, D](#)). Evaluate the height of the maxillary tray handle and the occlusal rim; arbitrarily approximate it to the length of the upper lip. Then, verify the mandibular tray in the same

manner and restrict the mandibular tray height to the lower lip.

5. Border molding in a single step ([Fig. 3A](#)) performed by using a medium-viscosity elastomeric impression material (Impregum; 3M ESPE). Check for any tray exposures and trim the exposed regions of the impression ([Fig. 3B, C](#)); repeat the procedure until border molding is complete and satisfactory.
6. Make the definitive impressions ([Fig. 3D](#)) by using a low-viscosity elastomeric impression material (Impregum; 3M ESPE).
7. Establish the labial fullness, occlusal plane, and occlusal vertical dimension and record the arbitrary centric jaw relation (CR). Then, verify the CR with gothic arch tracing by using intraoral tracers ([Fig. 4A-C](#)). The gothic arch tracing is an essential step for fragile or functionally impaired edentulous patients. It can be omitted at the discretion of the clinician in younger edentulous patients.
8. Mark the reference lines (midline and canine line) on the wax rims and register the CR using an

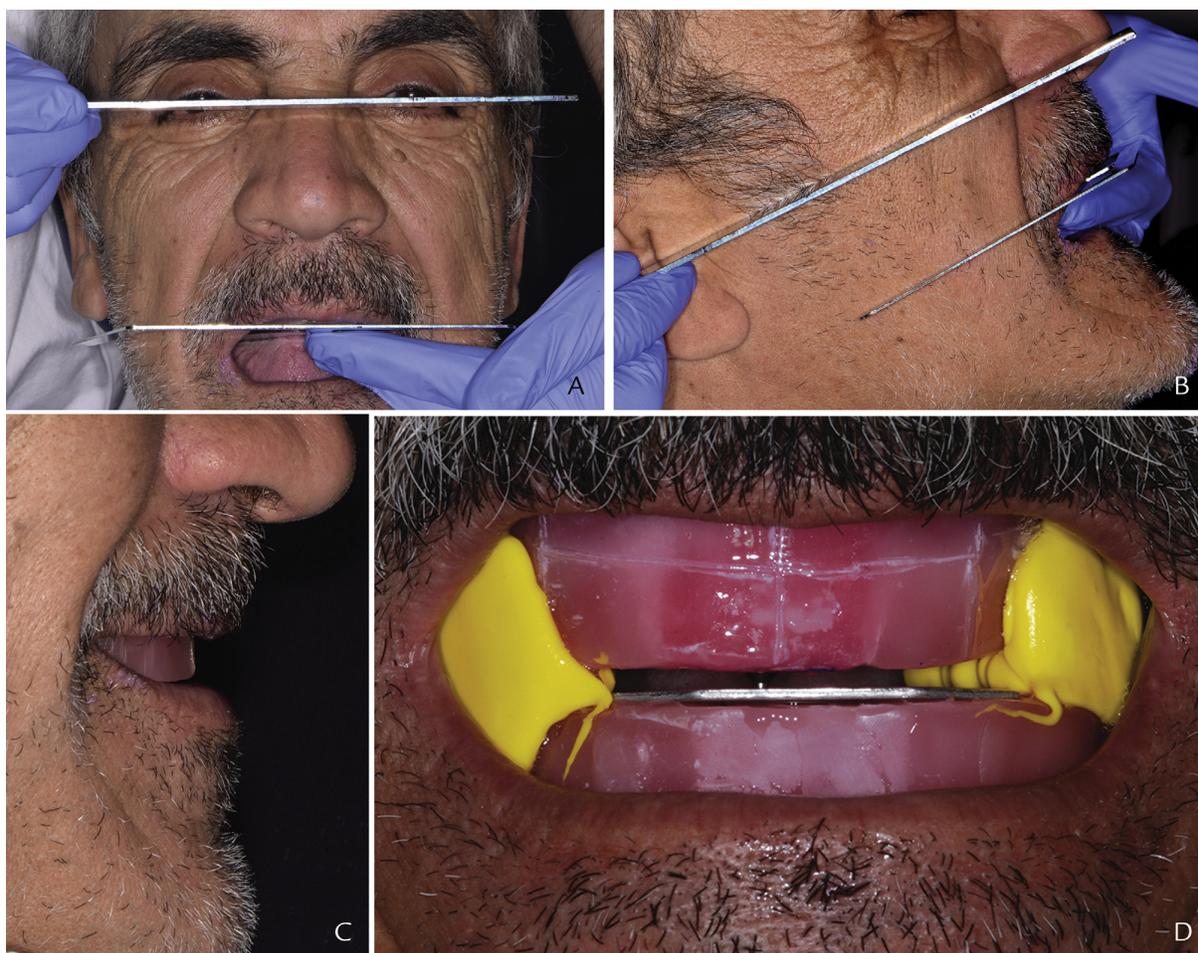


Figure 4. Jaw relations. A, Establishing anterior plane of occlusion with Fox plane. B, Establishing posterior occlusal plane. C, Verifying labial fullness, support, and esthetics. D, Verifying centric relation using gothic arch tracing.

elastomeric occlusal registration material (Jet Bite; Coltène). Note the shape, size, form, and shade of the tooth. Obtain relevant photographs.

9. Scan the block comprising the definitive impressions and the jaw-relation records and store the resultant scan data in standard tessellation language (STL) file format. Transfer the STL files, photographs, and laboratory work authorization form with specific instructions to the digital denture laboratory through a connection software program (AvaDent Connect; Global Dental Science Europe BV).
10. Import the scan data into a design software program (AvaDent Design; Global Dental Science Europe BV), align the scans, and establish the peripheral boundaries (Fig. 5A-C).
11. Generate a virtual tooth arrangement for a digital preview (Fig. 5D). Evaluate the digital preview and modify if necessary.

12. Transfer data to a CAM software program, mill the prostheses, and finish and polish the dentures.

Visit 3:

13. Inspect the received dentures for manufacturing defects or flaws (Fig. 6A).
14. Deliver the dentures after clinical adjustments (Fig. 6B-D); give postinsertion instructions along with denture hygiene and maintenance information to the patient.

TECHNIQUE 2: A NEARLY DIGITAL WORKFLOW FOR FABRICATING CAD-CAM CDS

Construction of a CAD-CAM milled maxillary CD and a CAD-CAM milled mandibular resin interim RPD by using a nearly digital workflow is presented.

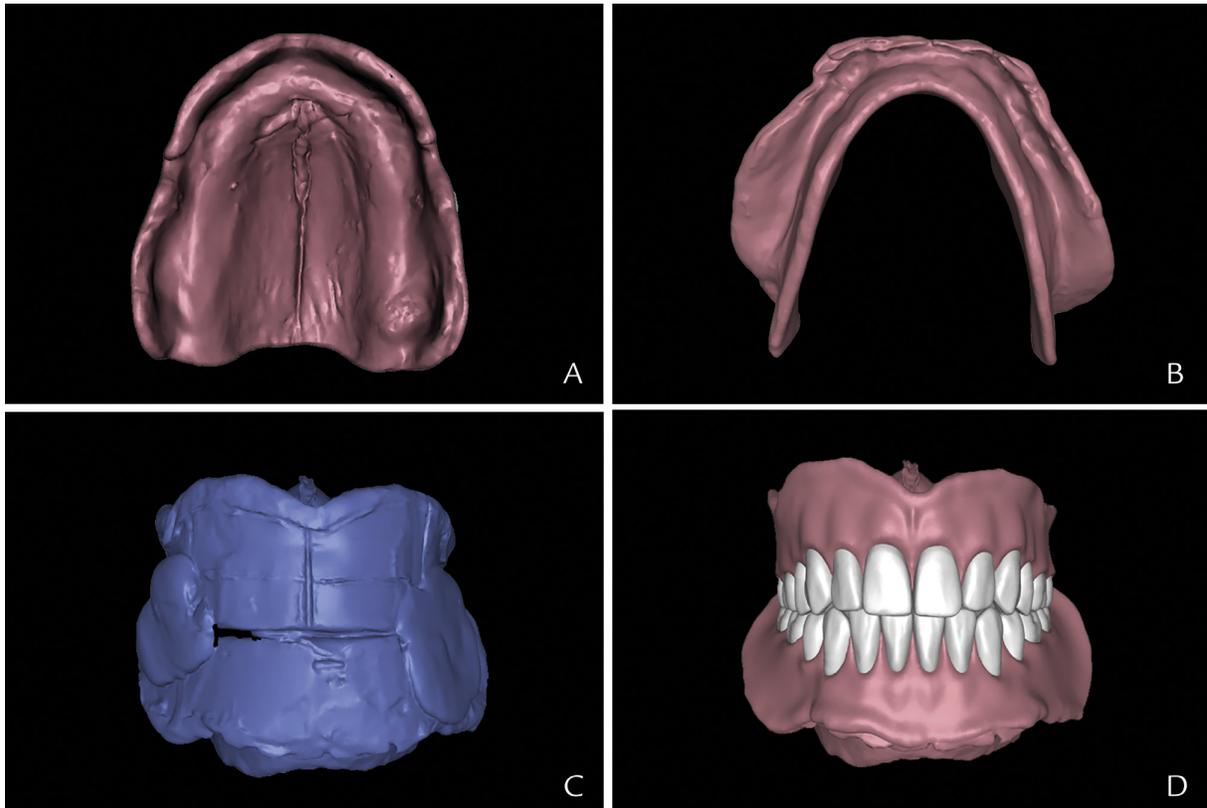


Figure 5. Digitizing clinical records and virtual tooth arrangement. A, Scanned maxillary edentulous impression. B, Scanned mandibular impression. C, Scanned jaw relation record. D, Digital preview of virtual tooth arrangement.

Visit 1:

1. Scan the patient's completely edentulous maxillary and partially edentulous mandibular arches by using an intraoral scanner (3Shape TRIOS; 3Shape A/S) (Fig. 7). During scanning, approximate the peripheries and retract the soft tissues and frenal attachments with the thumb and index finger. Obtain assistance from a second operator during the scanning of the mandibular arch.
2. Measure the lip length by using a Papillameter (AvaDent; Global Dental Science Europe BV). Verify the lip length measurement in different views; exercise care to maintain the labial fullness while establishing the lip length (Fig. 8).
3. Measure the vertical dimension of rest as a first step.
4. Register arbitrary vertical and horizontal jaw relations using a putty polyvinyl siloxane elastomeric material (President; Coltène).
5. Mix and knead the putty material into a ball. Pre-shape and place the putty ball in between the patient's jaws and request the patient to gently close down to the desired vertical dimension of occlusion (VDO) (Fig. 9). Use any bimaxillary support for the putty material if this is easier to handle, for example, the centric tray (Ivoclar Vivadent AG).
6. Establish the labial fullness and support by gently molding the lips on the putty while the patient maintains the VDO position. Scan this putty record by using a laboratory scanner (IScan D103i; Imetric 3D SA). Record the shape, size, form, and shade of the tooth. Obtain relevant photographs.
7. Convert all scans to STL files and import them into a third-party 3D alignment software program (GOM Inspect; GOM GmbH) to align the scans (Fig. 10).
8. Transfer the aligned scans with the necessary patient information and photographs to the digital dental laboratory through the connect software (AvaDent; Global Dental Science Europe BV).
9. Using the scans, fabricate the record bases (Wagner try-in plates [WTIs]; Global Dental Science Europe BV)⁴² to reconfirm the VDO, tooth positions, and CR. The maxillary WTI comprised a milled polymethylmethacrylate resin record base with the anterior tooth arrangement in wax and



Figure 6. Definitive result. A, CAD-CAM milled complete dentures. B, Intraoral retracted frontal view of inserted dentures. C, Frontal view of smile with dentures in place. D, Profile view of smile with dentures in place. CAD-CAM, computer-aided design and computer-aided manufacturing.

molars (Fig. 11A). The mandibular milled record base comprised wax blocks on the posterior segments and an anterior tooth arrangement in wax (Fig. 11B).

Visit 2:

10. Adjust the WTIs and register definitive jaw relations (Fig. 11C).
11. Scan the confirmed jaw relations by using the intraoral scanner (Fig. 11D) and transfer the scans to the digital dental laboratory.
12. Generate the virtual tooth arrangement for a digital preview (Fig. 12).
13. Evaluate, modify, and validate the preview and then fabricate the prostheses. Finish and polish the CAD-CAM CDs and RPDs.

Visit 3:

14. Inspect and evaluate the quality of the received dentures. Insert the dentures after clinical adjustments (Fig. 13). Give instructions concerning denture management and hygiene care and specify maintenance requirements.

DISCUSSION

The first protocol combined the benefits of traditional clinical procedures and the use of conventional materials and instruments for capturing the clinical records. No elaborate armamentarium or added investment was required to practice this protocol. With the aid of its modified custom tray, all necessary clinical records

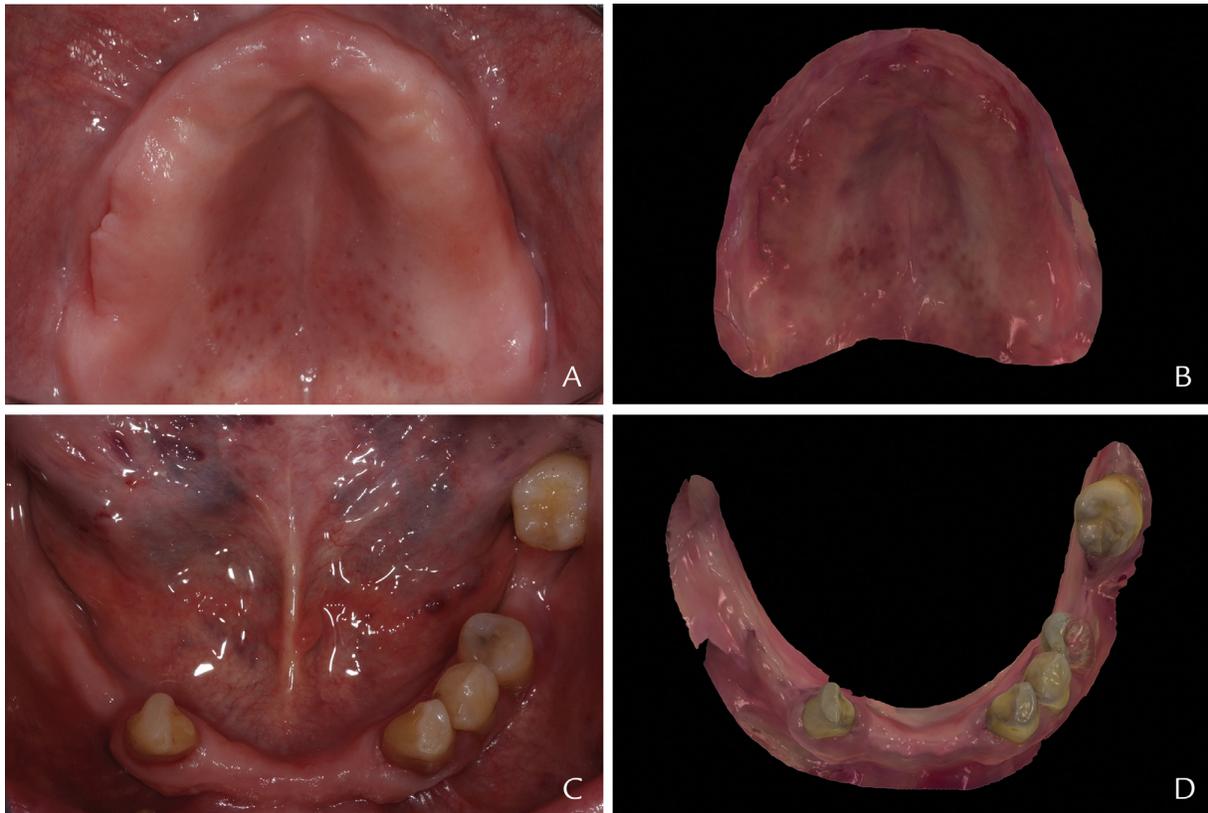


Figure 7. Initial situation and optical scans. A, Completely edentulous maxilla. B, Optical scan of edentulous maxilla. C, Partially edentulous mandible (Kennedy Cl. II div. 2). D, Optical scan of edentulous mandible.



Figure 8. Registering lip length with Papillameter (AvaDent; Global Dental Science Europe BV). A, Positioning of Papillameter. B, Measuring lip length by using Papillameter while maintaining lip in relaxed state. C, Lateral view showing positioning of Papillameter to maintain labial support.

were captured in a single block. The resultant block was then digitized to provide all the relevant parameters to the design software, aiding in prostheses fabrication by CAD-CAM milling. The elastomeric impression materials used in this protocol were

selected so that they did not impede the wax rims present on the modified trays. A further advantage was that the block could be digitized later without the risk of complications that may arise due to dimensional changes.



Figure 9. Jaw relations. A, Ball of polyvinyl siloxane putty placed in between jaws, patient instructed to close gently. B, Lips molded gently to establish approximate lip support and fullness. C, Establishing arbitrary approximate vertical dimension of occlusion.

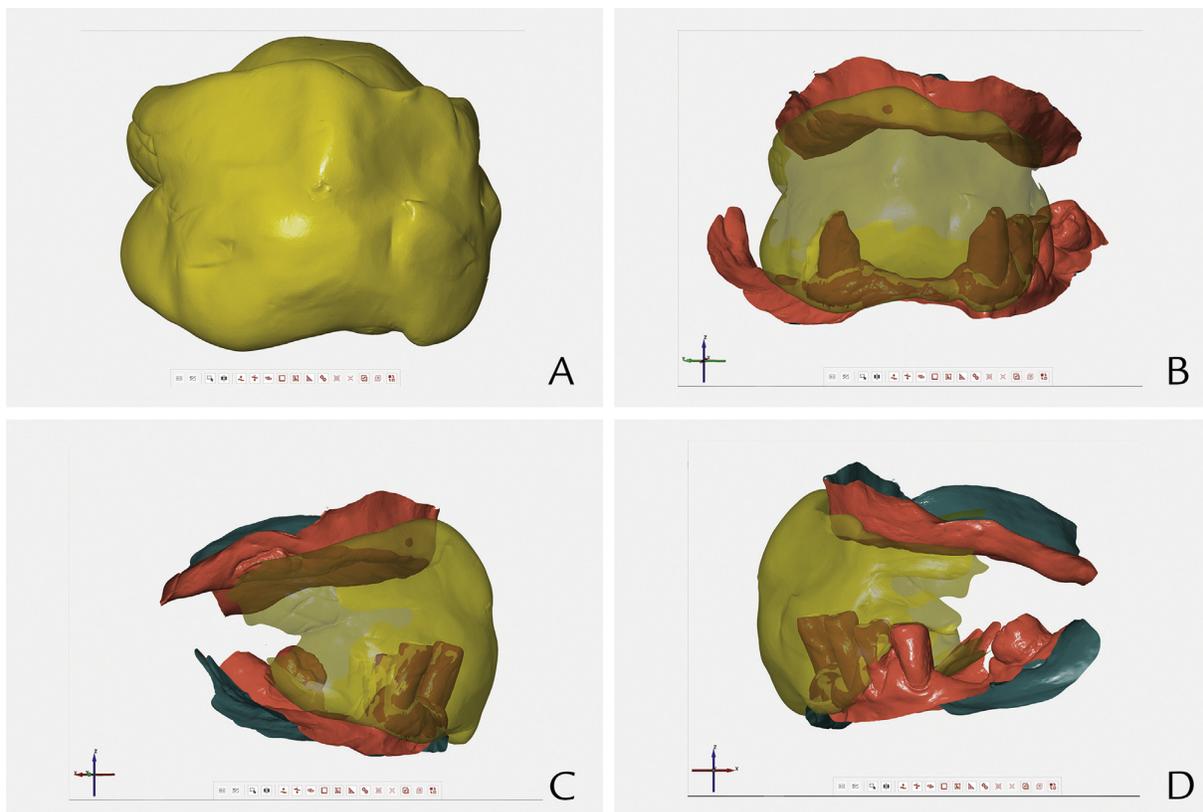


Figure 10. Aligning optical scans with scan of putty block. A, Scan of putty record. B, Frontal view of aligned scans. C, Right lateral view of aligned scans. D, Left lateral view of aligned scans.

Alternatively, elastomeric impression materials could be substituted by a conventional low-fusing modeling plastic impression compound (ADA type 1 Impression compound; Kerr Corp) and zinc oxide impression pastes (Impression paste; SS White Manufacturing Ltd) for the peripheral border molding and definitive impressions. If chosen to do so, a slight protocol modification then needs to be made, wherein the

impressions are first made and the occlusal rims are then fabricated chairside on custom trays. However, this will take slightly longer as the occlusal rims have to be fabricated chairside and impressions could be damaged. Therefore, having the rims already fabricated on the trays and using elastomeric impression materials were preferred. Although the gothic arch tracing step could be optional in younger edentulous patients, it is



Figure 11. Definitive jaw relation with record bases (WTI). A, Maxillary WTI with tooth arrangement in wax to first premolars with milled molar. B, Mandibular WTI with central incisors and posterior occlusal wax blocks. C, WTIs in centric relation. D, Optical scan of WTIs in centric relation to register definitive jaw relation. WTI, Wagner try-in plates.

imperative in elderly patients with reduced motor control. The major advantages with this protocol include the avoidance of a learning curve, familiarity with materials and procedures, reduced chairside time, and no increase in clinical costs.

The second technique demonstrated that clinically acceptable CAD-CAM CDs can be fabricated with a nearly digital workflow, although a few limitations do exist. Positioning of the denture peripheries and the posterior palatal seal areas on the optical scans is still arbitrary but can meet clinically acceptable standards. Compression of the posterior palatal seal area was performed by the manufacturers on request. The denture peripheries could not be well defined as would have been generally possible with conventional border-molded dentures. Registering jaw relations had to be performed in a 2-step procedure involving an arbitrary preliminary capture followed by a definitive, refined registration. This step still required physical processes as technology, to the best of the authors' knowledge, does not exist for a fully digital capture currently; hence, the nearly digital in the title of this report. Despite these

practical difficulties, the fit, retention, and stability of the fabricated dentures were excellent. The definitive result could be considered clinically acceptable, resulting in a satisfied patient.

SUMMARY

1. CAD-CAM dentures can be successfully fabricated by using conventional procedures and materials, with a reduced number of clinical visits and without the use of complex or elaborate armamentaria.
2. The described nearly digital workflow can produce clinically acceptable CAD-CAM dentures.
3. Current technology still does not permit the recording of peripheral boundaries and jaw relations in a truly functional state.
4. Perhaps, a truly functional impression may not be required for a CAD-CAM denture as in the case of a conventional denture because of the excellent fit, manufacturing precision, and absolute lack of distortion of the denture-bearing tissues in the absence of compression during scanning.

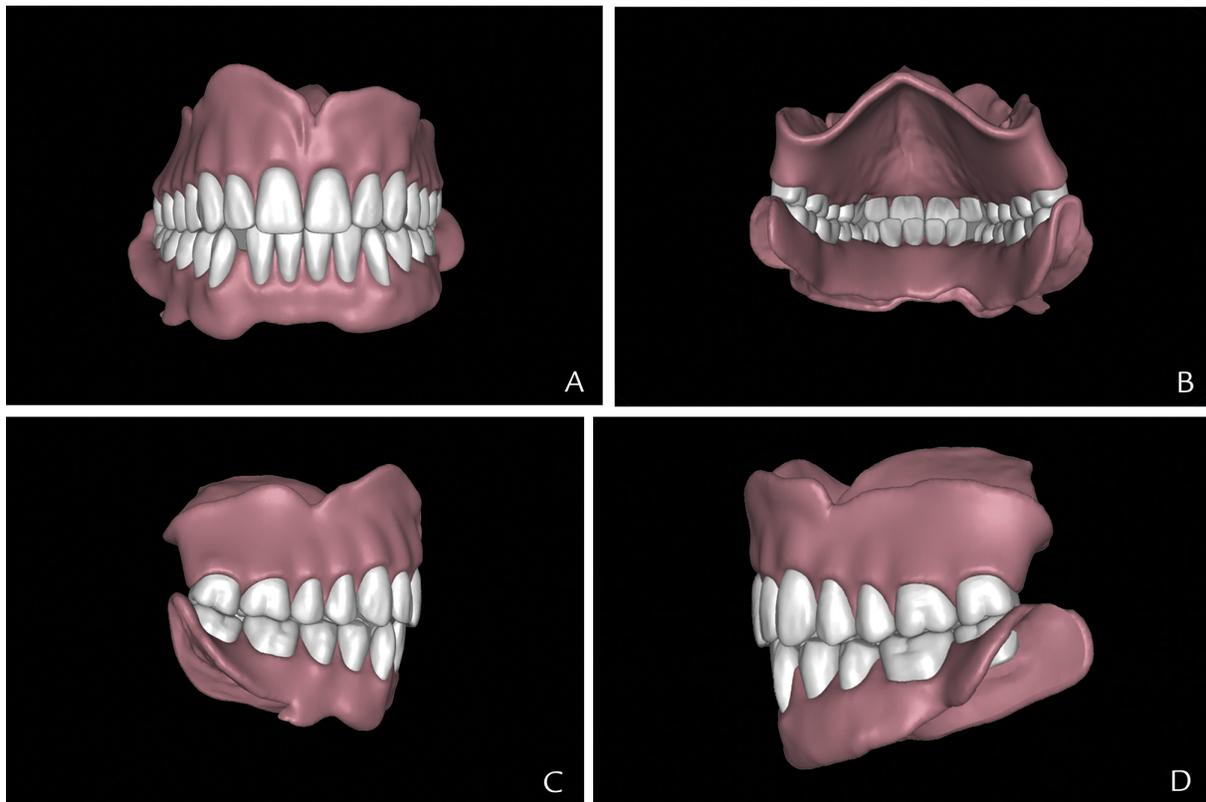


Figure 12. Digital preview showing virtual tooth arrangement. A, Frontal view. B, Posterior view. C, Right lateral view. D, Left lateral view.



Figure 13. Definitive result. A, Finished prostheses in situ with lips retracted. B, Frontal view of smile with prostheses in place. C, Profile view of smile with prostheses in place.

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