

The All-on-4 Concept: A Paradigm Shift in Full-Arch Rehabilitation

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Abstract: Severe alveolar ridge atrophy following tooth loss presents significant challenges in prosthetic rehabilitation. The All-on-4 concept, developed by Paulo Malo, offers a predictable and cost-effective solution for full-arch rehabilitation in edentulous patients. By strategically placing four implants—two anteriorly and two posteriorly at an angle—this technique maximizes bone utilization, minimizes the need for grafting, and enhances prosthetic stability. Multi-unit abutments and the Malo Guide play crucial roles in achieving accurate implant positioning and prosthetic alignment. The All-on-4 procedure can be performed using conventional flap or flapless guided techniques, with immediate loading providing significant advantages in treatment efficiency and patient comfort. While biomechanical stability and high survival rates validate the concept, careful planning and maintenance are essential to avoid complications such as prosthetic fractures and screw loosening. This review explores the principles, components, surgical protocol, and clinical outcomes of the All-on-4 treatment concept, emphasizing its advantages, limitations, and long-term effectiveness in implant dentistry.

Keywords: All-on-4 concept, Multiunit components, Malo guide.

Introduction: Severe alveolar ridge atrophy following tooth loss presents significant challenges in prosthetic rehabilitation. Conventional removable dentures often fail to provide adequate function and comfort. Implant-supported prostheses offer a superior alternative, with fixed full-arch restorations significantly enhancing patient quality of life. However, traditional implant protocols require extensive bone grafting and multiple implants, leading to prolonged treatment time and higher costs.

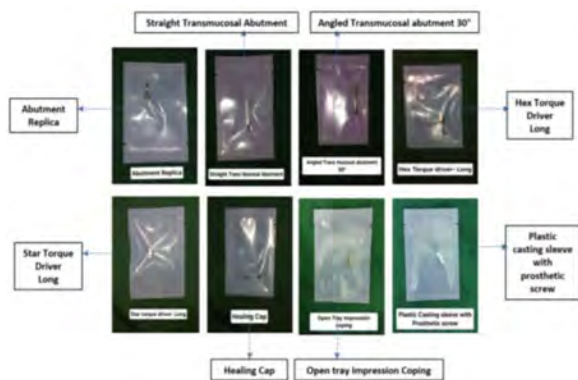
The All-on-4 concept, developed by Paulo Malo, provides an efficient solution by utilizing four implants: two anteriorly placed vertically and two posteriorly placed at an angle of up to 45°. This configuration maximizes the use of available bone, increases prosthetic stability, and reduces cantilever

forces. The multiunit abutments, available in straight and angulated designs, facilitate proper prosthesis positioning. The Malo Guide assists in ensuring accurate implant placement, leading to a predictable and successful outcome.

Applications of All-on-4:

The All-on-4 protocol is indicated for:

- Completely edentulous patients requiring full-arch rehabilitation.
- Patients with insufficient bone volume for conventional implants without grafting.
- Individuals seeking a minimally invasive, cost-effective alternative to traditional implant-supported prostheses.
- Cases requiring immediate prosthetic function and rapid recovery.



All-on-4 Kit:



A standard All-on-4 surgical kit typically includes:

- Precision drills for osteotomy preparation.
- Multi-unit abutments in various angulations.
- Guide pins and depth gauges for accurate implant positioning.
- Torque wrenches and implant insertion tools.
- Open tray impression copings for accurate prosthetic fabrication.

Malo Guide:



The Malo Guide is a surgical aid designed to ensure accurate implant positioning and angulation. It assists in maintaining an optimal anterior-posterior spread and reduces the risk of surgical misalignment. The guide also plays a crucial role in enhancing the predictability of prosthetic outcomes, particularly in

complex cases where bone resorption is significant.

Multi-Unit Components: Multi-unit abutments are essential in the All-on-4 concept as they facilitate optimal prosthetic positioning and angulation. These components include:

- Straight and angled abutments (e.g., 17°, 30°) for accommodating implant inclination.
- Titanium copings and prosthetic screws.
- Impression copings and analogs to ensure accurate prosthetic fitting.
- Temporary cylinders for provisional restorations.

Multi-Unit Kit: The multi-unit kit is a comprehensive system that includes various components necessary for successful prosthetic rehabilitation in All-on-4 cases. The key components include-

1. Multi-Unit Abutments:

- Available in straight and angled variations (17° and 30°).
- Designed to optimize the emergence profile for prosthetic restorations.
- Various collar heights to accommodate different soft tissue levels.

2. Prosthetic Screws:

- Secure the prosthesis to the multi-unit abutments.
- Manufactured from high-strength titanium for durability.
- Compatible with different prosthetic designs, including screw-retained restorations.

3. Impression Copings:

- Open-tray and closed-tray options for accurate transfer of implant position to the laboratory.
- Ensures precise prosthetic fitting by capturing the exact angulation and depth of implants.

4. Analog Components:

- Used in laboratory models to replicate the position of the multi-unit abutments.
- Essential for fabricating accurately fitting prosthetic restorations.

REVIEW

5. Temporary and Final Prosthetic Cylinders:

- Used for both provisional and definitive prosthetic restorations.
- Provide a stable interface between the multi-unit abutments and the prosthesis.

6. Torque Wrenches and Drivers:

- Essential for accurate placement and secure tightening of multi-unit abutments and prosthetic screws.
- Ensures optimal torque values are applied to avoid mechanical failures.

These components work together to ensure the long-term success and stability of All-on-4 prosthetic rehabilitations.

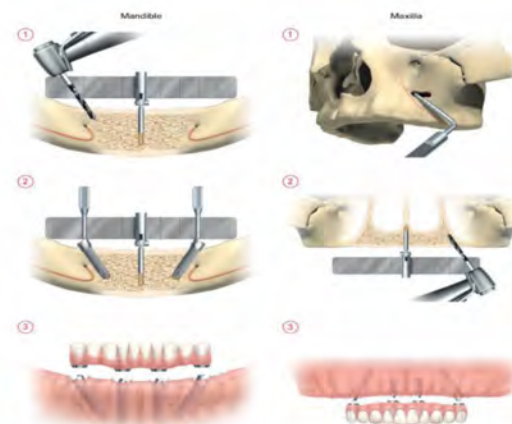
Surgical procedure of All on 4: It can be performed in two ways that is with flap or without flap (flapless).

- With flap: It is traditional method, uses standardized all on 4 guide for predictable and optimal positioning of implant.
- Without flap (flapless): It is modern technology, uses computer-based planning, customized template to correctly drill and position the implant.

The All-on-4® treatment concept can be performed in two ways:



- Conventional flap procedure with traditional planning and a standardized All-on-4® Guide for predictable and optimized positioning of the implants.
- 3D diagnostics and treatment planning and a custom designed surgical template to correctly drill and position the implants.



Products needed for restorative procedure: It involves multiunit abutments, prosthetic screws, prosthetic kit, lab components, etc.

For Placing 30° Multi-unit Abutments Non-engaging, the jig construction includes:

1. Impression coping open tray multi-unit
2. Guide pin
3. Abutment holder
4. Jig stabilizer
5. 30° multi-unit abutment non-engaging
6. Abutment screw

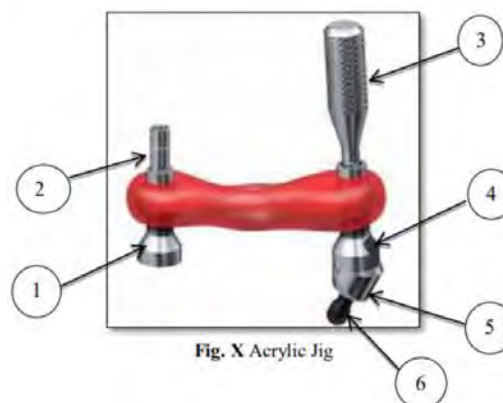


Fig. X Acrylic Jig

Discussion: The All-on-4 concept has been extensively studied and validated for its ability to provide immediate function, excellent long-term survival rates, and reduced surgical morbidity. The tilted implant approach optimizes anterior-posterior spread, enhancing biomechanical stability while avoiding anatomical limitations such as the

maxillary sinus and mental foramina. As the distal implants are tilted to further minimize cantilever length, this less invasive alternative requires fewer implants. Although long-term research is lacking, short-term clinical trials confirm the efficacy of the All-on-4 idea. The primary objective of surgical procedures like angled implant placement or bone regeneration is to restore masticatory function, comfort, and aesthetics, ultimately improving social comfort and self-esteem. Implant-supported fixed prostheses achieve these goals, enhancing patient satisfaction and success rates. Traditionally, dental implants are placed vertically, but challenges arise in fully edentulous jaws, such as poor bone quality, low volume, and the need for bone grafting. Distal tilting of implants proves advantageous by preserving anatomical features, allowing for longer implants with robust cortical anchorage to support prosthetics. This approach offers biomechanical and therapeutic benefits for fixed restorations with less intrusion compared to grafting operations using typical axial implants. The All-on-4 concept originated in 1999, with Mattsson and colleagues treating severely resorbed edentulous maxillae by placing four to six implants in the premaxilla to avoid sinus augmentation. In challenging clinical circumstances involving inadequate bone volume and the need for bone grafting in fully edentulous patients, the use of angled implants in the All-on-4 approach provides a viable treatment option, offering excellent long-term results and better load distribution. Also, the use of the Malo Guide and multiunit abutments plays a crucial role in achieving accurate implant positioning and prosthesis alignment. Additionally, immediate loading offers significant advantages, including shorter treatment time, improved patient comfort, and reduced costs. Limitations include technique sensitivity and the need for precise planning to avoid overloading the implants. Careful occlusal adjustments and regular follow-ups are necessary to prevent complications

such as prosthetic fractures and screw loosening.

Conclusion: The All-on-4 treatment concept provides a predictable and cost-effective solution for edentulous patients. Its ability to eliminate the need for bone grafting, combined with high implant survival rates and patient satisfaction, makes it a valuable option in modern implant dentistry. Long-term studies continue to support its efficacy, reinforcing its role as a gold standard for full-arch rehabilitation.

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Materials and Methods: The transition from conventional to digital workflow in maxillofacial prosthodontics involves several key stages: data acquisition, digital design, and fabrication. This section outlines the materials and methods employed at each stage, including 3D imaging techniques, CAD software, and various additive manufacturing technologies.

1. Data Acquisition: Data acquisition is the first critical step in the digital workflow. It involves capturing detailed information about the defect site using various scanning technologies. Medical scans such as computed tomography (CT), cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI) provide comprehensive data, particularly useful for internal structures. Surface scanners, including structured light scanners, laser scanners, and intraoral scanners, are used for external surface details. Combining these technologies ensures accurate and complete data for prosthesis design [1,2].

Medical Scanning

1.	Computed Tomography (CT)	Specific to craniofacial imaging.
2.	Cone Beam Computed Tomography (CBCT)	Useful for hard tissues, limited resolution for soft tissues, with radiation dose increasing with resolution.
3.	Magnetic Resonance Imaging (MRI)	Excellent for detailed soft tissue imaging, suitable for auricular and orbital prostheses but not ideal for imaging multiple bony structures simultaneously.

Surface Scanning

1.	Laser Scanners	Use a laser line and a CCD to capture light pattern distortion, determining the surface's 3D coordinates through triangulation.
2.	Structured Light Scanners	Project a light pattern onto the object and capture the image to determine 3D coordinates.
3.	Facial and Intraoral Scanners	Capture detailed surface data.
4.	Photogrammetry	Extracts 3D measurements from 2D images to create surface models.
5.	Scanning Physical Casts	Plaster or alginate casts can be scanned if direct patient scanning isn't feasible.

Table 1: shows Medical and Surface Scanning Techniques for Soft Tissue Reconstruction.

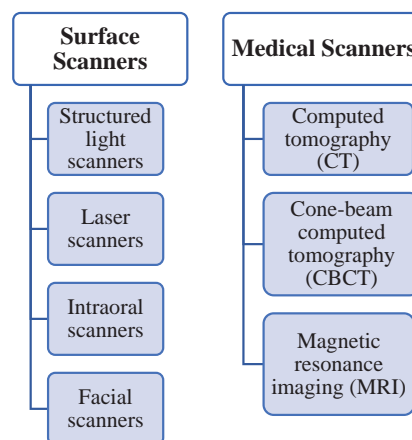


Figure 1: Types of 3D scanners

2. Computer-Aided Design (CAD): Once the data is acquired, it is processed using CAD software to design the prosthesis. Advanced CAD software allows for intricate designs, precise adjustments, and simulations to ensure the prosthesis meets the patient's specific needs.

3D design of soft tissue reconstructions can be achieved using several approaches:

- a. **Preoperative Scanning:** To capture the most natural form of the anatomy to be reconstructed, it is advisable to scan the healthy facial surface before surgery.
- b. **Mirroring Technique:** If a preoperative scan is unavailable, a mirror image of the healthy side can be used. This involves directly scanning the healthy side or using a model obtained from a conventional impression. The 3D image is then mirrored and superimposed on the affected area using CAD software to determine the correct position, resulting in the creation of an STL file.
- c. **Virtual Donor Approach:** A virtual "donor," such as a family member, can be used. The anatomical part to be reconstructed is scanned from the donor and combined with the patient's anatomical surface.
- d. **Digital Library Usage:** A digital library can be utilized to select a suitable size and shape for the reconstruction. The clinician can choose the appropriate design based on the patient's anatomy, which can then be visualized by the patient and the medical team before the reconstruction.^[11]

Popular software tools include:

- **Meshmixer and Blender:** Freeware tools offering a range of functions for duplicating, cutting, and sculpting 3D models.
- **Zbrush:** High-cost software preferred by professionals for its advanced capabilities.
- **Plus ID Institute Software:** Developed specifically for facial prosthetic design, integrating advanced algorithms for colour and texture replication.^[2,3]

3. Rapid Prototyping and Additive Manufacturing: Rapid Prototyping (RP), also known as Solid Freeform Manufacturing, is a relatively new technology used to create three-dimensional shapes from virtual designs. RP can be categorized into subtractive and additive manufacturing processes. Subtractive manufacturing involves the use of a CNC (Computer Numerical Control) router, which cuts the prosthesis from a solid block of polymer material, such as polyurethane. Recently, additive manufacturing, particularly 3D printing, has become the preferred method. This process constructs 3D physical models layer by layer from CAD files, offering greater flexibility and precision compared to traditional subtractive techniques.^[5,9,10]

- **Additive Manufacturing (3D Printing):** Technologies such as Fused Deposition Modeling (FDM), Stereolithography (SLA), and Selective Laser Sintering (SLS) are commonly used.^[9]
- **Subtractive Manufacturing:** CNC milling and laser cutting offer alternative methods for producing components with high precision.^[13,15]

Digital Applications in Maxillofacial Prosthodontics: Digital applications in maxillofacial prosthodontics span across various stages from diagnosis to the final prosthesis. Advanced imaging technologies enable accurate diagnosis and treatment planning. Digital design tools facilitate the creation of customized prostheses that fit perfectly and look natural. Additionally, digital workflows allow for virtual try-ins and adjustments, significantly reducing the number of physical appointments needed.^[10,12]

3D Printing: 3D printing allows for the precise fabrication of complex geometries that would be difficult or impossible to achieve with traditional methods. This includes:

- i. Custom Implants and Prostheses: Tailored to the patient's anatomy, offering improved fit and function.
- ii. Surgical Guides: Assisting in the accurate placement of implants during reconstructive surgery.^[14]

Additive Manufacturing:

1. Fused Deposition Modeling (FDM): Involves extruding melted thermoplastic filament to build objects layer by layer. It is cost-effective but has limitations in resolution.
2. Stereolithography (SLA): Uses a UV laser to cure liquid resin into hardened plastic. It offers high resolution and smooth finishes.
3. Selective Laser Sintering (SLS): Uses a laser to sinter powdered material, creating strong and durable parts. It is suitable for complex geometries.
4. Material Jetting: Deposits droplets of material which are then cured, allowing for multi-material and multi-colour prints with high precision.
5. Binder Jetting: Powder printing, also known as binder jetting, uses injet technology in a 2D printer to combine layers of powdered material, such as gypsum or starch, with liquid resin. The advantage of this approach is the ability to use multiple printheads, each emitting a different color, allowing for his 3D printed parts in full color
6. Silicone 3D Printing: These printers create realistic, customized silicone prostheses directly from 3D models using platinum-catalyzed silicone.

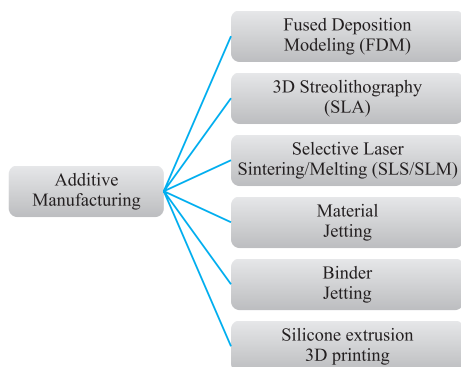


Figure 2: Additive manufacturing techniques

Figure 2 shows some additive manufacturing approaches that can be used to create complex objects from a variety of materials such as acrylic rigid polymers, wax, moulds, and even complete prosthesis

Software for CAD:

- i. Commercial Software: Includes Geomagic Studio, Zbrush, Rapidform, Rhinoceros, FreeForm, Magics, 3-Matic, Solidworks and Cinema 4D.
- ii. Open-Source Software: Includes Makerware, Meshmixer and Visual Toolkit (VTK).^[2,3,11]

Virtual Surgical Planning (VSP): VSP enables surgeons to plan and simulate procedures using digital models. This improves surgical precision and reduces intraoperative time.

Augmented Reality (AR) and Virtual Reality (VR): AR and VR technologies are emerging tools for both surgical planning and patient education. These technologies provide immersive experiences that enhance understanding and collaboration among the surgical team. Technologies like Vuforia and Unity 3D have been utilized to develop apps facilitating complex computer capabilities, including image and object recognition, and real-world interactions. These apps employ augmented reality (AR) to overlay 3D models onto live video streams captured by the device's camera. For instance, an AR application was developed allowing prosthodontists to manipulate and resize photos to align with treatment plans, with visual buttons enabling control over various aspects like movement and size. The resulting scene is saved as a downloadable Android app for convenient access.^[6]

Digital Shade Matching: Digital shade matching utilizes software tools to accurately match the colour of prostheses to the surrounding tissues of patient's faces. This technology ensures natural-looking aesthetics and patient satisfaction.^[7,8]

Discussion:

Conventional Workflow: The conventional workflow for maxillofacial prostheses involves several manual steps: making physical impressions, creating plaster casts, sculpting wax patterns, and multiple try-ins before finalizing the prosthesis. This process is time-consuming, requires significant manual dexterity, and can be uncomfortable for patients.

The process of creating a maxillofacial prosthesis involves several steps. Initially, an accurate impression of the area needing the prosthesis is obtained using suitable impression materials like hydrocolloid alginates or elastic silicone polymers, chosen based on factors such as the type and size of the defect. Custom trays may be necessary, and some anatomical undercuts are blocked to facilitate easy removal of the impression without causing tissue damage. Once the impression is poured, a gypsum cast is obtained, and a wax model of the missing anatomical part is crafted. The wax is carefully carved to replicate natural morphological details. After a try-in to ensure proper fit and aesthetic appearance adjustments, moulds are produced using the final wax-up via the lost wax method. The final prosthesis is then fabricated using suitable materials, such as acrylic resins or silicones, depending on the complexity of the defect. For intraoral and complex defects involving a part or the complete dental arch, an impression of the opposite arch and mounting in a semi-adjustable articulator may also be necessary before the final fitting. [2,3]

Digital Workflow: In digital manufacturing of maxillofacial prostheses, the process involves several key steps. First, defect data acquisition is crucial, which can be achieved through medical scans like computed tomography (CT), cone beam computed tomography (CBCT), or magnetic resonance imaging (MRI), generating files in DICOM format. Surface scanners such as laser

scanners and intraoral scanners are also utilized for defect data acquisition. Photogrammetry, which extracts three-dimensional measurements from two-dimensional images, is another method used to produce 3D surface models of patients' faces.

The design of the maxillofacial prosthesis, whether external or internal, is then achieved using various CAD programs and software suites, either open-source or commercially available. Rapid prototyping, particularly additive manufacturing, is employed to produce the final prosthesis. The prostheses can be manufactured indirectly by obtaining a model or mold of the prosthesis, followed by conventional workflow for anatomic part processing, or directly by 3D printing with suitable materials such as silicone-based elastomers and acrylic resins.

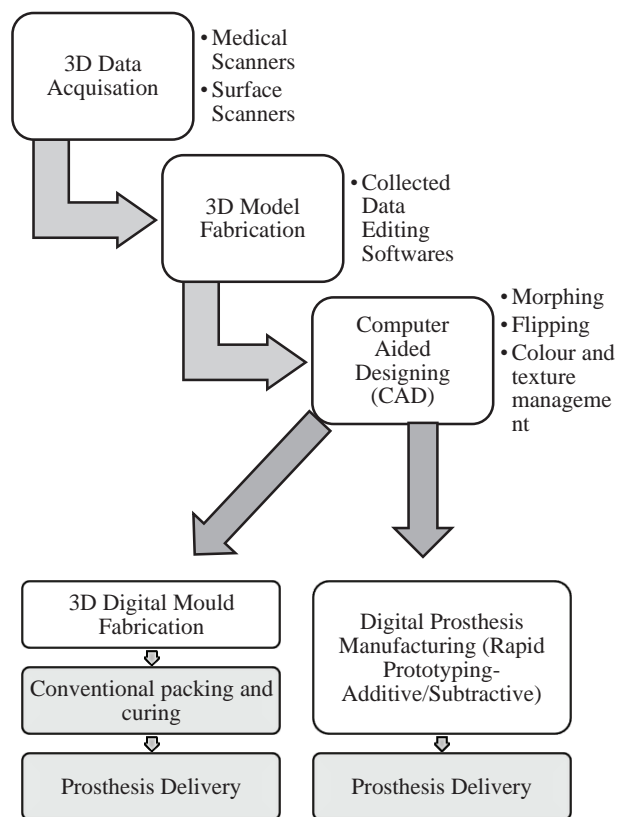


Figure 3: Digital Workflow for Fabrication of Maxillofacial Prosthesis

Comparative Analysis:

Efficiency: Digital workflows are faster, reducing

the total time from diagnosis to delivery of the prosthesis.

Precision: Digital tools offer higher accuracy and consistency, minimizing errors and rework.

Patient Comfort: Digital techniques are less invasive and more comfortable for patients, particularly during the data acquisition phase.

Cost: While the initial investment in digital equipment is high, the overall cost can be lower due to reduced labour and faster turn-around times.

The integration of digital technologies in maxillofacial prosthodontics represents a significant advancement in patient care. Digital workflows enhance precision, reduce patient discomfort, and improve the overall efficiency of the prosthesis fabrication process. However, the transition from conventional to digital methods poses challenges, including the need for training, high initial costs, and the adaptation of clinical practices.

Advantages of Digitization in Maxillofacial Prosthodontics:

1. **Improved Precision and Accuracy:** Digital techniques such as 3D scanning and computer-aided design (CAD) allow for highly precise and accurate prosthetic design and fabrication, leading to better-fitting prostheses.
2. **Enhanced Efficiency:** Digitization streamlines the workflow, reducing the time and labour required for prosthesis production compared to traditional methods, leading to increased productivity and cost-effectiveness.
3. **Customization:** Digital technologies enable the creation of highly customized prostheses tailored to the individual patient's anatomical features and aesthetic preferences, resulting in improved patient satisfaction and outcomes.
4. **Better Communication and Collaboration:** Digital platforms facilitate seamless communication and collaboration between clinicians, technicians, and patients, allowing for clearer visualization and understanding of treatment plans.

Challenges and Limitations:

1. **Initial Investment and Costs:** The upfront costs associated with acquiring digital equipment and software can be substantial, limiting access to smaller clinics or facilities with limited budgets.
2. **Technical Expertise Requirement:** Effective utilization of digital tools requires specialized training and expertise, which may not be readily available to all dental professionals, leading to potential barriers to adoption.
3. **Material Limitations:** While digital technologies offer versatility, some materials used in 3D printing may lack the durability, biocompatibility, or aesthetic properties required for certain prosthetic applications.
4. **Workflow Integration Challenges:** Integrating digital workflows into existing clinical practices may pose challenges, requiring adjustments to traditional protocols, workflows, and infrastructure, which can disrupt established routines and processes.

Future Prospects: Research over the past two decades has highlighted the potential shift from a labour-intensive conventional workflow to a digitalized protocol for fabrication of maxillofacial prosthesis using CAD/CAM technology. However, current software and interfaces are often expensive and not optimized for this purpose, limiting access primarily to skilled dental professionals or CAD engineers.^[4]

As demand for digital approaches in maxillofacial rehabilitation grows, there's a need for more user-friendly software modules, akin to those used in dental clinics and laboratories. Institutions can contribute by developing 3D libraries of morphological variations for easier design access.

Efforts are required to simplify data acquisition methods, improve software accessibility, enhance prosthetic esthetics and fit and provide biocompatible materials for direct printing of maxillofacial prostheses. Despite advancements, an indirect

approach involving 3D-printed moulds for silicone injection, with manual colour individualization, remains necessary to achieve comparable esthetic outcomes to analogical methods in many cases.

Conclusion: The digital workflow in maxillofacial prosthodontics offers substantial benefits over

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