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CLINICAL REPORT

A digital workflow for full-arch implant fixed prosthesis: Clinical application of a 3D-printed polychromatic flangeless trial denture, anatomic bone reduction guide, and intraoral scanning for definitive prosthesis fabrication

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Abstract

This clinical report presents a comprehensive digital workflow for rehabilitating a patient with maxillary terminal dentition using a full-arch, implant-supported fixed dental prosthesis (FP-1). It highlights the integration of a 3D-printed polychromatic flangeless trial denture and a customized anatomic bone reduction template, enabling prosthetically driven implant planning and optimal bone architecture modification. The workflow incorporated fully guided implant surgery using sequential templates and immediate loading with a closed-mouth pickup system. Intraoral scanning protocols were employed for definitive prosthesis fabrication. This approach addressed high esthetic risks while achieving surgical precision, efficient treatment execution, and favorable clinical outcomes.

As life expectancy increases, there remains a significant population of edentulous individuals requiring dental interventions, despite the overall global decline in edentulism.[1] Immediate loading of implant-supported complete-arch fixed dental prostheses (ISCFDPs) has become a preferred treatment approach for patients, offering instant esthetic outcomes, functional restoration, and reduced discomfort compared to conventional approaches.[2,3]

ISCFDPs can be classified into three types according to Misch's classification: FP-1 (ISCFDPs that replace only the teeth), FP-2 (ISCFDPs with overcontoured teeth replacement), and FP-3 (ISCFDPs that replace both teeth and gingiva).[4] The choice of prosthesis is customized to each patient's unique anatomical features, considering factors such as maxillary central incisor positioning, the dynamics of the maxillary lip, facial support, and the edentulous ridge architecture (Lip-Tooth-Ridge, LTR, classification).[5]

In general, reduction of the alveolar ridge is indicated in cases requiring prosthetic space, hiding the transition line between tissue and prosthesis.[6] However, in maxillary edentulous cases, postextraction healing often results in a flat ridge, making the development of a scalloped soft tissue contour unpredictable. This challenge is particularly relevant in FP-1 restorations and LTR Class I-HER (high esthetic risk) cases, where high lip mobility exposes the transition line between the prosthesis and the ridge.[5–7] Advancements in digital technology have revolutionized prosthetic-driven implant planning, especially for edentulous patients. The 3D imaging and implant planning software allow precise preoperative design, ensuring accurate implant placement while preserving vital structures and optimizing aesthetic and functional outcomes.[8] For ISCFDPs, digitally designed surgical templates significantly enhance treatment predictability.[3,5,9] Traditionally, flat surgical guides determine ridge reduction levels, but their design often fails to accommodate the functional and esthetic demands of ISCFDPs.[3,10,11]

With no significant difference in implant survival rates across loading protocols for ISCFDPs,[12,13]

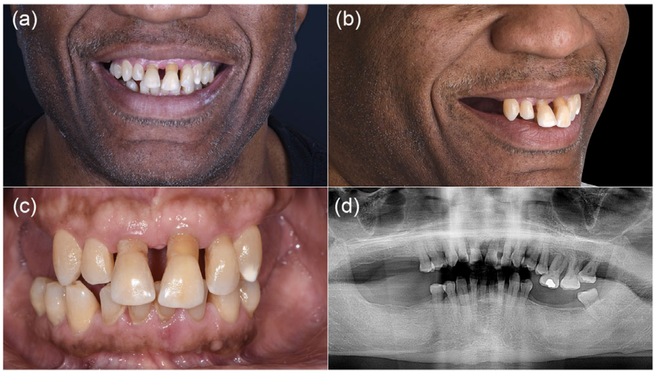

FIGURE 1 Pretreatment presentation. (a) Extraoral view of smile, frontal view. (b) Extraoral view of smile, lateral view. (c) Intraoral view. (d) Pretreatment panoramic radiograph.

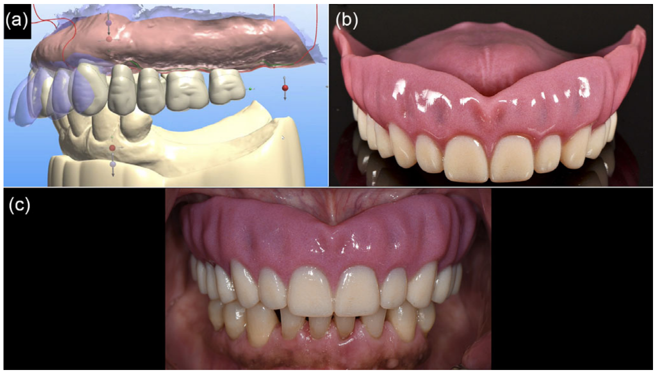

FIGURE 2 Immediate maxillary 3D-printed multichromatic denture. (a) Digital design. (b) 3D-printed monolithic polychromatic denture. (c) Delivery.

immediate interim ISCFDPs have become a popular treatment option.[14–17] The conventional approach involves converting a denture into a screw-retained interim restoration with interim abutments,[17–20] but alternative techniques have emerged.[21–23] One of the innovative methods is the closed-mouth pickup technique (Smart Denture Conversion—SDC system; Keystone Dental Inc), which eliminates the need for extensive denture perforations.[24] This system secures titanium cylinders to the multiunit abutments (MUA) using a unique split prosthetic screw, allowing easy denture removal before major adjustments.[24] This SDC system streamlines the chairside conversion process and enhances the strength of the interim prosthesis by minimizing access size.

This case report showcases using a 3D-printed polychromatic flangeless trial denture and a customized anatomic bone reduction template to contour bone architecture and gingival contours while ensuring optimal prosthetic space for an FP-1 restoration. Additionally, the closed-mouth pickup system improved the strength and efficiency of the immediate interim ISCFDPs, seamlessly integrating with a fully guided implant placement workflow for enhanced surgical precision and esthetic predictability. Lastly, the intraoral scan (IOS) protocol was used to fabricate prototype and definitive prostheses.

CLINICAL REPORT

Initial exam and clinical findings

A 63-year-old male presented with the chief complaint, "My upper front teeth keep getting longer, and many of my teeth need to be removed. I do not want anything removable in my mouth". Extraoral assessment revealed an unsatisfactory appearance due to excessive gingival display at a full smile, attributed to vertical maxillary excess (VME), occlusal plane disharmony, and incisal-edge malposition (Figure 1a,b). Periodontal examination confirmed generalized stage IV, grade C periodontitis with multiple class III maxillary mobile teeth (Figure 1c,d). The patient was presented with several treatment options, including conventional complete dentures, implant-assisted removable prostheses, and ISCFDP. He carefully considered all options and chose to proceed with extracting the remaining maxillary teeth, followed by placing six implants to support a maxillary ISCFDP. It was also explained to the patient that, although his reluctance to wear a removable prosthesis was fully understood, implant planning should be based on the ideal tooth arrangement, which is best evaluated using an interim denture. For this reason, wearing an interim denture prior to implant planning and placement was recommended. The importance and necessity of this approach were acknowledged, and informed consent for the proposed treatment sequence was obtained. Furthermore, three dental implants and implant-supported crowns were to be completed in the mandible. This clinical report focuses on the maxillary rehabilitation; however, the mandibular implant treatment was also conducted during the same time frame as the maxillary rehabilitation.

Treatment planning

A diagnostic IOS was made with an intraoral scanner (Trios 4 Wireless, 3Shape A/S), and an interim maxillary denture was designed using computer-aided design (CAD) software (3Shape Dental System, 3Shape A/S). The 3D-printed monolithic polychromatic denture was additively manufactured utilizing polyjet technology (TrueDent; Stratasys) (Figure 2a,b). The interim denture was delivered immediately following tooth extraction and was used by the patient for 2 weeks to verify esthetics, phonetics, centric relation, and vertical dimension of occlusion (OVD) (Figure 2c). To determine the optimal prosthetic design, a second set of monolithic polychromatic dentures was 3D-printed with elimination of labial denture extension as a flangeless trial denture. This modification allowed objective and subjective esthetic evaluation of facial support without the denture flange (Figure 3).

Based on the esthetic assessment, the esthetic risk was classified as high, given the visibility of the maxillary ridge during a full smile (Figure 3). The LTR classification was

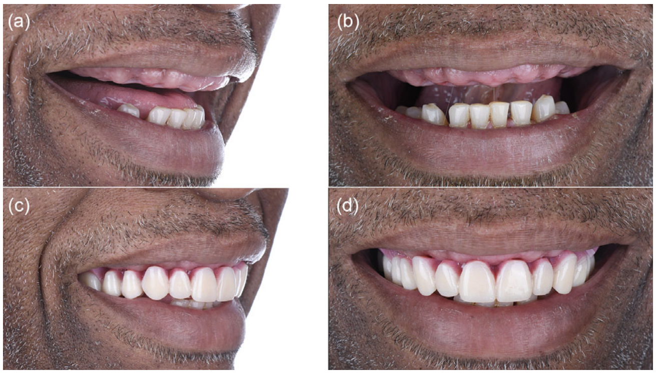

FIGURE 3 Flangeless trial denture. (a) Lateral view without trial denture. (b) Frontal view without a trial denture. (c) Lateral view with trial denture. (d) Frontal view with trial denture.

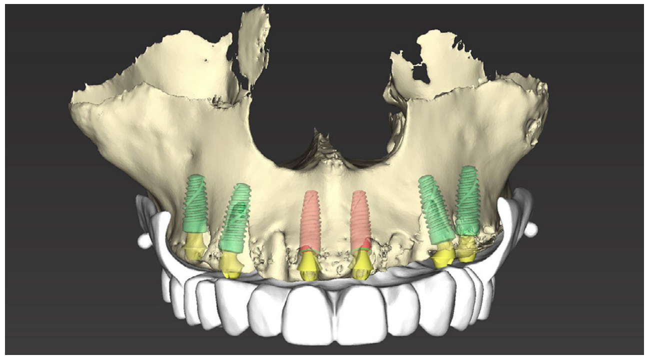

FIGURE 4 Digital implant planning simulation enhances communication between the restorative dentist and the surgeon by providing a comprehensive and interactive visual representation of the treatment plan.

classified as Class I-HER (high esthetic risk).[5] This scenario involved a high esthetic risk, requiring meticulous planning and execution. The OVD and incisal edge position were evaluated. Minor bone reduction was deemed necessary based on esthetic, phonetic, and occlusal considerations, along with patient feedback to reduce gingival display during smiling. The flangeless trial denture was used for the dual scan procedure by attaching fiducial markers (CT-Spot 119; Beekley Corp) to it. The interim denture was scanned with a laboratory scanner (E4; 3Shape A/S) to facilitate subsequent surgical template design. The digital scan of the interim denture was necessary for designing the fixation pin positioning template, as the flange was required to position the fixation pins.

Digital implant planning

After the dual scan using the flangeless trial denture, two sets of digital imaging and communications in medicine (DICOM) data were imported into implant planning software (coDiagnostiX, Dental Wings Inc) along with the digital scan of the interim denture. These files were merged using fiducial markers and the anatomy of the denture teeth. The maxillary implant plan included six bone-level implants (BLC; Institut Straumann AG, 4.5 × 10 mm at site #3, 4.5 × 12 mm at sites #5, #12, and #14, and 3.75 × 12 mm at sites #8 and #9). Based on the trial denture insertion, the OVD was adequate, but the gingival and tooth display were slightly excessive. Straight MUAs (RB/WB Screw-Retained Abutment, Straight, Ø 4.6 mm, GH 2.5 mm, TAN; Institut Straumann AG) were planned for sites #3 and 14, while angled multiunit abutments were selected to address the discrepancy between the desired tooth position and the available alveolar bone anatomy. Specifically, 17° angled abutments (RB/WB Screw-Retained Abutment, Angled 17°, Ø 4.6 mm, GH 3.5 mm, TAN; Straumann AG) were planned for sites #5 and 12, and 30° angled abutments (RB/WB Screw-Retained Abutment, Angled 30°, Ø 4.6 mm, GH 3.5 mm, TAN; Straumann AG) for sites #8 and 9 (Figure 4).

After determining the implant positions, MUAs, and the required amount of bone reduction, three sets of sequential surgical templates were digitally designed using implant planning software (coDiagnostiX, Dental Wings Inc.). First, a fixation pin positioning template with three fixation pins was generated based on the interim denture (Figure 5a). Second, an anatomical bone reduction template was designed (Figure 5b). Specifically, after communicating with the patient to achieve the desired prosthetic margins below the smile line and reduce gingiva and tooth display (as per the patient's desires), the prosthetic margin should be positioned apically about 3 mm from the flangeless trial denture. A scalloped cut profile was outlined following the new desired prosthetic margin, and the anatomical bone reduction template was generated 3 mm away from this profile by setting the "Profile offset" parameter to 3 mm (Figure 5c) in the implant planning software (coDiagnostiX). Third, an implant placement template was generated according to the planned implant position and designed to be stabilized by fixation pins, ensuring precise implant placement (Figure 5d).

Both the fixation pin positioning template and the implant placement template were 3D-printed (Asiga Max; Asiga) using surgical template resin (KeyGuide Resin; Keystone Industries) (Figure 6a,b), while the anatomical bone reduction template was fabricated using selective laser melting (SLM) with cobalt-chromium (Co–Cr) alloy (Bertram Dental Labs) (Figure 6c). Additionally, the digital scan of the flangeless trial denture was milled in PMMA (Ivotion Dent Multi; Ivoclar Vivadent) to serve as the immediate loading device (Figure 6d).

Implant placement and immediate loading procedure

Implant placement and immediate loading were performed under local anesthesia. The fixation pin positioning template was placed to facilitate osteotomy for fixation pin drills (Figure 7a). A full-thickness flap was elevated following an incision to expose the alveolar crest. The anatomical bone

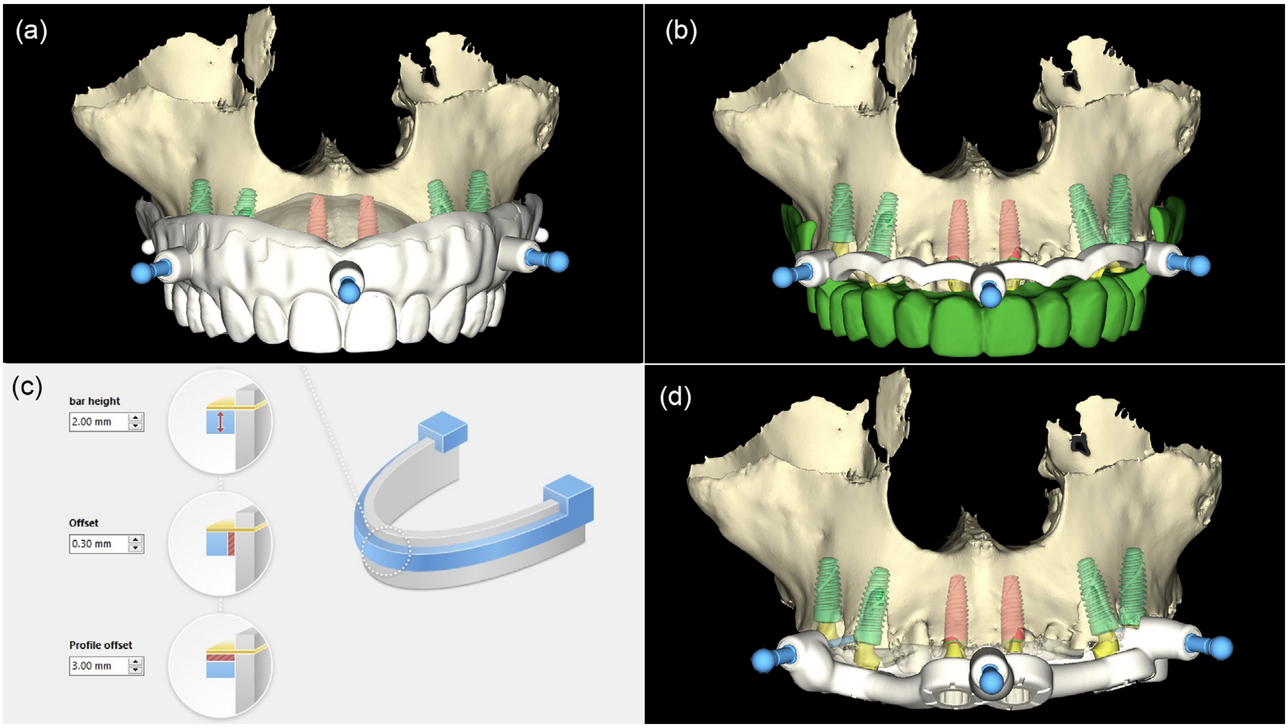

FIGURE 5 Digitally designed sequential surgical templates for static computer-aided implant surgery (s-CAIS). (a) Fixation pin positioning template. (b) Anatomical bone reduction template. (c) "Profile offset" parameter set to 3 mm, (d) implant placement template.

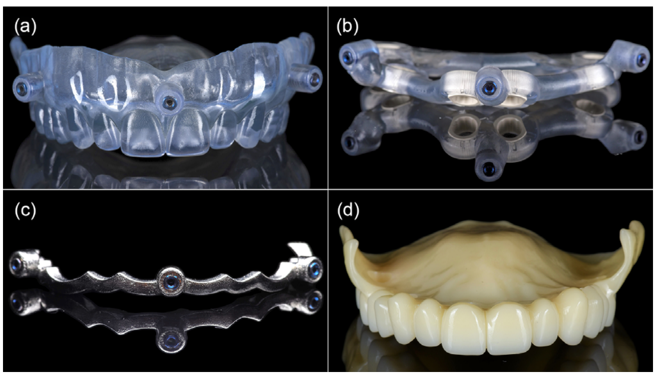

FIGURE 6 Additively manufactured surgical guides and an immediate loading device. (a) Fixation pin positioning template, (b) implant placement template, (c) anatomical bone reduction template, and (d) immediate loading device.

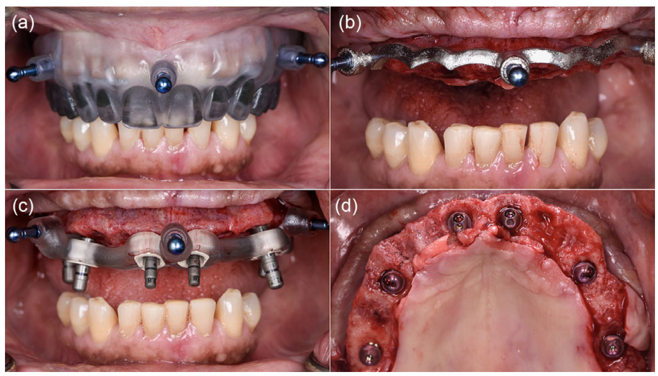

FIGURE 7 Static computer-aided implant surgery. (a) The fixation pin positioning template secured in position. (b) An anatomical bone reduction template was used to guide bone reduction. (c) An implant placement template was used to guide implant placement. (d) Multiunit abutments were placed, and the immediate loading device was prepared for pickup.

reduction template was positioned using the fixation pins, and bone reduction was performed with a round bur according to the template (Figure 7b). Subsequently, the implant placement template was secured with the same fixation pins, and six bone-level implants were placed in a fully guided manner according to the surgical protocol (Figure 7c). All implants achieved primary stability at 50Ncm, after which MUAs were placed onto the implants and torqued to 35Ncm (Figure 7d). The immediate loading device was converted to an interim ISCFDP by using the closed-mouth pickup technique (Smart Denture Conversion—SDC system) (Figure 8a). The interim ISCFDP was finished and polished (Figure 8b,c). A postoperative panoramic radiograph was obtained to assess implant placement and prosthetic adaptation (Figure 8d).

Fabrication and delivery of definitive prosthesis

Three months postimplant placement and immediate loading, digital data was acquired using an intraoral scanner (Trios 4 Wireless; 3Shape A/S). The scanning process began with capturing the maxillary interim ISCFDPs in situ,

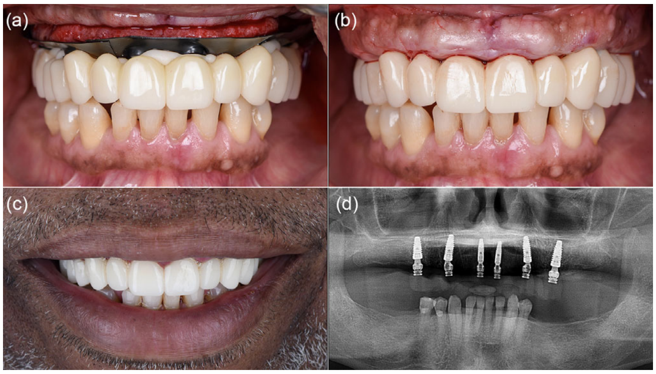

FIGURE 8 Immediate loading procedure. (a) An immediate loading device and a closed-mouth pickup technique were used to complete an interim implant-supported complete-arch fixed dental prosthesis (ISCFDP). (b) Postsurgical intraoral view of the interim ISCFDP in situ. (c) Postsurgical extraoral smile view of the interim ISCFDP. (d) Panoramic radiograph.

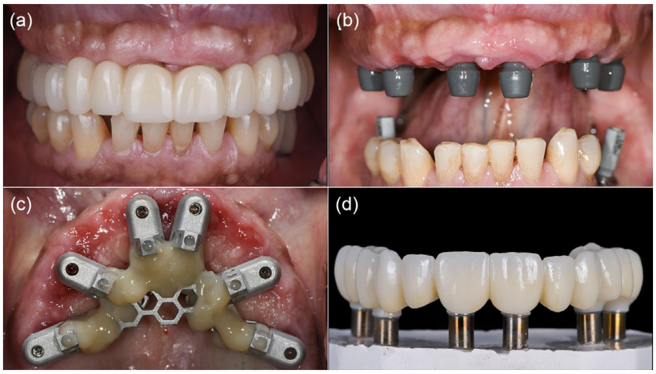

FIGURE 9 Data collection for definitive implant-supported complete-arch fixed dental prostheses (ISCFDPs). (a) Scanning the maxillary interim ISCFDPs, opposing dentition, and maxillomandibular relationship. (b) A soft tissue scan was obtained using soft tissue scan caps. (c) Scanbodies were luted with a metal frame. (d) Definitive ISCFDP was luted to the titanium copings on the verification stone cast.

mandibular dentition and implants, along with the maxillomandibular relationship (Figure 9a). Subsequently, soft tissue scan caps were hand-tightened onto MUAs, and a maxillary soft tissue scan was obtained, ensuring sufficient data for the fabrication of the definitive ISCFDPs (Figure 9b). Next, implant scanbodies (Optisplint; Digital Arches) were hand-tightened to the MUAs. To enhance accuracy, the metal frame was trimmed and luted to the scanbodies using an ultralow shrinkage light-polymerizing composite resin (Filtek Supreme Flowable Restorative; 3M, St Paul, MN) intraorally (Figure 9c). Finally, the splinted scanbodies-metal frame assemblies were removed from MUAs and scanned extraorally. MUA analogs were attached to splinted scanbodies-metal frame assemblies, and a verification stone cast was poured using type IV dental stone (Silky-Rock; Whipmix).

These digital data were aligned in the software (exocad Dental CAD; exocad GmbH) to design a prototype prosthesis to confirm the desired functional and esthetic outcomes. After the trial insertion of the prototype prosthesis, the definitive monolithic zirconia ISCFDP was fabricated on titanium copings (Variobase for Bridge/Bar cylindrical coping; Institut Straumann AG, Basel, Switzerland) using a multichromatic blend of 3 and 5 mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP and 5Y-TZP) (IPS e.max ZirCAD Prime; Ivoclar Vivadent), along with translucent, semitranslucent, and opaque self-glazing pastes (Esthetic System Kits; Jensen Dental). The definitive ISCFDP was luted to the titanium copings using a dual-polymerizing resin luting agent (Panavia V5; Kuraray America, Inc.) on verification stone cast (Figure 9d). The definitive ISCFDP was then delivered intraorally after clinical and radiographic assessments (Figure 10a,b,c).

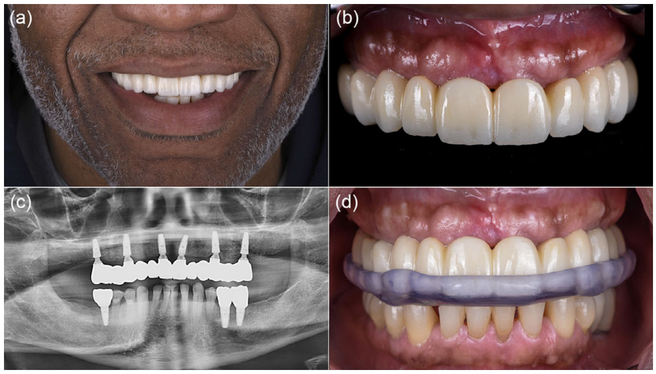

FIGURE 10 Definitive restorations were placed. (a) Posttreatment extraoral view of smile. (b) Posttreatment intraoral presentation. (c) Posttreatment panoramic radiograph. (d) 3D-printed occlusal splint.

Maintenance and follow-up

One week after the delivery of the final prosthesis, a maxillary full-arch occlusal splint was digitally designed based on an IOS performed with a leaf gauge with 3 mm opening in the anterior region. The occlusal splint was 3D-printed using resin (KeySplint Hard, Keystone Dental Inc.). The occlusal scheme was established to ensure simultaneous posterior contacts in centric relation occlusion, with anterior guidance achieved during protrusive and lateral excursions (Figure 10d). The patient was instructed to wear the occlusal splint during sleep to protect the prosthesis and maintain occlusal stability. The follow-up appointment was scheduled 1 month after delivery of the occlusal splint, during which a prophylactic cleaning was performed by a dental hygienist using an air polishing unit (Airflow Prophylaxis Master; EMS Electro Medical System SA) with erythritol-chlorhexidine powder (Airflow Plus; EMS Electro Medical System SA). Subsequent follow-up appointments were scheduled at 3 months and thereafter at 6-month intervals. The patient expressed satisfaction with the esthetics, phonetics, and masticatory function of the definitive prosthesis at 1-year follow-up.

DISCUSSION

This article highlights that with comprehensive diagnosis and careful treatment planning, integrating analog and digital workflows provides an adequate approach for restoring terminal dentition with a CAD-CAM, FP-1, ISCFDP. Maxillary edentulous patient rehabilitation with implant-supported dental prostheses presents greater challenges compared to the mandibular arch due to anatomical constraints, biological considerations, and particularly esthetic demands that influence prosthetic design, whether fixed or removable.[25] The decision-making process requires careful assessment, beginning with the establishment of optimal tooth positions and an appropriate OVD in centric relation (CR). If both parameters need to be determined, as in this patient's case, fabricating a conventional or interim complete denture is typically the first step in the diagnostic workflow. A sequential approach was adopted to enhance predictability and treatment outcomes. An immediate interim maxillary complete denture was delivered to verify proper esthetics, phonetics, and maxillomandibular relationship. A key advantage of utilizing an interim denture is the ability to assess the patient's facial profile in different conditions—without a prosthesis, with a diagnostic denture, and with a flangeless diagnostic denture (Figure 3). This sequential evaluation facilitates an objective determination of the necessity for facial support, a factor that significantly impacts the final prosthetic design and its esthetic and functional outcomes.

The Lip-Tooth-Ridge classification was classified as Class I-HER (high esthetic risk). Reducing esthetic risk would require vertical alveoloplasty to reposition the prosthesis-ridge transition line apically below the smile line. However, this approach would compromise the available alveolar bone for implant placement, making the procedure invasive and irreversible. Excessive bone reduction would also eliminate the possibility of an FP-1 or FP-2 prosthesis, leaving FP-3 as the only viable option. FP-1 was chosen as the definitive prosthesis, necessitating meticulous treatment planning and precise execution to achieve a predictable and esthetic outcome. Therefore, the anatomical bone reduction template, derived from the flangeless mock-up try-in diagnostic denture, holds significant value, as demonstrated in this report. It seamlessly transitioned from accurate diagnostics to predictable surgical procedures, optimizing treatment outcomes.

Virtual implant planning, combined with a comprehensive diagnostic process and digital scanning protocols, facilitates a prosthetically driven approach to implant placement.[26] This methodology enables precise visualization of ideal prosthetic tooth positioning, restorative space, osseous architecture, abutment selection, and soft tissue contours, ensuring a predictable and optimized treatment outcome. Additionally, artificial intelligence (AI) is gaining significant traction in digital implant planning, with guided and robotic-assisted implant surgeries improving placement accuracy, reducing surgical invasiveness, and enhancing long-term treatment success.[27] In this case report, the authors implemented a sequential static computer-aided implant surgery (s-CAIS) approach, utilizing an anatomical bone reduction template. This approach was chosen to prevent potential displacement of the implant placement template, a risk commonly associated with stackable template systems.

Material selection for each template in s-CAIS is essential for achieving surgical precision, durability, and procedural efficiency. The two primary materials used in template fabrication—printing resin and Co–Cr—offer distinct advantages based on clinical requirements.[28,29] 3D-printed resin is widely preferred due to its cost-effectiveness and ease of fabrication. However, a minimum material thickness is required to maintain structural integrity during surgery to prevent fractures or deformations that could compromise template stability. Conversely, Co–Cr templates, despite higher production costs, provide greater strength and rigidity, enabling a thinner, more space-efficient design. This enhances surgical accessibility and minimizes intraoperative obstructions.[28,29] Additionally, material selection influences critical template design parameters, such as offset values, which are crucial for accurate fabrication and clinical performance. Failure to account for these material-specific properties may result in technical complications that affect surgical precision and efficiency.

The definitive ISCFDP was fabricated using an intraoral digital workflow, optimizing efficiency during the prosthetic phase. A key advantage of the OptiSplint (Digital Arches) system, utilized in this case, is its splinted scanbody-metal frame assemblies, which not only facilitated digital data acquisition but also serve as a verification device for producing a verification cast to ensure the passive fit of the definitive prostheses. This enables physical verification of digital workflow, enhancing the accuracy of cementation and occlusal adjustments, thereby minimizing chairside modifications and improving the overall treatment predictability.[30]

Despite the successful outcome presented in this case report, certain limitations must be acknowledged. It is worthwhile noting the changes in tooth form and shape, especially in the anterior teeth, from the flangeless trial denture to the definitive monolithic zirconia ISCFDP. The tooth form and shape in the flangeless trial denture were more triangular, while in the definitive ISCFDP, they were more square. Although bone reduction was planned and performed according to the proposed tooth form and shape, the exact amount of hard and soft tissue remodeling was challenging to predict. To avoid dark spaces in the embrasure region, the tooth form and shape were modified. These possible changes were explained to the patient at the treatment planning stage, and potential esthetic discrepancies between the trial and definitive prostheses should be clearly communicated to the patient. The report describes a single patient case, limiting generalizability of the findings. Variations in anatomical features, healing responses, and patient-specific esthetic demands could influence treatment outcomes in other cases.

Additionally, using advanced digital technologies and materials such as 3D-printed polychromatic dentures and Co-Cr templates may not be accessible in all clinical settings due to cost or equipment availability. Future clinical studies involving larger sample sizes and extended follow-up periods are necessary to validate these results.

CONCLUSION

This report emphasizes the clinical value of using an anatomically designed bone reduction template derived from digital planning and a flangeless trial denture for achieving predictable, prosthetically driven outcomes in FP-1 restorations. Unlike conventional flat guides, the anatomic template matched the desired prosthetic contours, allowing minimal yet effective bone reduction to preserve esthetics and soft tissue harmony. By leveraging a fully digital workflow, including intraoral scanning and guided surgery, the treatment ensured precision, efficiency, and improved esthetic and functional results in full-arch implant rehabilitation.

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