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DENTAL TECHNIQUE

CAD-CAM complete digital dentures: An improved clinical and laboratory workflow

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ABSTRACT

The purpose of this article was to present a novel clinical workflow for the fabrication of complete dentures using computer-aided design and computer-aided manufacturing (CAD-CAM) technology. The dental technique consists of 3 clinical steps and 2 laboratory phases that result in the production of 2 CAD-CAM milled complete denture bases with prefabricated teeth. The integration of analog and digital procedures and materials maximizes their benefits in the planning and fabrication of complete dentures, with the goal of improving clinical outcomes. (J Prosthet Dent 2025;133:1430-1435)

Srinivasan et al[1] described a "nearly digital workflow" for fabricating complete dentures (CDs) using computer-aided design and computer-aided manufacturing (CAD-CAM). The protocol involved 3 clinical visits and the use of an intraoral scanner (IOS) directly on the residual alveolar ridges, The Wagner Try-In (WTI) protocol was used for verifying the maxillomandibular relationship (MMR) and the delivery of milled CDs.[1] However, this workflow had limitations, including that the direct use of an IOS can result in the insufficient fit and retention of the CD.[2,3] A putty interocclusal record (IR) has been used for a partially edentulous mandible[1] where stabilization is improved compared with a completely edentulous arch, and the lack of references prevents the dental laboratory technician from being guided in positioning the teeth on WTIs. Additionally, CAD-CAM monolithic dentures have drawbacks that may not always be addressed.[2,3]

Integrating analog and digital procedures has shown promise in enhancing clinical success and patient satisfaction.[4,5] Despite IOS limits in completely edentulous patients,[6–11] digital technologies have brought significant advantages. WTIs have successfully replaced traditional trial bases[1,12] that require stone cast wax modifications, whereas 3-dimensionally (3D) printed bases fit as accurately as the definitive prosthesis.[12,13] facilitating the tracing process, phonetic evaluation, and maxillomandibular registration.[12] Milled CD bases offer better tissue surface adaptation and less tooth movement compared with conventionally fabricated ones, as they are not affected by polymerization shrinkage.[14,15] This leads to higher retention, fewer traumatic ulcers,[15–17] and, thanks to the reduced monomer release and resin properties, increased density, flexural strength, color stability, stain resistance, and reduced *Candida albicans* adherence.[18–21]

Milled CDs can be produced as monolithic, with or without teeth,[22] depending on the overall dimensions and other considerations, including esthetics and occlusion.[12] In some CD systems incorporating a shell geometry technology, the gingival papilla architecture cannot be modified, so the height of the papilla peaks is

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not adjustable.[22] Moreover, because of the static papilla architecture, positioning the disk for tooth and base design can result in excessive milling of some regions such as the tuberosity and retromolar pad.[22] An alternative approach involves milling both the base and the entire arch of teeth from 2 blocks and bonding them together. This prevents individual tooth dislodgement as could happen with separated teeth, but those milled lack the esthetics of prefabricated multilayer ones.[12] Furthermore, managing a monolithic block can be challenging, as unified teeth limit the personalization of the tooth arrangement in terms of axis and position compared with individual denture teeth.[12] Stock denture teeth for digital CD are designed with a reduced tissue surface to allow placement in predetermined sockets in the denture base.[12,23] However, achieving accurate positioning during bonding can be challenging, potentially altering the occlusion.[24] The optimal offset value for the precise positioning of artificial teeth has been reported to be 0.2 mm,[23,25] but differences in tooth positioning may still occur compared with the digital design.[26,27]

Therefore, the first goal of the present technique was to update the Srinivasan et al technique[1] by integrating digital and analog procedures while also adding some clinical guidance. The second goal was to introduce a technological innovation for the predictable bonding of prefabricated teeth to milled denture bases.

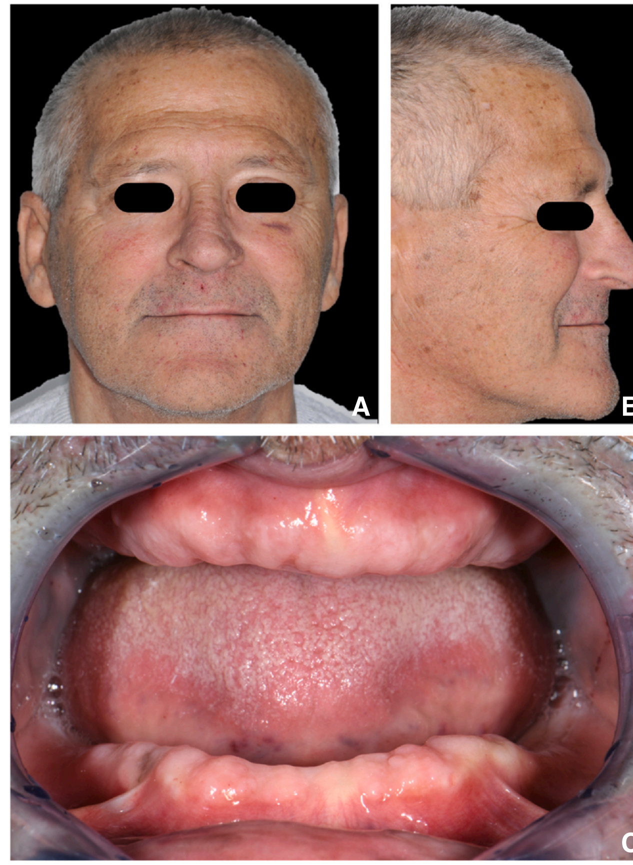

Figure 1. A and B, Frontal and lateral view of patient. C, Maxillary and mandibular residual alveolar ridges.

TECHNIQUE

First Clinical Appointment

1. Make initial patient extraoral and intraoral photographs (Fig. 1).
2. Make extended irreversible hydrocolloid impressions (Hydrogum; Zhermack) (Fig. 2A).
3. Register an arbitrary occlusal vertical dimension using a polyvinyl siloxane (PVS) putty (Elite HD+ Putty; Zhermack)[1] and apply a light-body PVS to its intaglio surface (Fig. 2B, C).
4. Mark the putty IR with reference esthetic lines[28] (Fig. 2B) and make a photograph of the patient at maximum smile in natural head position using a digital single-lens reflex camera (D300; Nikon Corp) with a 105-mm macrolens (f/2.8 EX DG Macro; Sigma).[29,30]
5. Scan the impressions and the IR using an IOS (TRIOS 5; 3Shape A/S) and align them (Fig. 2D).

First Laboratory Stage

1. Plan the patient smile according to the reference lines on the IR and then the 3D virtual tooth arrangement using a CAD software program (Denture Guide; Ruthinium) (Fig. 3A, B) (Video 1).[30–32]
2. Design and 3D print the WTIs and a tooth positioning guide (TPG) using a digital light processing printer (LightBuilder 4K; Dental Maker). For the TPG, use a 3D printed resin (Acryprint 3D Guide, Ruthinium) with 0-degree angulation printing and a 50-μm layer thickness. Set a 0.07-mm offset for proper fit of the teeth (Fig. 3C)
3. Position the modified prefabricated stock teeth (Ruthinium Acry Plus A3; Ruthinium) inside the TPG and mount them on a tripod. Use pink wax to bond the teeth to the base (Fig. 3D).
4. Remove the tripod from the bases using a slow speed bur (Carbide Burr 1/8; Dynabrade).

Second Clinical Appointment

1. Evaluate and adjust the WTIs at the definitive MMR (Fig. 4A, B).
2. Make a closed mouth impression using PVS (Hydrorise Implant Light; Zhermack) (Fig. 4C).[33]

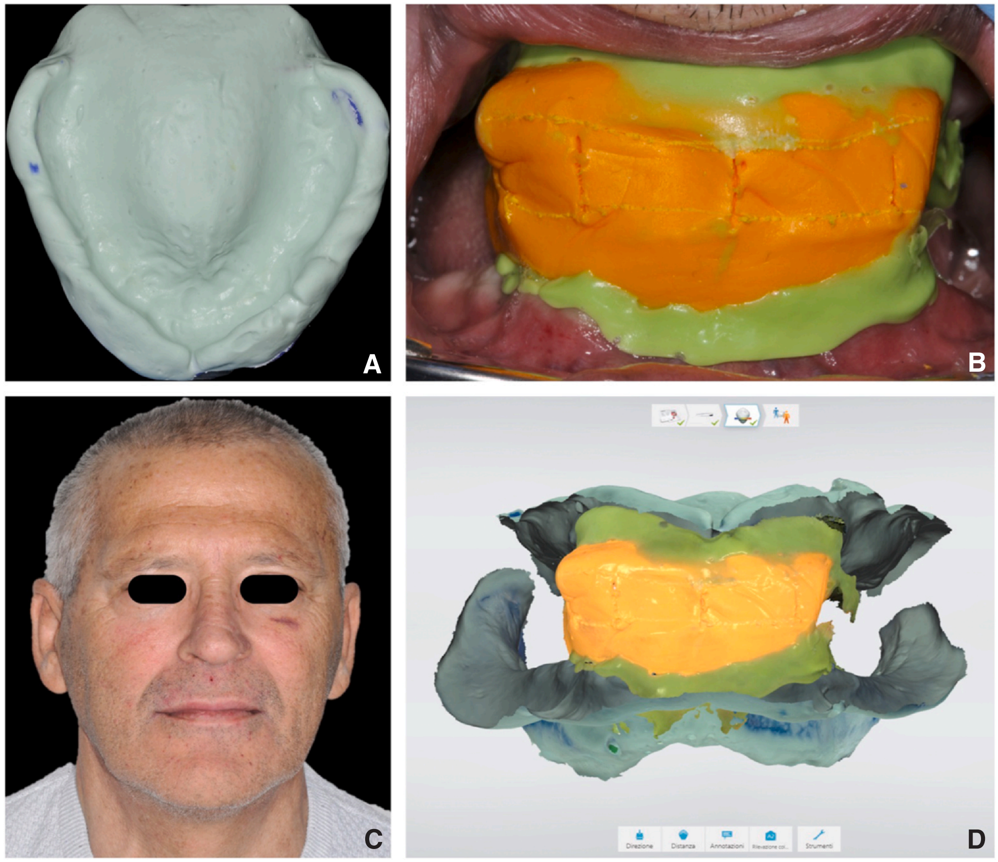

Figure 2. First clinical appointment and steps. A, Maxillary impression made with irreversible hydrocolloid. B, Putty IR marked with smile, canine, and median lines and arbitrary line dividing mandibular and maxillary prosthetic spaces. C, Extraoral view of patient with putty IR in place establishing lip support and fullness. D, Scanned impressions aligned through IR. IR, interocclusal record.

Second Laboratory Stage

1. Plan the definitive CD bases and tooth arrangement. Set a 0.2-mm offset for CD sockets.[23,25]
2. Mill the CD bases using a 5-axis milling machine (DVX 52D Plus; DG Shape) (Fig. 5A).
3. Design and 3D print the definitive TPG (Fig. 5B) (Video 2).
4. For the bonding phase, drill teeth, airborne-particle abrade, apply monomer, and bond them to CD sockets using polymethyl methacrylate resin[34] (Acry Self P, Ruthinium) (Fig. 5C) (Video 3).

Third Clinical Appointment

1. Evaluate the CDs, make clinical adjustments, and provide care and maintenance instructions (Fig. 6A, B).

DISCUSSION

This technique allows the fabrication of CDs by integrating both IOS and impression materials, as well as milled bases with prefabricated teeth, in only 3 clinical visits, as for other digital workflows on edentulous patients.[1,4,5,22,32] Compared with analog workflows, the technique reduces clinical time by incorporating wax rims with teeth in WTIs and secondary impressions with the MMR record in a single step.[35] Compared with digital workflows, key modifications in the impression and IR techniques should improve predictability and the clinical outcomes.

Irreversible hydrocolloid impressions of the residual alveolar ridges were made instead of intraoral scans because of the higher accuracy and extension of conventional impressions.[7–9] These impressions were then scanned with an IOS, preserving all captured information. Making a putty IR at the desired vertical dimension, enabled the dental laboratory technician to articulate virtual casts in a more predictable way, subsequently reducing adjustments of WTIs differently from many other digital techniques.[4,5,22] Marking the esthetic reference lines on the IR allows the planning of more predictable esthetics according to clinical indications, differently from the method of Srinivasan et al.[1] It also facilitates the superimposition between the patient's 2D photograph and the STL files for the virtual tooth arrangement.[29–31] However, the spatial occlusal plane orientation, as well as the esthetics and tooth exposure, need

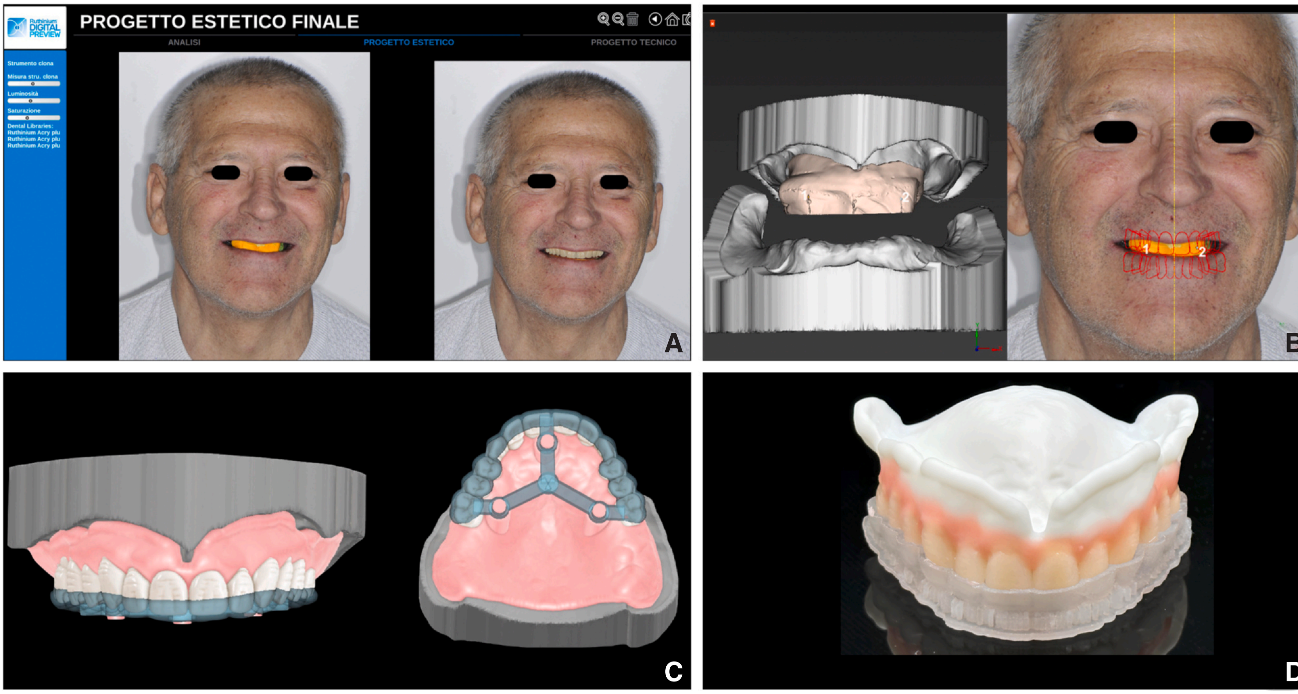

Figure 3. First laboratory stage. A, Virtual smile planning. B, Alignment of smile preview with 3D STL files using reference lines marked on IR. C, 3D virtual teeth setup and WTI project. D, Maxillary WTI with 3D printed teeth positioning guide. IR, interocclusal record; 3D, 3-dimensional; STL, standard tessellation language; WTI, Wagner Try-In.

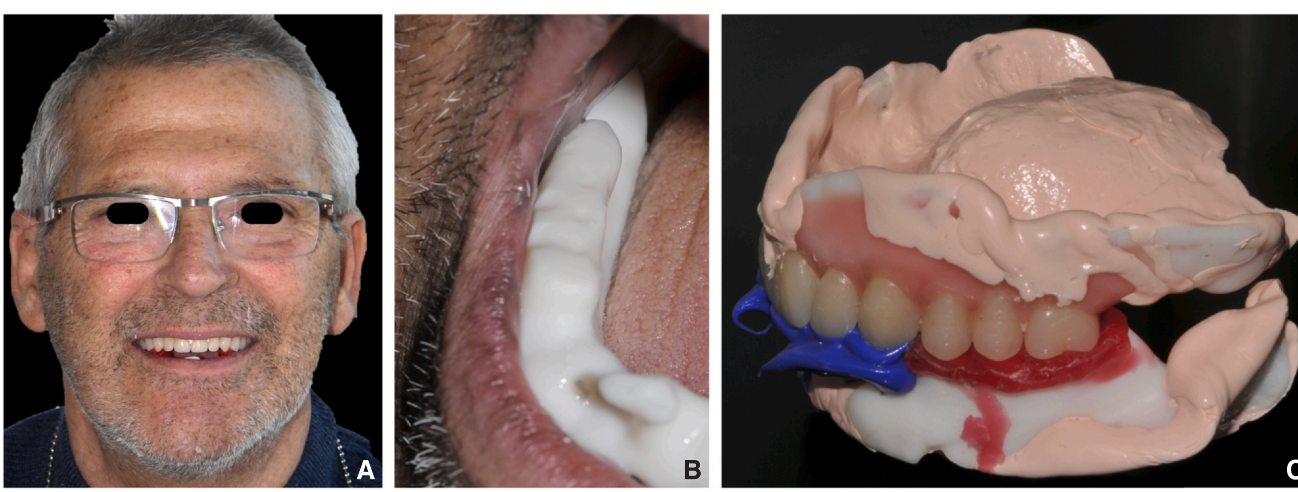

Figure 4. Second clinical appointment. A, Evaluation of OVD and esthetics with WTIs. B, assessment of neutral zone. C, WTIs relined with rigid PVS and stabilized at established maxillomandibular relationship. OVD, occlusal vertical dimension; PVS, polyvinyl siloxame; WTIs, Wagner Try-Ins.

to be verified by using the WTIs. Relining the IR with light-body PVS improved its stabilization on the soft tissues and enhanced the matching process with the scanned impressions by capturing fine tissue details.

The novelty consists in the fabrication of a TPG connected to the CD base with a tripod. This approach uses prefabricated teeth offering better esthetics than milled ones and the possibility of being individually fixed into the sockets. This also allows modifications of the gingival architecture, zenith level, and position in the definitive CDs.[36] Moreover, the bonding of the teeth to the CD bases can be done without any 3D printed cast and articulator. However, this could also be a limitation, as the definitive CDs cannot be repositioned on an articulator for occlusal evaluation and adjustments.

In the TPG design phase, establishing the insertion axis of the teeth in the CD base and, conversely, in the TPG, is essential. In the presented protocol, an offset of

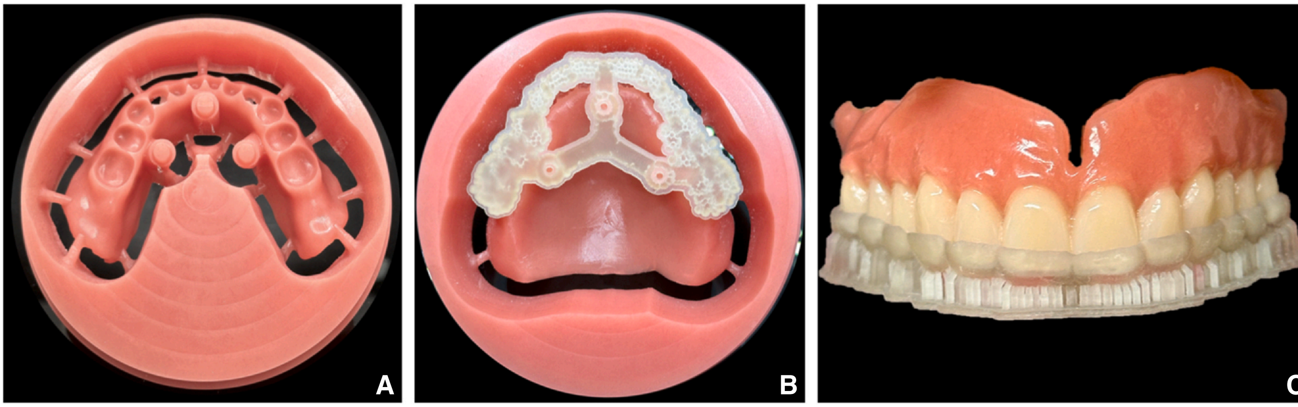

Figure 5. Second laboratory stage. A, Milled mandibular denture base with tripod. B, 3-dimensionally printed definitive teeth positioning guide on milled denture base. C, Definitive polished maxillary complete dentures with teeth bonded to denture base.

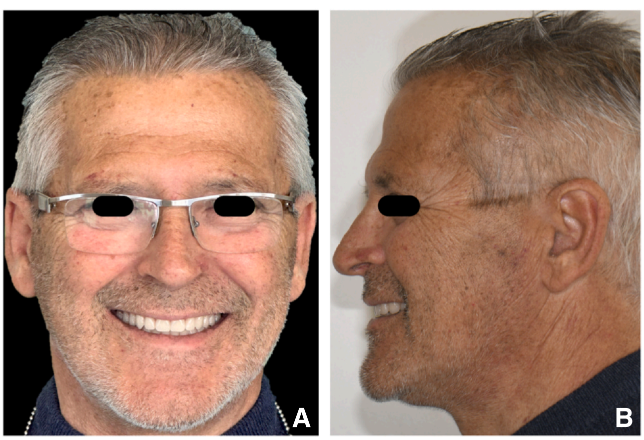

Figure 6. Complete denture delivery. A and B, Frontal and lateral view of patient smiling.

0.07 mm was applied between the tooth suprabulge and the TPG, and a 0.2-mm offset was set between teeth and sockets.[23,25] The use of a milled positioning key to ensure the ideal seating of the teeth has been proposed.[37] However, as the key was not connected to the CD base, the teeth could be positioned differently from the plan, and the offsets might differ from the ideal depending on the insertion axis of the teeth.[25] Additionally, the size of the suprabulge tooth portion to be included in the TPG to avoid displacement and which material is best suited for a guide with this specific application remains unclear. The procedures performed before bonding the teeth could also affect the established fit between the teeth and the sockets. Furthermore, the risk of tooth dislodgements is higher compared with monolithic CDs or complete arch milled teeth.

From a clinical perspective, registering an initial MMR using a putty IR can be challenging. Moreover, a monoblock can fix the patient's mandible in an unreliable position, potentially requiring additional time and adjustments in the subsequent clinical steps. Further improvements may revise these aspects of the technique.

SUMMARY

This analog-digital approach enables CD fabrication without physical casts and reduces overall time. Conventional impressions improve the retention of CD bases, and WTIs facilitate clinical maneuvers because of the improved fit compared with conventional trial bases. The milled CD bases eliminate the resin polymerization shrinkage, ensuring better tooth and base stability. Prefabricated resin teeth ensure optimal esthetic and function.

PATIENT CONSENT

The authors obtained consent from the patient to publish his clinical intraoral and extraoral photographs.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2024.11.016.

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