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DENTAL TECHNIQUE

# Workflow for guided implant placement based on anatomic landmarks and the CAD-CAM fabrication of a prosthetic framework for an implant-supported fixed dental prosthesis

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## ABSTRACT

Digital workflows integrating computer-aided design and computer-aided manufacturing (CAD-CAM) have improved precision in implant-supported prostheses. This article describes a step-by-step technique for guided mandibular implant placement and the CAD-CAM fabrication of a patient-specific titanium bar based on cone beam computed tomography (CBCT) segmentation, anatomic reconstruction, and a functional digital waxing. The workflow combines prosthetically driven planning with anatomic reference alignment to enhance bar adaptation and prosthetic accuracy. The digital sequence allows clinicians and dental laboratory technicians to virtually design and verify the bar on a 3-dimensionally printed mandibular model before clinical application, minimizing chairside adjustments and improving interdisciplinary communication when providing complex complete arch implant-supported prostheses. (J Prosthet Dent 2026;135:694-699)

In edentulous patients with advanced mandibular resorption, complete arch prostheses present anatomic and biomechanical challenges.[1] Accurate implant positioning, management of the prosthetic space, and passive framework adaptation are critical for long-term success.[2] Conventional techniques often fail to accommodate anatomic constraints, leading to unfavorable implant angulations, reduced prosthetic clearance, and misfitting prostheses that compromise function, esthetics, and mechanical longevity.[3]

Computer-aided design and computer-aided manufacturing (CAD-CAM), cone beam computed tomography (CBCT), and virtual planning have transformed implant dentistry by enabling anatomically guided, prosthetically driven prostheses.[4–7] Previous digital workflows, including guided surgery, photogrammetry, and virtual patient integration, have improved implant placement and data registration[8] but often emphasize prosthetic design without fully incorporating bone morphology into the substructure planning.[9] Consequently, discrepancies may persist between implant positioning and prosthetic alignment, particularly in patients with advanced ridge resorption where anatomic landmarks are critical to achieving passive framework fit.[10]

The technique presented integrated CBCT-based anatomic modeling, prosthetically driven implant placement, and digital waxing alignment to design and fabricate a custom mandibular bar within a fully digital workflow. This approach bridged the gap between surgical and prosthetic stages, improving the precision of bar adaptation, facilitating communication among clinical and laboratory teams, and enhancing reproducibility in complex mandibular reconstructions.

The authors have no conflict of interest to declare.
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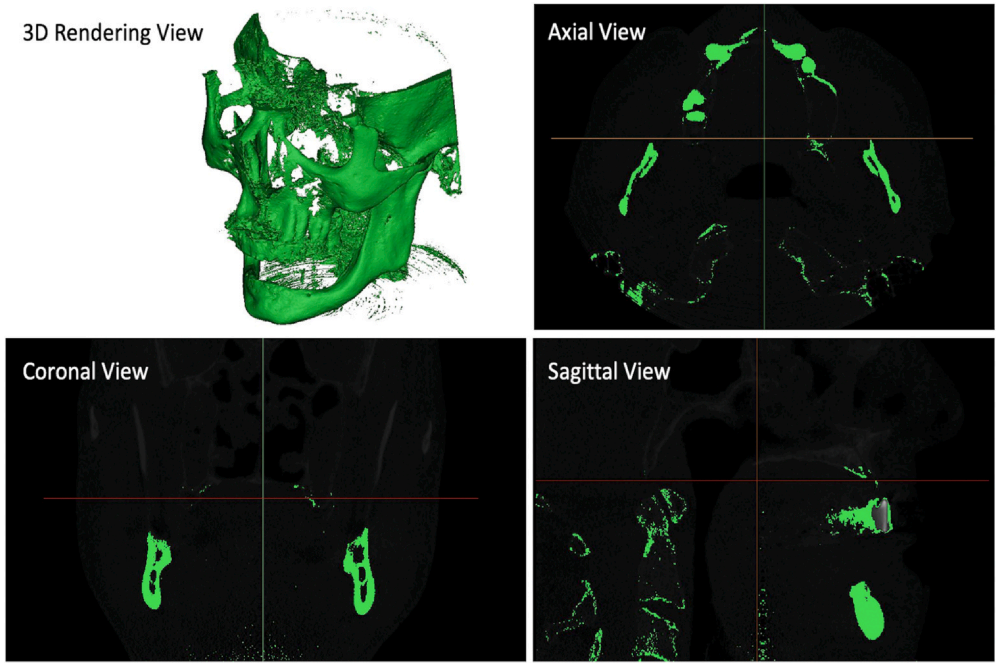


**Figure 1.** Cone beam computed tomography-based 3-dimensional anatomic reconstruction of edentulous mandible with advanced resorption.

## TECHNIQUE

A fully digital workflow for guided implant positioning and the CAD-CAM fabrication of a custom mandibular framework supporting an implant-supported fixed dental prosthesis that integrates CBCT-based anatomic modeling, prosthetically driven planning, virtual abutment angulation, and digital waxing definition is described. The bar was designed in a CAD software program, adapted to anatomic and prosthetic parameters, and fabricated by subtractive manufacturing. This protocol enhanced implant positioning accuracy and framework adaptation, enabling predictable and efficient planning for providing a complete arch prosthesis.

1. Acquire a high-resolution CBCT scan of the edentulous mandible and import the Digital Imaging and Communications in Medicine (DICOM) dataset into a medical imaging software program (Mimics; Materialise NV, 3DSlicer; Brigham and Women's Hospital and Harvard Medical School, or InVesalius; Renato Archer Information Technology Center). Segment the mandibular bone to isolate relevant landmarks, including the mandibular canal, mental foramina, and cortical contours. Export the segmented model as a standard tessellation language (STL) file and refine the surface topology by removing artifacts and smoothing irregular areas to obtain an accurate 3D anatomic model for virtual implant positioning (Figs. 1, 2).
2. Evaluate bone volume and anatomic limitations such as ridge asymmetry and posterior resorption. Position 2 axial anterior implants in the interforaminal region and 2 tilted posterior implants in the premolar zones (Straumann Tissue Level Roxolid SLA; Institut Straumann AG) by following a 4-implant distribution for an implant-supported fixed complete arch prosthesis to optimize implant spread and avoid the mandibular canal. Record the implant angulations relative to the basal plane and export the numeric data from the planning software program (coDiagnostiX; Dental Wings, Exoplan; exocad, or BlueSkyPlan; Blue Sky Bio). For the present patient, posterior implants were placed at 67 to 80 degrees relative to the occlusal plane, and anterior implants were placed vertically (70 to 90 degrees) and aligned with the mandibular symphysis and basal cortical support (Fig. 3).
3. Select screw-retained abutments (Screw-Retained Abutment; Institut Straumann AG) based on implant angulation, peri-implant soft tissue thickness, and prosthetic requirements. Use 17- or 30-degree angled abutments when redirection is needed and straight abutments when implants are axially positioned. Verify parallelism in cross-sectional and occlusal views to ensure a common path of insertion. Digitally align the diagnostic waxing to reestablish the occlusal vertical dimension and interarch relationships. Scan the waxing and import it into the CAD environment as a volumetric reference for the bar design (Figs. 4, 5).

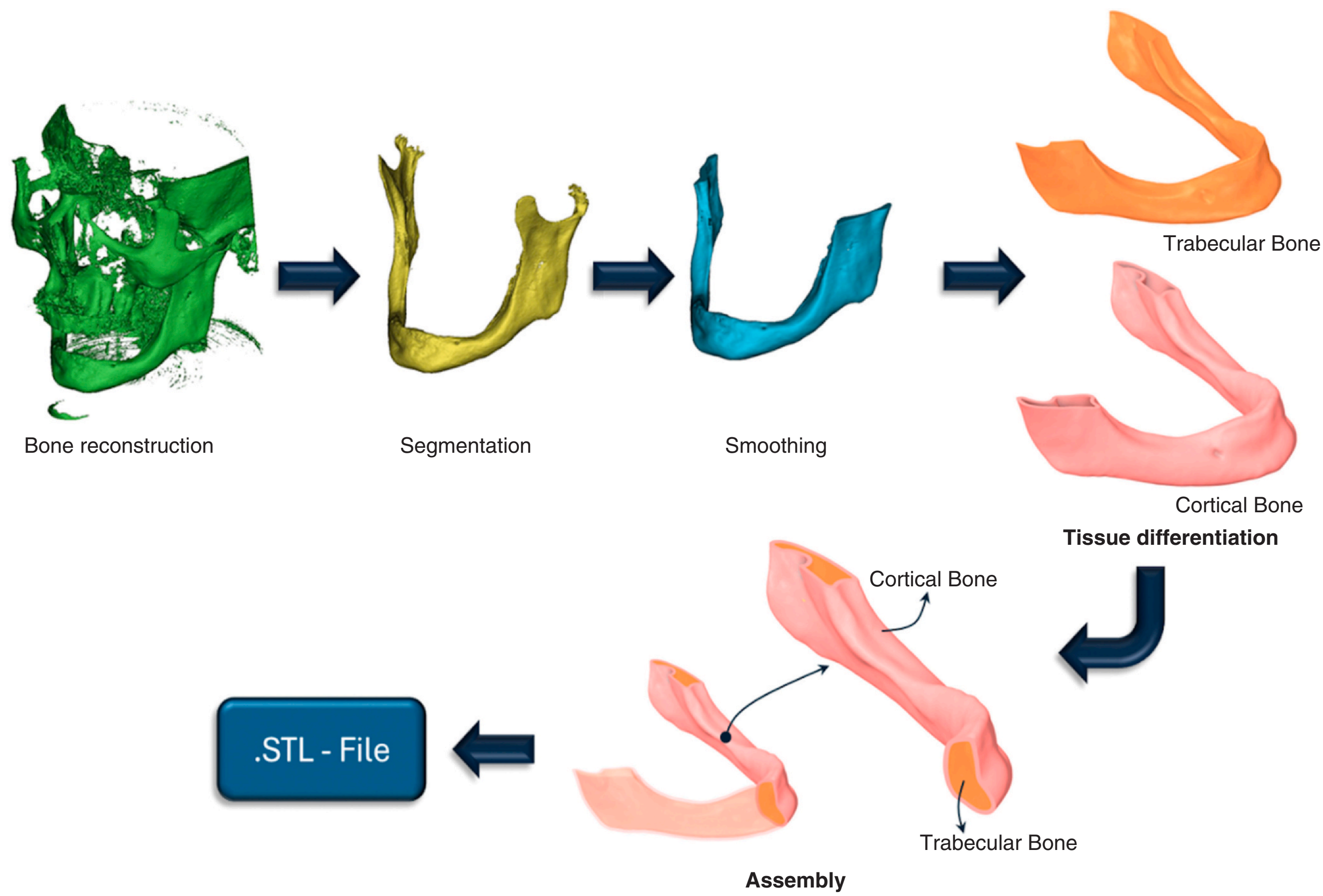


**Figure 2.** Topological refinement and anatomic labeling of segmented mandible for digital planning.

4. Import the waxing and implant-abutment complex into CAD software program (SpaceClaim; Ansys Inc) to design the mandibular bar by following the arch curvature and prosthetic envelope. Incorporate precise abutment interfaces, contours that facilitate oral hygiene, and localized reinforcements to withstand occlusal loads while maintaining clearance from the peri-implant mucosa. Superimpose the framework, implants, and digital waxing in frontal, sagittal, and occlusal views to verify fit and spatial coherence. Confirm passive fit and proper emergence profiles before fabrication (Figs. 6, 7).
5. Export the final CAD design as an STL or CAM file and mill it from grade V titanium (Ti-6Al-4V alloy; ISO 5832-3/ASTM F136) using a 5-axis milling machine (M5 Heavy Metal; Zirkonzahn GmbH). Remove the supports, surface finish, and polish using a rotary cut-off and polishing unit (Trennschleifgerät; Zirkonzahn GmbH). Clean the framework in an ultrasonic cleaner (Elmasonic P; Elma Schmidbauer GmbH) and verify the dimensions with a digital caliper (Mitutoyo Corp.) Evaluate the adaptation on a 3D printed mandibular cast or by digital superimposition with the reference STL file. Verify the passive fit visually and digitally before clinical application (Fig. 8).

## DISCUSSION

The digital workflow presented should provide a structured and reproducible approach to designing and fabricating a custom mandibular framework in patients with advanced ridge resorption. Integrating anatomic modeling, prosthetically guided implant positioning, and virtual abutment angulation, this technique should improve passive framework fit and reduce chairside adjustments compared with conventional analog protocols.

The early incorporation of a digital waxing allows the bar to be designed in harmony with the planned restoration and soft-tissue contours. Screw-retained abutments with variable angulations facilitates a common path of insertion and enhances the prosthetic fit. The workflow supports communication between surgical and laboratory teams, allowing digital modifications without remaking physical models.

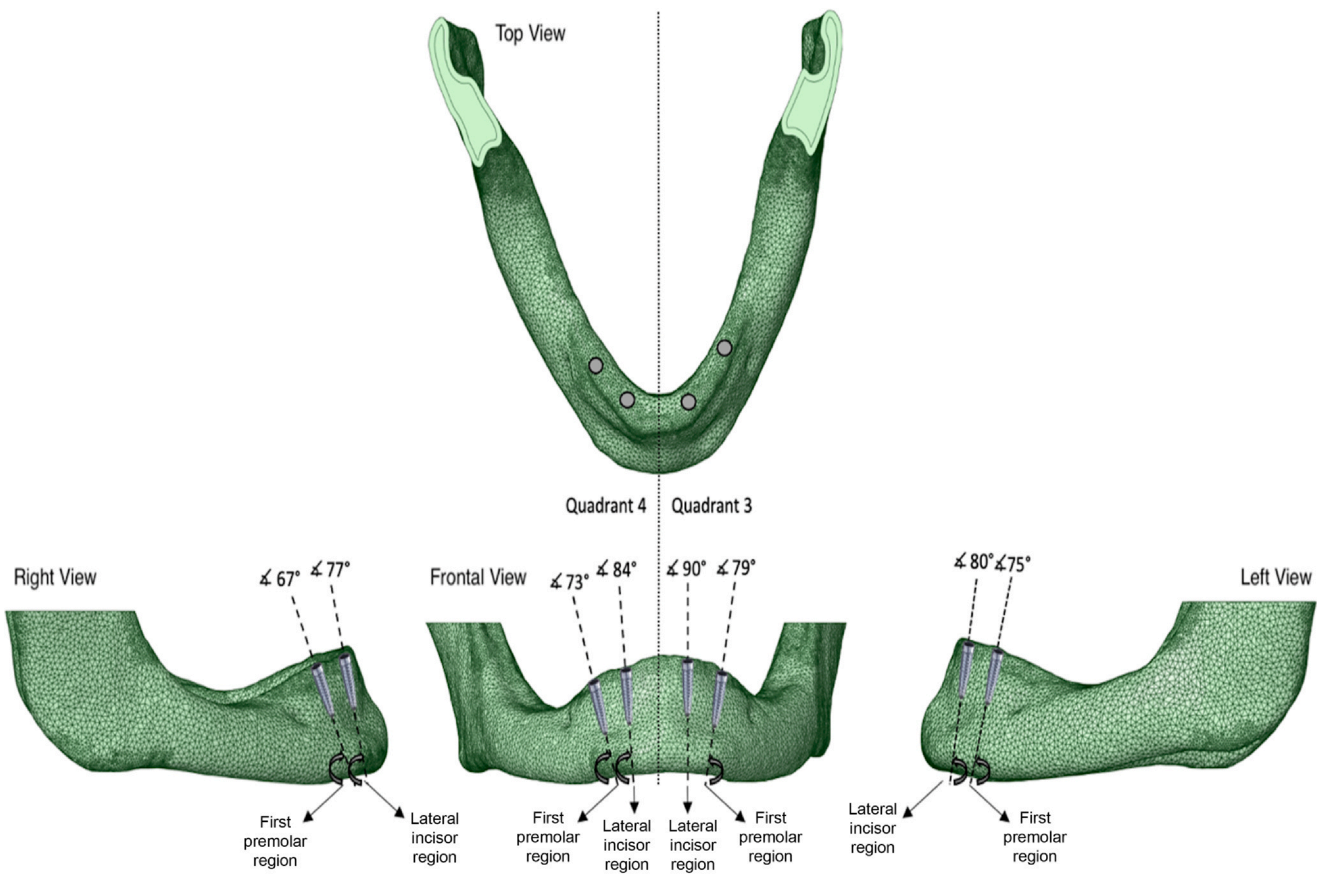


**Figure 3.** Implant positioning in relation to anatomic landmarks and prosthetic zones.

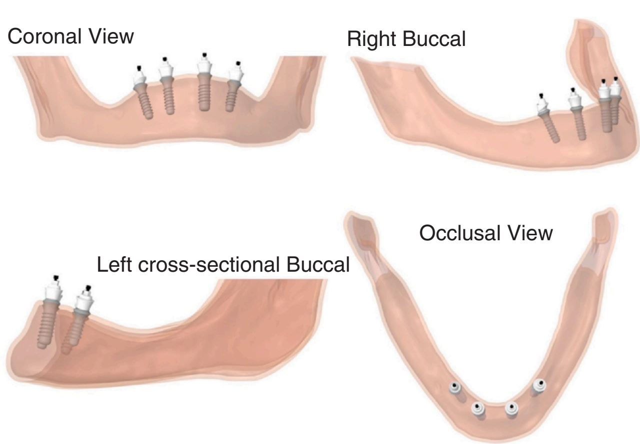


**Figure 4.** Digital alignment of screw-retained abutments to standardize prosthetic insertion path.

Validation on a 3D printed (Neptune 3 Pro; Elegoo Technology Co Ltd) mandibular model confirmed the passive adaptation of the titanium bar. However, mechanical testing and clinical follow-up are necessary to verify long-term performance. The protocol is indicated for edentulous patients with severe ridge resorption or

**Figure 5.** Digital waxing on a printed mandibular cast used to restore vertical dimension and facial support. Asymmetry corresponds to the original diagnostic pattern used for digital reference.

anatomic irregularities where traditional methods are limited and contraindicated when interarch space is insufficient or unstable soft tissues are unstable for a screw-retained design.

## SUMMARY

A digital technique for prosthetically guided implant positioning and the CAD-CAM fabrication of a custom mandibular framework supporting an implant-

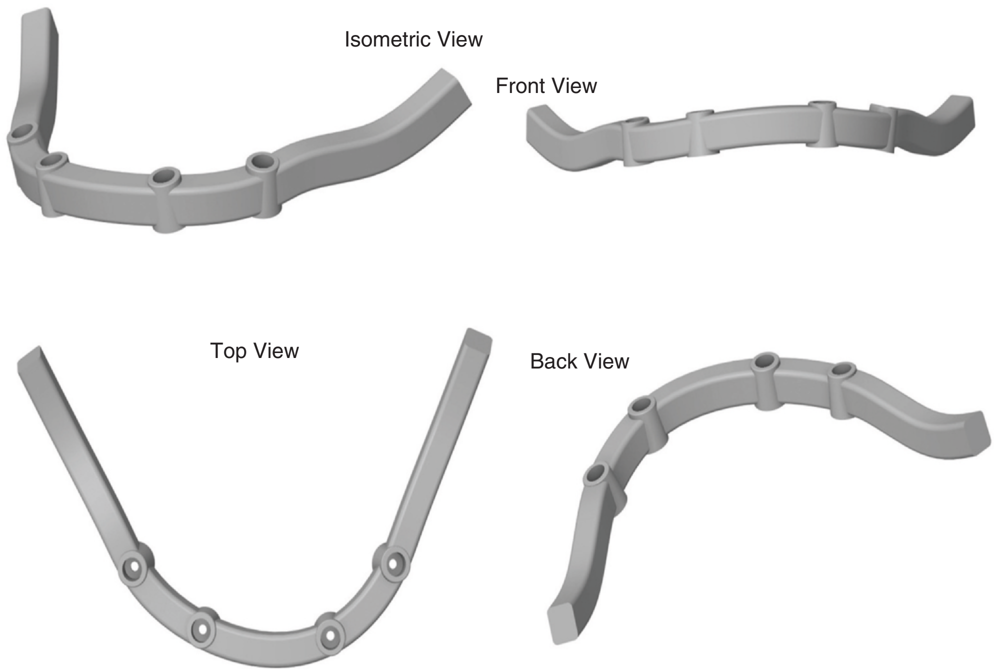


**Figure 6.** Custom bar design adapted to mandibular curvature and prosthetic envelope.

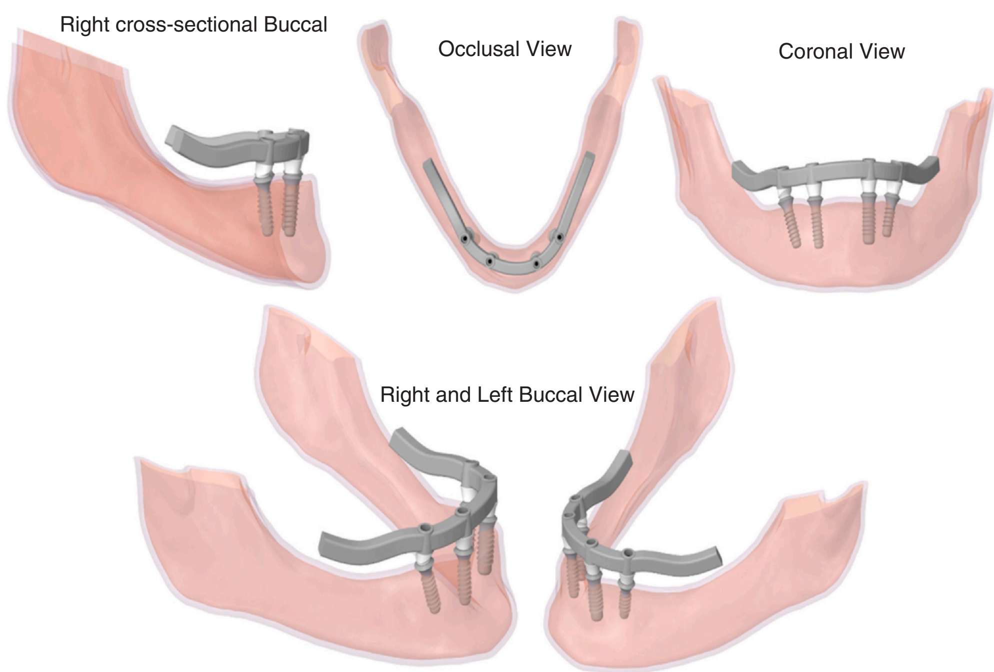


**Figure 7.** Digital superimposition of all components to verify prosthetic coherence and fit.

supported fixed dental prosthesis is presented. The workflow integrates CBCT-based segmentation, virtual implant positioning, screw-retained abutment angulation, and digital diagnostic waxing. Each step is executed digitally to reproduce anatomic and prosthetic parameters with high precision. The titanium-milled framework demonstrated a passive fit on a 3D printed mandibular cast, confirming the accuracy of the digital workflow. The protocol provides clinicians and dental laboratory technicians with a predictable, fully digital method for fabricating patient-specific frameworks in complex mandibular rehabilitations.

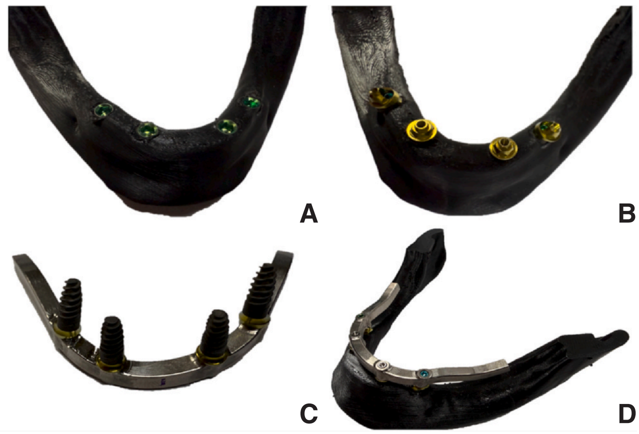


**Figure 8.** Digital workflow validation: titanium bar fitting on 3D printed mandibular cast. A, Implants positioned in mandibular cast. B, Screw-retained abutments screwed to implants. C, Titanium bar connected to screw-retained abutments and implants. D, Final seating of titanium bar on 3D printed cast for passive fit verification. 3D, 3-dimensionally.

## REFERENCES

1. De Souza AB, Papaspyridakos P, Weber HP, Vazouras K, Matarazzo F. Effect of dental implant therapy on the preservation of orofacial tissues: A systematic review and meta-analysis. *Clin Oral Implants Res*. 2023;34:240–256.
2. Eid HS, Zohdy MM, Nour M, Salah T. A comparative analysis of the passivity of fit of complete-arch implant-supported frameworks fabricated using different acquisition techniques. *J Prosthet Dent*. 2024;131:477.e1–477.e8.
3. Gómez-Polo M, Sallorenzo A, Ortega R, et al. Influence of implant angulation and clinical implant scan body height on the accuracy of complete-arch intraoral digital scans. *J Prosthet Dent*. 2024;131:119–127.
4. Liaropoulou GM, Kamposiora P, Bertos Quílez J, Cantó-Navés O, Foskolos PG. Reverse impression technique: A fully digital protocol for the fabrication of the definitive fixed prosthesis for completely edentulous patients. *J Prosthet Dent*. 2024;132:1118–1122.
5. Negreiros WM, Sun TC, Gallucci GO, Hamilton A. Digital verification and correction of digital intraoral scans for fixed implant rehabilitation of edentulous arches: A dental technique. *J Prosthet Dent*. 2023;129:395–399.
6. Park JS, Alshehri YFA, Kruger E, Villalta L. Accuracy of digital versus conventional implant impressions in partially dentate patients: A systematic review and meta-analysis. *J Dent*. 2025;160:105918.
7. Ortensi L, La Rosa GRM, Ciletta S, Grande F, Pedullà E. Evaluation of the accuracy of digital impressions with different scanning strategies: An in vitro study. *J Dent*. 2024;151:105433.
8. Massuda CKM, de Carvalho MR, de Moraes JB, Pallos D, Kim YJ. Accuracy of guided dental implant surgery using a fully digital workflow: A case series. *J Prosthet Dent*. 2024;132:973–980.
9. Cuéllar LR, López-Vaca OR, Martínez-Vega RA, Valencia-Niño CH. Digital technique for anatomic design and bone-implant interface analysis of a custom bar for a mandibular implant-supported fixed dental prosthesis. *J Prosthet Dent*. 2025;134:957–961.
10. Abduo APJ, Ibrahim H, Barazanchi A. Seating-related adaptation and deformation of components of removable partial denture frameworks fabricated by different workflows. *J Prosthet Dent*. 2025;133:1080.e1–1080.e9.

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