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The Digital Workflow for the Design and Fabrication of Digital Overdenture

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ABSTRACT

This clinical technique article describes the clinical and digital workflow for the design and fabrication of implant-retained overdentures using a fully digital approach. The study emphasizes efficiency, predictability, and patient-centered care. The workflow describes the digital implant planning, guided surgery, CAD/CAM bar fabrication, and final prosthesis insertion. This protocol aims to inform both clinical practice and education while laying the groundwork for broader investigations.

Keywords: Digital dentures, Digital design, Surgical guide, 3D printing, Guided surgery, Overdenture, Edentulous patients.

1. Introduction

The introduction of "Digital Dentures" was made possible by the development of intraoral scanners, which enable the scanning of both hard and soft tissues. The earliest workflow by Goodacre described the procedure for the fabrication of digital complete dentures in three appointments (1). The first appointment involves taking scans of the edentulous arches and an interocclusal record. The second visit is the try-in visit, where tooth positions are confirmed, and the third visit is the insertion visit. This protocol set the groundwork for the implementation of CAD/CAM (Computer-Aided Design/ Computer-Aided Manufacturing) in removable prosthodontics, potentially reducing chair time and the number of required dental visits (2). Additional advantages include the ability to capture tissues in their actual mucostatic state, which is particularly important in patients with flabby tissues, and the color image of the scan, which enables the differentiation of the denture extensions (2).

Some limitations of digital impression making for the moving tissues of the mandible necessitate a reline impression of the mandible and modification of the scanning technique. Additionally, there are high initial costs, limited access to digital tools in specific settings, and a steep learning curve for clinicians transitioning from conventional methods (3). Strategies to overcome barriers to implementing digital dentistry techniques in everyday practice include evaluating practitioners' technology perceptions, comprehensive training programs, and intensive hands-on educational courses (4).

The use of scanning has numerous applications in the field of removable prosthodontics, for example, complete dentures, removable partial dentures, immediate dentures and maxillofacial prosthesis (5).

This clinical technique article outlines the protocol for digital implant planning, as well as the design and fabrication of a surgical guide, a milled titanium bar, and a 3D-printed digital denture (Figure 1). This project holds educational value by clearly documenting the clinical and laboratory workflow involved in the design

and fabrication of digital overdentures for a 55-year-old patient. By presenting each step in a structured and practical manner, the work serves as a comprehensive guide for general practitioners and postgraduate dental students. It aims to demystify the digital overdenture protocol, enhance the understanding of contemporary prosthodontic practices, and bridge the gap between traditional techniques and modern digital solutions in removable prosthodontics.

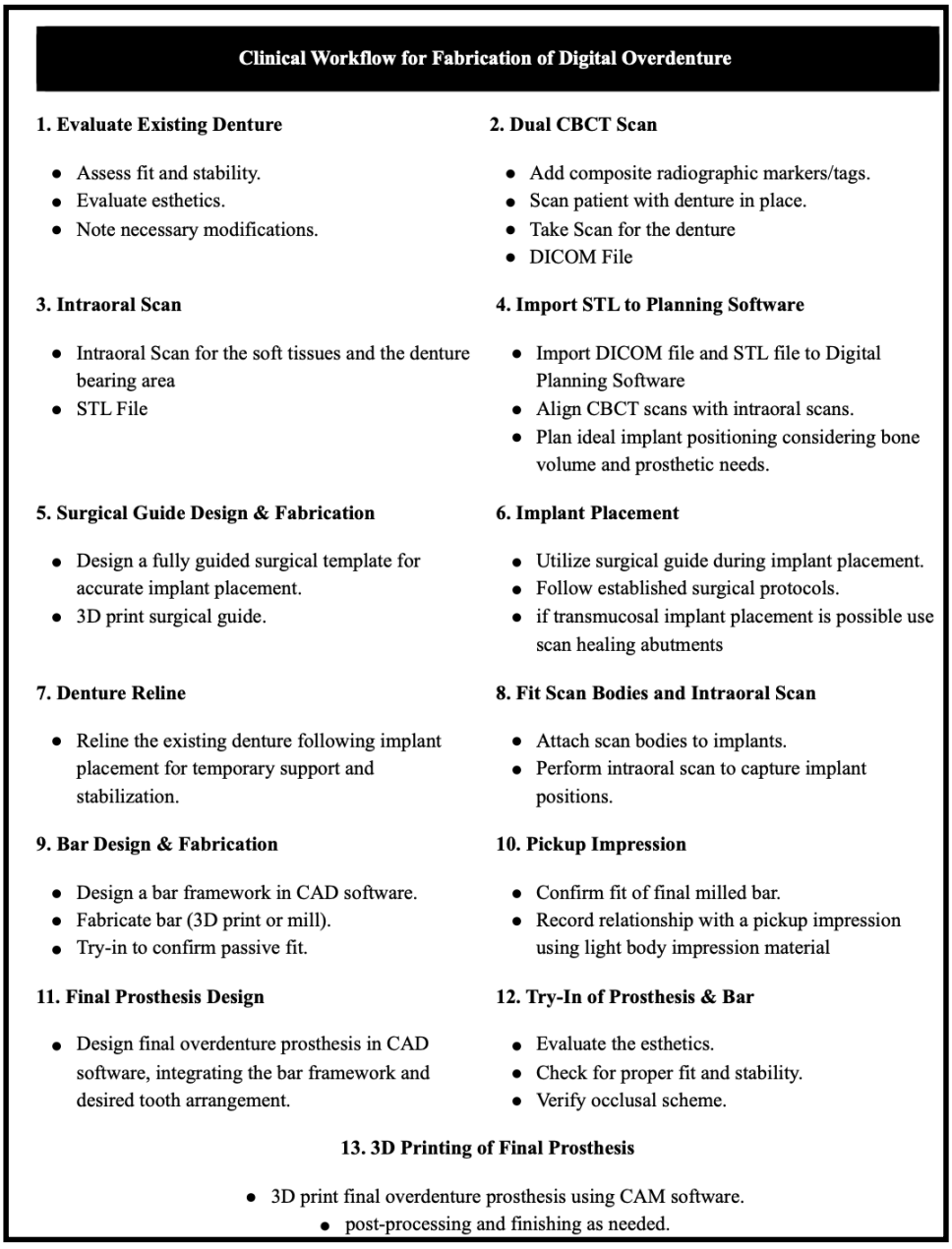

Figure 1: Clinical workflow for fabrication of digital overdenture

2. Clinical Workflow

2.1 Patient Selection and Inclusion Criteria

A 55-year-old healthy male presented Jordan University of Science and Technology Dental Teaching Clinics with complete maxillary edentulism for over six months and sought a removable implant-retained prosthesis. Clinical evaluation and CBCT imaging demonstrated adequate bone volume and favorable ridge morphology to allow digitally guided implant placement without the need for augmentation. The patient was medically fit (ASA I), a non-smoker, and had no contraindications to implant surgery.

2.2 Pre-prosthetic Assessment

Institutional Board Approval was obtained, and the patient signed informed consent for participation and for using the photographs for educational and publication purposes.

The Prosthodontic Diagnostic Index PDI criteria were applied for comprehensive patient examination (Table 1) (6). The integrated diagnostic criteria showed favorable mandibular ridge height in the anterior mandibular region (Type A). Residual ridge morphology resists vertical and horizontal movements in the maxilla (Type A), the muscle attachments were favorable in the mandible, which was conducive to the retention and stability of the mandibular denture (Type B), and a Class-I maxillomandibular relationship. However, since dental implants are needed, the integrated classification of the PDI diagnostic criteria is Class III.

Table 1: ACP checklist for classifying the completely edentulous patient

Checklist for classification of a completely edentulous patient	Class I	Class II	Class III	Class IV
Criteria 1: Mandibular bone height				
Type A: 21 mm or greater	✓			
Type B: 16 - 22 mm				
Type C: 11-15 mm				
Type D: 10 mm or less				
Criteria 2: Residual ridge morphology - maxilla				
Type A - Resists Vertical and Horizontal – Hamular Notch - No tori	✓			
Type B - No Buccal Vestibule, poor hamular Notch, no tori				
Type C - No anterior Vestibule - minimum Support, mobile anterior ridge				
Type D - No anterior/ posterior vestibule , tori , redundant tissue				
Criteria 3: Muscle attachment - mandibular				
Type A - adequately attached mucosa	✓			
Type B- No buccal attached mucosa + mentalis muscle				
Type C - No anterior buccal and lingual vestibule genioglossus and mentalis				
Type D - Attached mucosa only in the posterior area				
Type E - no attached mucosa, lip/cheek move tongue				
Maxilla - mandibular relationship				
Class I	✓			
Class II				
Class III				
Conditions require pre-prosthetic surgery				
Minor Soft Tissue Procedure				
Minor Hard Tissue Procedure				
Implants - Simple			✓	
Implant with bone graft - complex				
Correction of dentofacial deformities				
Hard tissue augmentation				
Major soft tissue revisions				
Limited inter-arch space				
18-20 mm	✓			
Surgical correction needed				
Tongue anatomy				
Large (occludes interdental space)				
Hyperactive (with retracted position)				

Modifiers				
Oral manifestations of systemic disease				
Mild				
Moderate				
Severe				
Psychosocial				
Moderate				
Major				
TMD symptoms				
History of paresthesia/dysesthesia				
Maxillofacial defects				
Ataxia				
Refractory Patient				

The SAC (Straightforward-Advanced-Complex) classification of implant dentistry, as defined by the International Team of Implantology (ITI) online diagnostic tool, was applied (7). The surgical classification was straightforward, given the simplicity of the surgical procedure and the absence of any need for additional augmentation procedures. However, prosthetic rehabilitation was classified as complex, given the need to fabricate a milled bar and 3D-printed dentures (Figure 2).

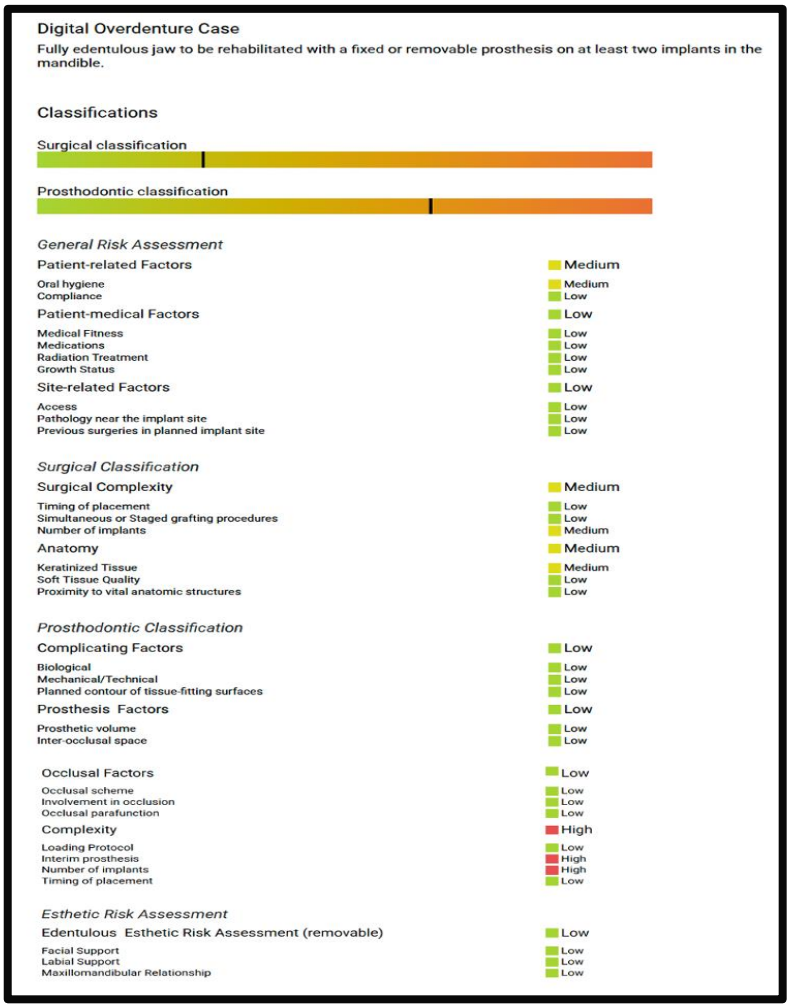

Figure 2: SAC classification

The rehabilitation process and digital treatment planning began with well-fitting dentures that provided intimate contact with the mucosa and exhibited no rocking movements. With correct occlusion at the correct vertical dimension, the existing complete dentures were evaluated based on their retention, support, and stability, as well as aesthetics, occlusion, and the health of the supporting tissues (Figure 3). The patient's expectations and preparedness to maintain and tolerate the denture were also evaluated at this stage, as they are considered crucial for the success of the rehabilitation.

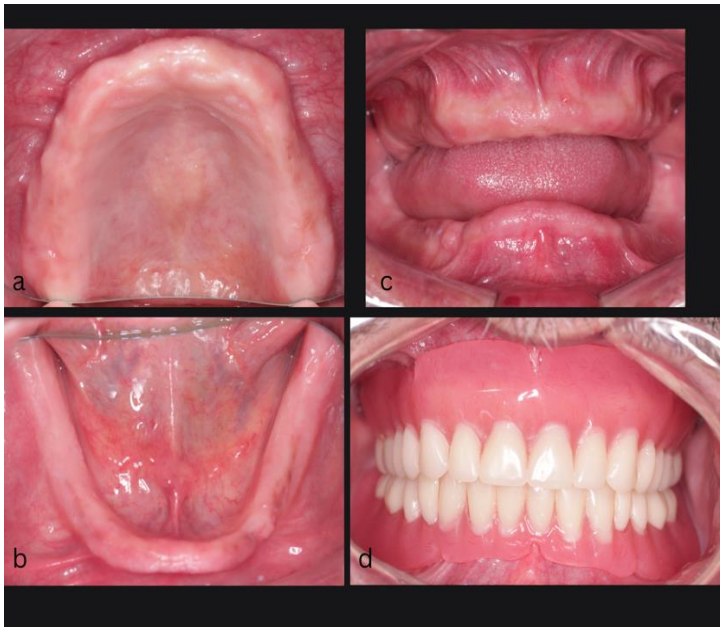

Figure 3: a. Edentulous maxilla, b. Edentulous mandible, c. Maxillomandibular relationship, d. Existing dentures

2.3 Dual Scan Technique

Cone beam computed tomography (CBCT) scans were used in surgical treatment planning for edentulous patients to obtain data for planning the implant site and creating a surgical guide for implant positioning, thereby eliminating the need for a radiographic guide that duplicates the patient's existing dentures.

The mandibular denture was marked with seven widely spaced composite tags on the cameo surface of the denture (Figure 4 a). These tags were crucial for referencing and aligning the denture during implant planning software use.

The Cone Beam Computed Tomography CBCT dual scanning technique started by scanning the patient with the marked denture at the correct vertical dimension of occlusion and centric relation using the CS8200 (Carestream Dental, USA) CBCT machine. The scan was taken while the patient was wearing the dentures in occlusion at centric relation, with the patient's mandible resting on the chin rest without biting on the bite fork. This step was essential to prevent the denture base from tipping, ensuring smooth alignment in the planning software. In addition, cotton rolls were placed in the maxillary and mandibular buccal vestibules to create "air space" in the final image, making it easier to trace and align dentures to the intraoral scan data at a later stage.

A second CBCT was made for the mandibular denture at a lower exposure. The denture was held on a styrofoam base, which also creates an air space around the mandibular denture in the final image (Figure 4 b).

An intraoral scan of the edentulous arches was made, forming the intaglio surface of the denture base using Trios 5 (3Shape, Copenhagen, Denmark) intraoral scanner (Figure 5 a). The intraoral scanner is used to scan and digitize the maxillary and mandibular arches along with the existing dentures, including their tooth positions and base forms, and a centric relation record (Figure 5 b). Scan files were saved in the standard tessellation language (STL) file format.

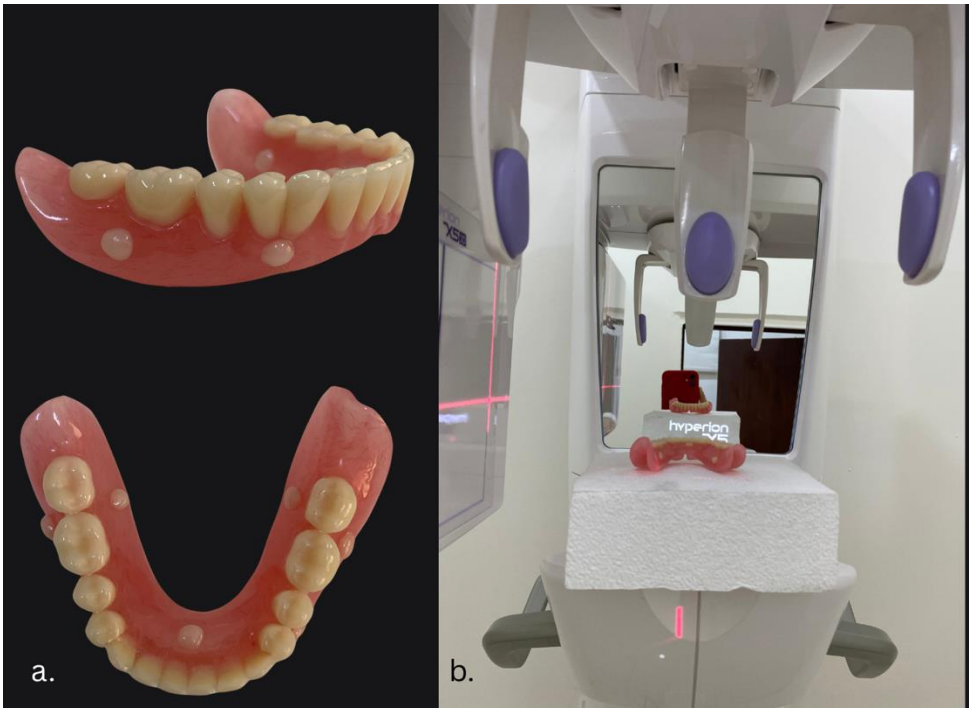

Figure 4: Dual scan technique, a. Composite tags on the cameo surface of the denture, b. Denture scanning using a styrofoam base, which is levelled at the approximate level of the mandible

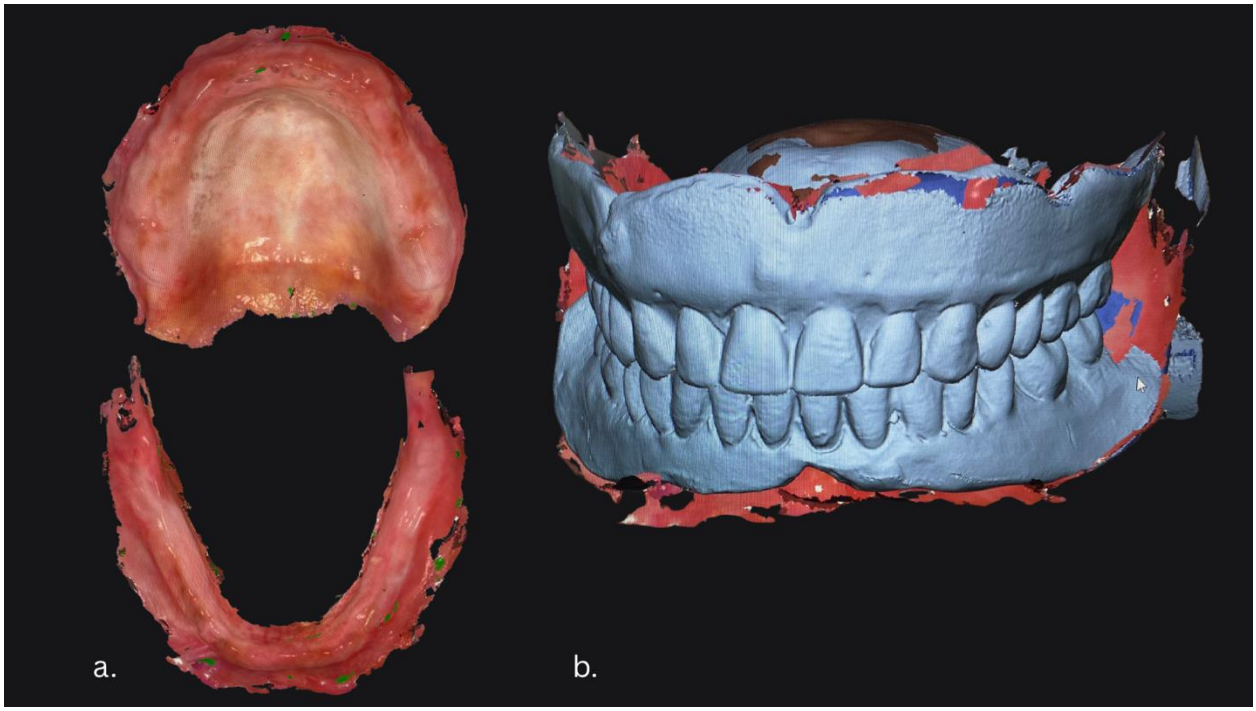

Figure 5: a. Intraoral scan, b. Denture scan

2.4 Digital Implant Planning, Surgical Guide Design and Fabrication

Intraoral scan (IOS) STL files and CBCT DICOM files were viewed using implant R2Gate (Megagen) CAD software, to plan the strategic position of the implants in the mandible (Figure 6). The software converts the DICOM data obtained from the Dual CBCT scan into STL and combines it with the data obtained from the IOS. All images were aligned to create a 3D model of the edentulous bone, soft tissues, and dentures,

allowing for accurate space analysis and implant position planning.

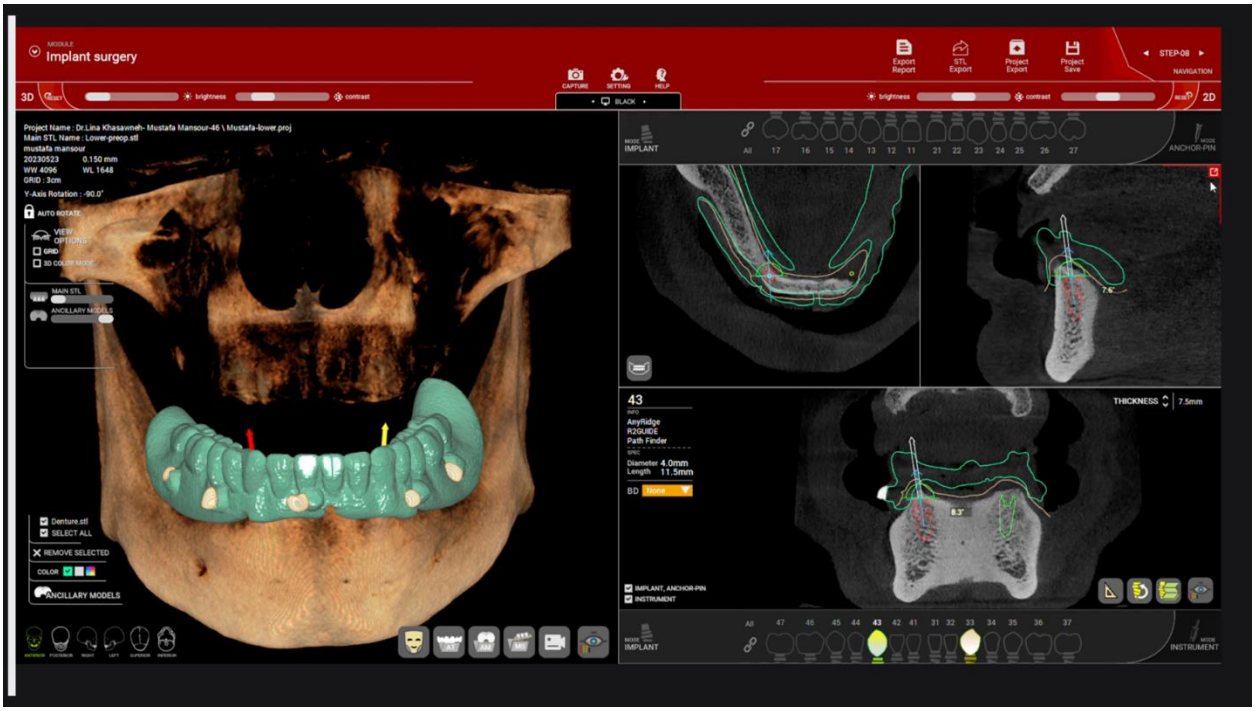

Figure 6: Digital planning using R2Gate software

Two bone–level Anyridge (Megagen, South Korea) dental implants of 4 mm and at least 8 mm length are planned in the mandibular canine–first premolar area. A sleeveless, keyless surgical guide with three anchor pins was designed and printed (Figure 7 a, b) (8).

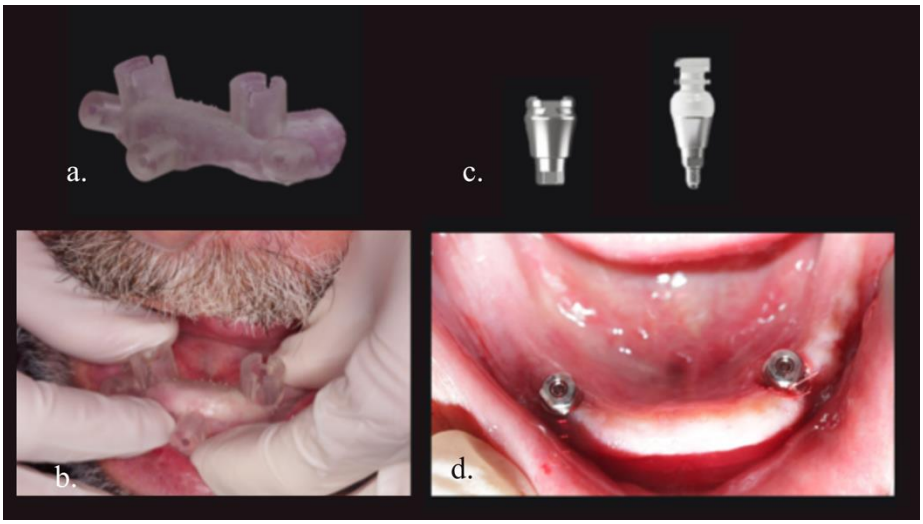

Figure 7: a. 3D printed surgical guide, b. Fitting of the surgical guide, c. Scan healing abutments, d. Transmucosal implant placement

2.5 Surgical Procedure

The surgical procedure was carried out under local anesthesia by a periodontist (R.A.). Flapless, fully guided placement was planned. The guide was tried on first to ensure an accurate fit, and the pins were used to secure it in place. A tissue punch was used to remove a small circular section of the keratinized tissue around the implant position. This is to ensure a minimally invasive procedure with minimal post-operative pain and discomfort. The drilling protocol of the R2Gate software (Megagen) was followed. Primary stability was measured using Osstell®. Implant Stability Quotient

(ISQ) value was 40 Ncm. Transmucosal scan healing abutment was placed (Figure 7 c, d).

2.6 Bar Design, Bar Printing, and Try-in

A scan body was snapped onto the scan healing abutment, and a new IOS was made using the Trios (5) (3Shape, Copenhagen, Denmark) scanner. The milled bar design was carried out using Exocad (Exocad DentalCAD; Exocad GmbH) software. A telescopic milled bar with sleeves and a distal locator Bredent ball attachment (Bredent, USA) was planned. Pre-prosthetic space analysis was conducted to analyze the space requirements for bar design. The vertical height for a bar was 14 mm from the implant shoulder to the incisal edge of artificial teeth (9), divided as follows; (2mm) between soft tissue and the bar, (4) mm for the patrix (bar) vertically, (3mm) for the matrix (clip), (5mm) for denture base and teeth. A PEEK replica was tried intraorally to ensure accurate, passive fit, and once confirmed, the titanium bar was milled (Figure 8. a).

2.7 Digital Denture Design, Fabrication, and Fitting

A digital replica of the patient's existing dentures was made (10). Wash impression material was used to reline the dentures, and a scan was made of the denture's intaglio surface. A centric relation record was made of the dentures in occlusion. The scan is then transferred to Exocad software (Exocad DentalCAD; Exocad GmbH). A PEEK Replica of the design was milled and used for try-in, and the housing for the telescopic attachment is incorporated into the mandibular denture (Figure 8. b).

Once the correct aesthetics, phonetics, and centric relation were confirmed, the complete digital design was printed using OnX Tough (SprintRay) 3D printed resin, and processing, staining, and characterization were carried out using Optiglaze (GC America, Inc). Conventional steps were then followed up for insertion (Figure 8 c).

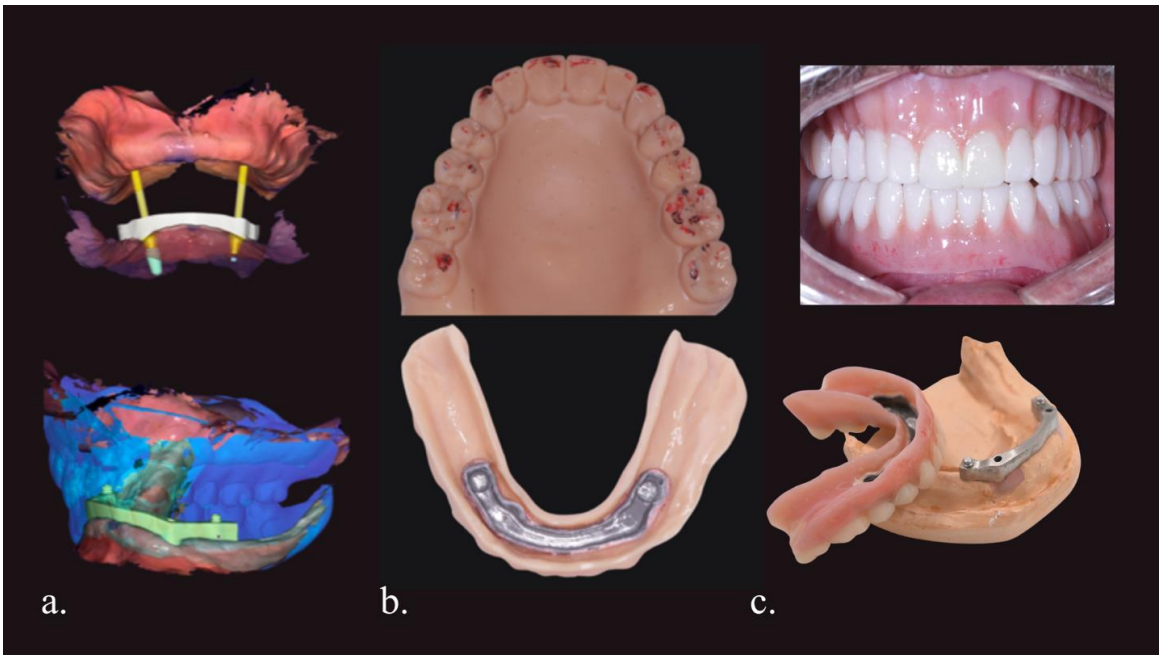

Figure 8: a. Restorative space analysis, b. Trial denture, c. Definitive prosthesis

2.8 Maintenance and Longevity

The patient was given post-operative instructions regarding the hygiene and maintenance of the overdenture. The denture must be daily cleaned with specialized denture cleansing tablets, in addition to using hand soap with lukewarm water after every meal for cleaning, and refraining from using toothpaste to clean the denture. In addition, the bar should be regularly cleaned with tooth brush and using interdental brushes for cleaning under the bar. The first recall visit was 24 hours after initial insertion, then at one week, then every three months in order to address any complications. The patient reported improved retention and masticatory function.

3. Results

This case report presents the digital workflow for oral rehabilitation of an edentulous patient using

digitally designed and fabricated maxillary complete denture and mandibular bar- retained overdenture. Data acquisition used digital tools for making impression, planning and designing soft tissue supported surgical guide for a flapless approach for implant placement.

The two mandibular implants achieved primary stability (40 Ncm), within the lower threshold of the commonly accepted stability range (35–70 Ncm) for immediate or early loading in overdenture cases. Space analysis confirmed an adequate restorative envelope (14 mm), aligning with recommended minimum space requirements (12–14 mm) for bar-retained overdentures. The PEEK bar prototype demonstrated a passive fit, consistent with reports that digital bar workflows reduce misfit and manual adjustments compared to conventional fabrication techniques.

The digitally fabricated maxillary dentures demonstrated exceptional retention due to the accuracy of fit between the intaglio surface of the denture and the soft tissues. In addition, the final 3D-printed overdentures seated accurately on the milled bar with minimal pressure spot adjustments, reflecting the reduced need for adjustment.

At follow-up visits, the patient showed healthy peri-implant soft tissues and reported markedly improved denture retention, comfort, and masticatory function, noting enhanced patient satisfaction and functional performance with implant-retained overdentures.

4. Discussion

In the present case, the customized CAD/CAM bar was designed according to the implant position and the morphology of the existing complete denture (11). A digitally guided workflow allows precise adaptation, with a printed bar replica tried intraorally to verify passivity before milling the definitive structure. The use of guided implant surgery facilitates accurate transfer of the virtual plan to the clinical setting. Previous studies indicated that a flapless, fully guided approach may reduce post-operative discomfort and improve soft tissue healing compared with open-flap procedures (12,13). The scan healing abutments used in this case contributed to optimal emergence profile development and soft tissue contouring (14).

Digital implant planning, which incorporates cone-beam computed tomography (CBCT) and intraoral scanning, enables a detailed evaluation of anatomical limitations and prosthetic requirements. CBCT images, aligned with a scanned denture containing radiopaque markers, facilitated prosthetically driven implant positioning. Virtual planning permits the selection of appropriate implant dimensions and angulation, and the surgical guide was exported in STL format for CAD/CAM manufacturing (15).

Transmucosal implant placement permitted the use of a healing scan abutment, onto which the scan body was subsequently attached. This approach reduced the number of required surgical interventions and allowed simultaneous fabrication of the bar sub-structure during the healing phase. The selected impression technique ensured accurate transfer of the implant positions to the definitive prosthesis.

Patients with bar retention may exhibit fewer prosthetic complications in the retention elements, but more problems at the level of the supporting mucosa (i.e., hyperplasia). However, the maintenance in overdenture might seem limited to renewal of the attachment device, particularly retentive clips of the bar, but this is still highly influenced by the bar design (16).

Long term follow-up data of two implant retained mandibular overdentures and their implants shows that survival rates are medium to high (17). Most commonly reported complications were the wear of the attachment and acrylic resin fracture (17).

Digital workflows for overdentures are emerging as a promising, increasingly accurate technique for implant prosthetic rehabilitation, with growing clinical evidence supporting their effectiveness. Recent studies demonstrated significant advantages, including reduced clinical appointments, improved precision, and high patient satisfaction (18).

5. Conclusions

The clinical outcome in this case reinforces the advantages of a fully digital, guided workflow for implant-retained overdentures. The integration of CAD/CAM technology, CBCT imaging, and guided surgery can enhance surgical precision, patient comfort, and prosthetically driven implant placement. Nevertheless, careful patient selection remains essential, particularly concerning available restorative space and peri-implant soft tissue conditions.

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design and fabrication of the surgical guide and definitive prosthesis.

Conflict of Interests

The authors have no conflict of interests to declare.

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