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CLINICAL OUTCOMES OF VIRTUAL SURGICAL PLANNING FOR TEMPOROMANDIBULAR JOINT RECONSTRUCTION USING 3D-PRINTED CUSTOMIZED PROSTHESIS

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ABSTRACT

Background: Alloplastic temporomandibular joint (TMJ) replacement is a well-recognized technique. However, handling significant excision in this region necessitates reconstructive steps that go beyond the typical TMJ prosthesis.

Objective: This study evaluates the results of standard and extended total temporomandibular joint replacement (eTMJR) using customized prostheses and computer-assisted surgery tools to address difficult TMJ reconstruction (TMJR).

Materials and Methods: The study is a retrospective case series including two institutions. Extended TMJ reconstruction (eTMJR) management and planning procedures are thoroughly explained, including preoperative clinical evaluation, imaging acquisition techniques, and virtual surgical planning (VSP).

Results: We included ten patients with different pathologies who were candidates for eTMJR, with a focus on both functional restoration and aesthetic rehabilitation. Overall, the application of our protocol and workflow permitted the reduction of complications and pain, restoring patients' masticatory function and esthetics. We analyzed Maximum Interincisal Opening (MIO) and Visual Analog Scale (VAS) scores preoperatively and at follow-up. Our findings show significant improvements in MIO and pain reduction, consistent with previous studies using virtual surgical planning (VSP) and 3D-printed custom prostheses.

Conclusions: For certain patients with significant temporomandibular joint and skull base (TMJ-SB) lesions, the eTMJR should be regarded as a secure and reliable surgical therapeutic technique. To carry out such subtle and intricate rebuilding, a precise preoperative procedure and workflow are necessary. This study underscores the importance of personalized treatment plans for TMJ reconstruction and highlights the efficacy of eTMJR in improving both occlusal function and quality of life.

KEYWORDS: TMJ prosthesis; eTMJR; virtual surgical planning; mandibular reconstruction; patient-specific surgery; computer-aided design

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INTRODUCTION

Numerous clinical conditions (such as articular ankylosis, neoplasms, congenital abnormalities, osteomyelitis, etc.) can influence the temporomandibular joint and skull base (TMJ-SB), which can alter the area's facial aesthetics and, most significantly, its masticatory function. As a result, people who have these disorders frequently suffer from incapacitating symptoms such as severe pain, localized swelling, jaw cracking or clicking, migraines, earaches, and extreme mandibular mobility limitation. Even while non-surgical treatments are successful in a variety of clinical settings, they might not be enough in cases with severe structural abnormalities or advanced joint degradation, which were previously treated with autologous replacements. Over the past 20 years, alloplastic TMJR has become the preferred treatment for end-stage TMJ diseases and a regular procedure for treating TMJ issues [1,2]. Nowadays, autologous transplantation is mostly exclusively used for pediatric patients or those whose alloplastic replacement has failed [3,4].

Following surgical intervention, standard TMJ prostheses may not always fit the need to reconstruct large surgical defects that may extend beyond the confines of the TMJ to the skull base, the lateral aspect of the skull, and the mandible as well [3,4]. Management of these complex temporomandibular joint (TMJ) disorders often requires advanced surgical techniques, including extended total TMJ replacement (eTMJR). Recent innovations, such as virtual surgical planning (VSP) and the use of customized prostheses, have dramatically enhanced the precision and outcomes of these complex surgeries by fulfilling any possible reconstructive needs [5]. Extended versions of custom-made TMJ prostheses can now be designed to satisfy the need for the replacement of not only articular components but also contiguous mandibular and/or temporal or zygoma bone defects with extended components for the ramus and fossa, respectively. This allows functional and aesthetically acceptable outcomes for the patient [6,7].

Moreover, Custom-designed implants combined with free tissue flaps offer a promising solution for restoring both the structure and function of the TMJ and surrounding areas. Mommaerts et al. and Briceno et al. [2,3] have demonstrated that such reconstructions not only restore the anatomical integrity of the TMJ but also improve occlusal function, facial symmetry, and overall patient satisfaction.

To give an indirect view of the morphology of the reconstructive implant, the eTMJR has recently been the target of several attempts to categorize the prosthesis type based on the extent of the defect. A new eTMJR classification scheme put forth by Higginson et al. in 2021 served as the foundation for our investigation **[Table 1]**. [2,6,7].

This study aimed to evaluate the effectiveness of eTMJR in patients with complex TMJ defects, focusing on functional outcomes, such as Maximum Interincisal Opening (MIO), and pain relief, as measured by the Visual Analog Scale (VAS). Furthermore, we explored the role of custom 3D-printed prostheses in enhancing surgical precision and long-term outcomes.

Study Design and Methods

Study Design: This is a retrospective case series multicentric study involving ten patients who underwent eTMJR with 3D-printed prostheses between 2021 and 2023. All cases were treated at the departments of Oral and maxillofacial Surgery at the Faculty of Dentistry—Beni Suef University and Faculty of Dentistry—Assiut University. The Institutional Review Board (IRB) of the Faculty of Dentistry, University of Assiut approved the study.

Patient Inclusion Criteria:

- Age: 18-70 years.
- Diagnosis: Various pathologies affecting the TMJ-SB area (e.g., articular ankylosis, neoplasms, congenital anomalies, trauma).
- Follow-up period of at least 1 year.
- Patients with complete clinical documentation.

TABLE (1) Modified 2021 eTMJR classification proposed by Higginson et al.

Category	Description
Fossa component	
FO	Standard fossa component (contained within fossa)
F1	Extending anteriorly to but not beyond the articular eminence
F2	Extending beyond the articular eminence anteriorly (zygomatic arch defect)
FB	Temporal bone defect not including auditory apparatus +/ - arch defect
F4	Temporal bone defect involving auditory apparatus +/ - arch defect
F5	Temporal defect extending to jugular foramen Mandible (ramus) component:
Mandible (ramus) component	
M0	Standard condyle-ramus component (proximal to angle of mandible)
M1	Extended proximal to ipsilateral mental nerve foramen/region
M2	Extended proximal to contralateral mental nerve foramen/region
M3	Extensive extending beyond contralateral mental nerve foramen/region
M4	Total alloplastic mandible (including both condyles)

Exclusion Criteria:

- Incomplete or missing clinical documentation.
- Patients with inadequate follow-up duration.

Clinical Examination:

A thorough clinical examination of the head and neck region was performed (e.g., search for oral lesions, swellings, malocclusion, laterocervical lymph adenomegalies, etc.). The TMJ function was evaluated by assessing the mandibular range of motion (maximum incisal opening (MIO), lateral movements, protrusion) and pre-auricular pain using a visual analog scale (VAS). In cases of suspected malignancy, an incisional biopsy was performed.

Preoperative Evaluation:

Each patient underwent routine preoperative examinations, including laboratory tests, radiographs, echocardiograms, and anesthesiologic evaluation. Tumor staging imaging was performed for confirmed malignancies, with CT scans of the neck, thorax, and abdomen.

Imaging Protocol:

To accurately plan the eTMJR procedure, the following imaging methods were used:

- **CT scan**: Detailed bone imaging to identify skeletal structures, lesions, and adjacent anatomical relationships with the following parameters: slice thickness = 0.625 mm, matrix = 512 × 512 px.
- **Magnetic resonance imaging (MRI)** was carried out using a 1.5-Tesla machine (Aera; Siemens; Erlangen, Germany). Several sequences were obtained to accurately represent the various anatomical features.
- **Computed Tomography Angiography (CTA)**: For cases requiring free bone flaps, to assess the vascular anatomy.
- **Intraoral Digital Scanning**: was carried out (Carestream Health Inc., Rochester, NY, USA; Carestream CS3600). Dental cusps were acquired in detail and integrated with CT data using the resulting Standard Tessellation Language (STL) files.

- **Virtual Surgical Planning (VSP)**: Segmentation of CT scans into the mandible, skull, and pathology regions, with integration of intraoral scanning. To accomplish matching superimposition and increase planning accuracy, image output—in the form of Digital Imaging and Communications in Medicine (DICOM) files—was then imported into Mimics (Materialise, Leuven, Belgium) and registered within the same coordinate system.

Surgical Guides and eTMJR Prosthesis Design and Manufacturing: Using VSP software, the custom prosthesis design was generated, and STL files were used for 3D printing. Following the surgeon's approval of the planning and the unique prosthesis design, the implant was additively developed through metal 3D printing and included several parts:

- **Glenoid fossa component**: Made of ultra-high-molecular-weight polyethylene (UHMWPE) and titanium alloy (Ti-6Al-4V) for cranial extensions.
- **Condyle/ramus component**: Primarily titanium alloy, designed for secure fixation and functional restoration.
- **Custom-fit surgical guides:** these are made to direct the planned osteotomies and screw hole drilling, securing the surgical guide, and securing the prosthesis in the desired location at the same time. Stereolithographic 3D printing was then used to print this guidance. To have them ready in the operating room, replicas of the various parts—such as the skull and the jaw with and without the resection—were also 3D printed and subsequently sterilized.
- Surgical Approach and Procedure:

All patients were given general anesthesia via percutaneous tracheostomy, oro-endotracheal, or naso-endotracheal intubation. The location and severity of the pathology determined the specific surgical strategy that was used. To expose the TMJ and the ramus and enable the completion of a regular TMJR, a preauricular incision was often made with a retro/submandibular approach and a small temporal extension. The surgical strategy for eTMJR, however, is determined by some variables, such as the extent of the disease, the soft and bone structures affected, and the need for reconstruction. Retro/submandibular access was frequently used in conjunction with a hemi-coronal approach when reconstructing the zygomatic arch or a portion of the temporal bone. On the other hand, an extended cervical approach, often with concurrent intraoral access was required if the lesion to be addressed reached past the ramus with various extensions, as the retro/submandibular approach was insufficient. A whole visor flap can be required if the problem that needs to be fixed is extensive or nearly so. Following the exposure of the surfaces to be osteotomized, the cutting guides were positioned and secured using titanium alloy screws that would also be utilized to secure the prosthesis by drilling guides and holes. Following the holes previously produced in the cutting guides, titanium alloy screws of varying diameters and lengths were used to position and secure the prosthesis once the osteotomies were completed.

Cutting guides were created and 3D printed when an eTMJR was combined with a free bone flap (free fibula flap, free iliac crest flap, etc.). Following consultation with the prosthodontist and integration into the VSP flow, if implants were to be placed in the free bone flap following a pre-planned virtual plan, this was done in the same procedure after the flap was harvested and mounted on the specially built prosthesis. To avoid postoperative sagging and alloplastic joint luxation, the prosthetic condyle was secured to the fossa component using a single non-resorbable stitch. In the event of a previously severe condition, we may occasionally place a fat graft around the new joint to aid in gliding and lower the chance of bone heterotopic development in case of a previously severe ankylotic joint. At the end of the procedure, an occlusion check was performed, and the surgical accesses were sutured.

Postoperative Care and Follow-Up:

Patients were closely monitored in the first month postoperatively with weekly follow-up visits. After the first month, follow-up continued monthly for six months and annually thereafter. Clinical outcomes were assessed by:

- **Pain**: Using a VAS scale.
- **Masticatory Function**: Through patient self-assessment of chewing ability and dietary adjustments.
- **Mandibular Range of Motion**: Measured by MIO and lateral/protrusive movements.
- **Radiological Assessment**: CT scans at 6 months post-surgery to assess prosthesis stability.
- **Data Collection:** Functional outcomes were assessed by measuring the Maximum Interincisal Opening (MIO) preoperatively and at 6 months postoperatively. Pain levels were assessed using the Visual Analog Scale (VAS). Additionally, patient demographics, including age, gender, diagnosis, and complications, were recorded. Follow-up periods ranged from 1 to 2 years.

RESULTS

Demographic and Surgical Data

The study included ten patients (5 males and 5 females) with an average age of 44 years (range: 18–70) years) with different diseases involving the TMJ-SB were treated with an eTMJR implant between 2021 and 2023, whose data are shown in **[Table 2]**.

TABLE (2) Characteristics of patients focusing on disease, eTMJR class, custom-made eTMJR, surgical approach, and complications characteristics.

Case No.	Age	Gender	eTMJR class	Diagnosis	Reconstructed structures	Fossa materials	Condyle materials	Complications	Surgical approach
1	23	male	F2M1	Left TMJ ankylosis due to old trauma	Unilateral Total joint replacement + orthognathic surgery	UHMPE	Titanium	None	Preauricular, intraoral and submandibular
2	18	female	F2M1	Left TMJ ankylosis	Unilateral Total joint replacement + orthognathic surgery	UHMPE	Titanium	None	Preauricular, intraoral and submandibular
3	27	Male	F2M1	Right severe TMJ ankylosis	Unilateral Total joint replacement	UHMPE	Titanium	None	Preauricular, intraoral and submandibular
4	21	male	FBM2	Ameloblastoma of right-side mandibular body, ramus and extending to the condyle and articular fossa	Unilateral Total joint replacement	UHMPE	Titanium fixed on fibula free flap	None	Preauricular and submandibular
5	34	female	F0M4	Previous surgery for mandibulectomy due to ameloblastoma with failed reconstruction	Bilateral Total joint replacement	Fixed to normal fossa	Titanium fixed on fibula free flap	Partial right facial palsy	Preauricular and extended cervical
6	38	female	F2M1	Right mandibular ameloblastoma related to posterior body, angle and ramus.	Unilateral Total joint and mandibular reconstruction with iliac crest bone graft	UHMPE	Titanium custom made	None	Intraoral
7	19	male	F2M1	left mandibular body solid ameloblastoma	Unilateral Total joint replacement	UHMPE	Titanium custom made	None	Preauricular, introral and extended cervical approach
8	43	female	F2M0	right condylar osteoma	Unilateral Total joint replacement	UHMPE	Titanium	Partial right facial palsy	Preauricular and submandibular
9	55	female	F0M2	left mandibular odontogenic keratocyst related to posterior body, angle and ramus	Unilateral Total joint replacement	UHMPE	Titanium	None	Preauricular and submandibular
10	49	Male	F0M2	right mandibular odontogenic keratocyst related to posterior body, angle and ramus	Unilateral Total joint replacement	UHMPE	Titanium	None	Preauricular and submandibular

Once identified, patient records including operative reports, clinical charts, and imaging were analyzed to obtain the data. All patients suffered from different conditions affecting the TMJ: TMJ ankylosis, pathology, and failed reconstruction. In total, 10 eTMJR were performed, 9 unilateral, and 1 bilateral following our protocol and workflow. The eTMJR was classified using the two-component modified eTMJR classification proposed by Higginson et al. **[Table 1]** [7].

Five subjects were classified as F2-M1 eTMJR, two F0M2, one FB-M2, one F2-M0, and one F0-M4.. Additionally, two patients underwent a hybrid autologous/alloplastic eTMJR with a free fibula flap. All the patients had normal TMJ hinge movement and consistent postoperative occlusion. There were no significant intraoperative problems noted.

The clinical outcomes for all patients are summarized in the Results [Table 3]. All patients showed improvements in MIO and pain levels post-surgery at 6 months follow-up periods. The following key findings were observed:

MIO Improvement: The MIO was assessed both preoperatively and postoperatively. All patients exhibited an increase in MIO, showing a mean MIO preoperative of 21.8 mm, compared to 31.7 mm at follow-up, with the most significant improvements in patients with more severe preoperative restrictions (e.g., Case 7, with an MIO increase from 12 mm to 30 mm).

VAS Reduction: Pain levels, as indicated by VAS scores, decreased significantly in all patients. The average VAS score was reduced. The patients reported an encouraging improvement in pain, decreasing significantly from 6.3 preoperatively to 2.2 at the 6-month follow-up.

Complications: Two patients (Cases 5 and 8) experienced complications, including partial facial palsy. However, these complications were related to the underlying conditions and not the surgical procedure. No implant failure or screw loosening of the fossa or mandibular components were observed.

Follow-up Duration: The follow-up period ranged from 1 to 2 years. The longer follow-up revealed sustained improvements in jaw function and pain relief. Two patients had already completed the two-year follow-up period, while the patient with the shortest follow-up time was one year.

TABLE (3) Pre and postoperative outcomes:

Case no	MIO before surgery(mm)	MIO at 6 months (mm)	VAS preoperative	VAS at 6 months	Follow up (Years)
1	18	33	7	2	2
2	20	35	6	1	2
3	14	27	8	3	1
4	21	30	7	5	2
5	29	33	8	1	2
6	24	31	5	3	2
7	12	30	7	1	2
8	18	31	6	1	2
9	29	33	5	2	2
10	33	34	4	3	2

DISCUSSION

Every maxillo-facial surgeon has difficulties while doing TMJR surgery, particularly when the entire TMJ-SB region is affected by pathological changes in the TMJ anatomy, making a typical TMJR practically impossible. More control and supervision during drilling and cutting could improve patient safety and accurate reconstruction, especially at the base of the skull, where important structures are directly adjacent to the TMJ. [8]. It's also true that pathological diseases that can be treated with eTMJR are far more difficult and different from those that need a traditional TMJR. Even with a precise VSP, there are always risks and complications associated with excision and reconstruction of such conditions, and they can arise in the operating room. The purpose of our suggested workflow is to demonstrate the advantages and effectiveness of a thorough eTMJR protocol for fixing significant flaws affecting the TMJ and surrounding structures. Surgery is known to be made easier and more accurate with VSP and 3D-printed surgical cutting guides and prostheses, especially when dealing with anatomical variances such as congenital abnormalities, ankylosis, or many operated joints [9].

Intraoperative modifications were required in certain situations, even though the implementation of our strategy helped us to reduce challenges and unforeseen hiccups in the operating room. It should be mentioned that these unanticipated circumstances allowed us to review and improve this protocol, resulting in the addition of specific features or modifications to the prosthesis, VSP, cutting guides, etc. The most common changes were to the mandibular component and glenoid fossa, although they were minimal.

In addition, we observed unpredictable reattachment of the jaw's elevator muscles and a lack of manual control over the condyle position into the fossa component before fixation. To address these problems, we made specific holes on the condylar head and in the gonial region. These holes allow the mandibular component to be sutured to the prosthetic fossa and the pterygoid-masseteric sling to be properly secured. When facial aesthetic is significantly distorted, as in examples 1 and 2, face remodeling is also possible with eTMJR and orthognathic surgery. To plan the best-matching eTMJR for these patients, the VSP mirroring tool and the ability to retrieve jaw and skull models from an internal software library were essential. In the medium- to long-term follow-up of TMJR patients, Sanovich et al. have previously documented improvements in MIO, pain recovery, food restriction, and quality of life (QOL) [10].

According to information initially developed by Elledge et al. For a classification system for eTMJR to be effective, it must be "unambiguous and easy to use; exhaustive and mutually exclusive so that each possibility exists in only one class; clinically relevant and appropriate; and flexible enough to accommodate any advances or changes in technology," [6]. Two parts make up this initial classification attempt: the "M" for the prosthesis's mandibular component and the "F" for its fossa component. Based on the size of the problem that needs to be fixed, each of these two characteristics is further separated into four subcategories. The goal of this categorization is to distinguish between the various degrees of mandibular, skull base, and fossa resection. Higginson et al. later changed this categorization system's F parameter in a three-tiered manner, seeking to streamline the categorization of fossas and promote dialogue between producers and clinicians [7]**.** Mommaerts et al. suggested another eTMJR subclassification scheme [2], this considered three possible challenges: concurrent contralateral mandibular osteotomy, occlusal modifications, and contour corrections. We believe that there is an additional point of reflection that could help put this classification into practice. The likelihood of hybrid, autologous, and alloplastic eTMJR is not considered by any of these classifications, as we did, for instance, in the situations of patients 4 and

5. In these situations, the eTMJR mandibular body practically recreates the alveolar bone process by supporting a free fibula flap, allowing for contextual or postponed dental rehabilitation. According to a small number of authors, this hybrid approach can result in satisfactory rehabilitation [1,13]. We believe that this feature should be considered within the eTMJR categorization due to the growing popularity of this kind of surgery.

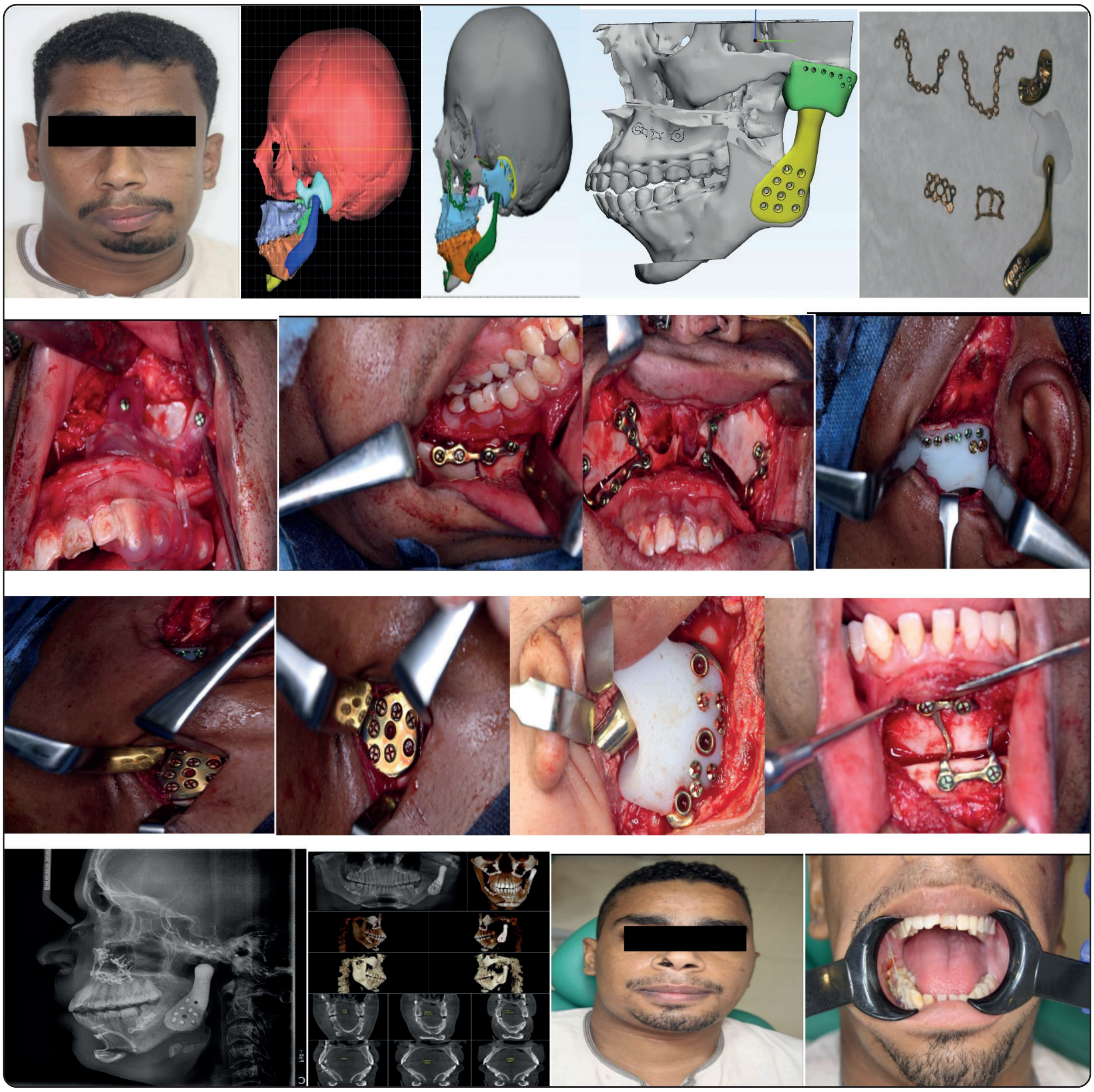
At the 6-month follow-up, MIO improved significantly in all patients in our study with a range of 22 mm to 32 mm (average increase of 10 mm), particularly in cases of severe ankylosis, where other treatment options have limited success. This mirrors the findings of Khattak et al. [4], who reported similar outcomes in patients with advanced TMJ dysfunction, and following findings from Mommaerts et al. (2020) [2] and Briceno et al. (2022) [3], who also reported enhanced MIO following TMJ reconstructions. The MIO increased from preoperative values to post-operative measurements in all cases. For example, case 1 had an improvement from 18 mm to 33 mm, and patient 7 experienced a dramatic increase from 12 mm to 30 mm. This is consistent with the benefits of VSP and customized 3D-printed prostheses, which allow for precise anatomical restoration and better functional outcomes. The largest improvements in MIO were noted in patients with more severe preoperative limitations, such as those with ankylosis (Cases 1,2 and 3). These results underscore the efficacy of VSP in restoring jaw mobility and function, which is critical for quality of life, especially for younger patients (Cases 2 and 5).

The reduction in pain, as measured by the VAS, further highlights the effectiveness of TMJ. As noted by Mommaerts et al. [2] and Briceno et al. [3], improving pain control is a key factor in enhancing quality of life for these patients. The reduction in pain, as measured by the Visual Analog Scale (VAS), was also significant in most patients and decreased significantly from a preoperative average of 6.3 to a postoperative average of 2.2. The largest reduction in pain was observed in patients 5 and 7 with ameloblastoma which is consistent with the findings of Govoni et al. (2023) [2], who also noted substantial pain relief following TMJ reconstructions. Overall, there was a notable reduction in pain levels across cases, with only one patient (Case 4) having VAS scores greater than 3 at six months. The customized prostheses likely contributed to reducing mechanical pain due to better alignment and function of the reconstructed TMJ. This improvement aligns with findings from previous studies on TMJ reconstruction, where personalized implants led to greater pain relief than standard prostheses.

While the overall complication rate was low, two patients experienced complications. Cases 5 and 8 had partial facial palsy post-surgery, both of which resolved with appropriate management. These results are consistent with reports from Khattak et al. (4), who documented similar complication rates in eTMJR surgeries. These complications, however, were not directly linked to the use of the 3D-printed prosthesis but were rather associated with the patients' pre-existing conditions and perioperative factors. Importantly, these complications did not result in permanent functional deficits, as most patients showed improvement in facial function and TMJ mobility. The relatively low complication rate is encouraging for the continued use of VSP and custom implants in TMJ reconstruction, although long-term follow-up is necessary to monitor for potential issues such as implant failure or long-term infections.

For many patients, there was significant functional recovery, particularly in chewing ability. Cases 1,2 and 3 (the patients with ankylosis) showed a marked improvement in MIO and masticatory function, allowing the patient to return to a normal diet post-surgery. This highlights the success of eTMJR in addressing severe functional deficits, which are often seen in TMJ disorders like ankylosis. The aesthetic outcomes were not directly assessed in this study, but improvements in occlusion (Cases 1 and 2) dramatic improvement) indirectly point to enhanced aesthetic results, which are often a key consideration in TMJ reconstruction.

The follow-up period varied among the cases, with the shortest being 1 year and the longest being 2 years. The long follow-up period for most patients provides valuable data on the durability and long-term effectiveness of the 3D-printed prostheses. Notably, all patients who had more than 1 year of



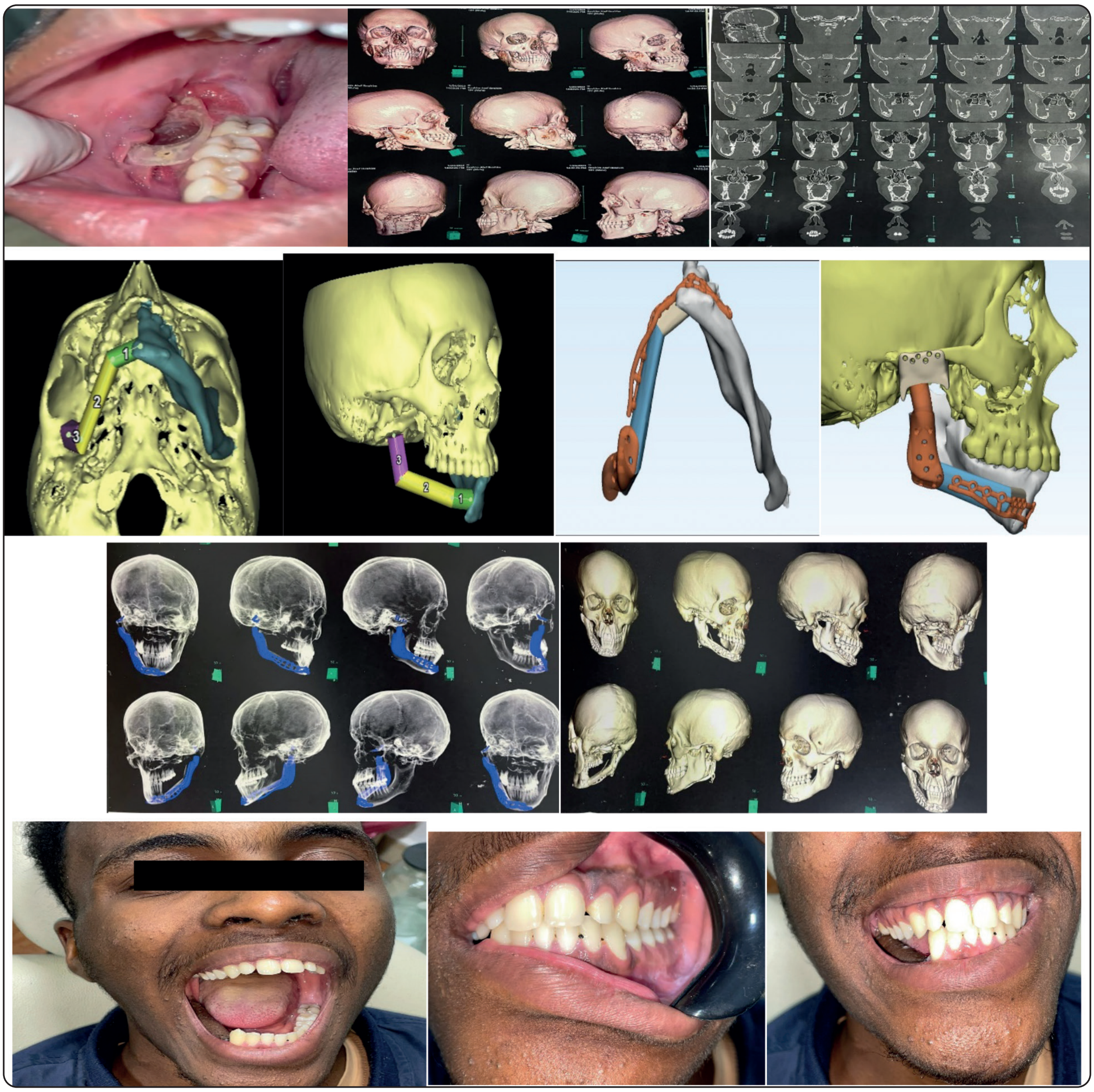
Case 1: A 23-year-old male patient with left TMJ ankylosis due to old trauma presented with occlusal canting, chin deviation, and facial asymmetry. Virtual treatment planning was done using Mimix and pro plan software programs to do orthognathic surgery for adjustment of facial features using patient-specific custom-made plated 3D printed as well as left TMJ reconstruction by constructing the ramus and condyle as one-piece titanium plate fixed with screws to the mandibular angle while the fossa is made by UHMPE fixed to the arch by screws as well

follow-up showed sustained improvement in MIO and pain relief, with no signs of implant failure or significant functional impairment. This suggests that the eTMJR procedure, aided by VSP and custom implants, offers long-lasting clinical benefits.

The results of our cases show that the implantation of the eTMJR prosthesis resulted in a considerable improvement in MIO and pain levels as well as an overall improvement in the patient's functional and aesthetic characteristics. Additionally, eTMJR permits early mobilization, which has been demonstrated to enhance functional outcomes in contrast to autologous reconstruction [11,12], as we have also observed in our patients. The outcomes of this study support the growing body of evidence indicating that eTMJR using custom prostheses and free flaps significantly improves

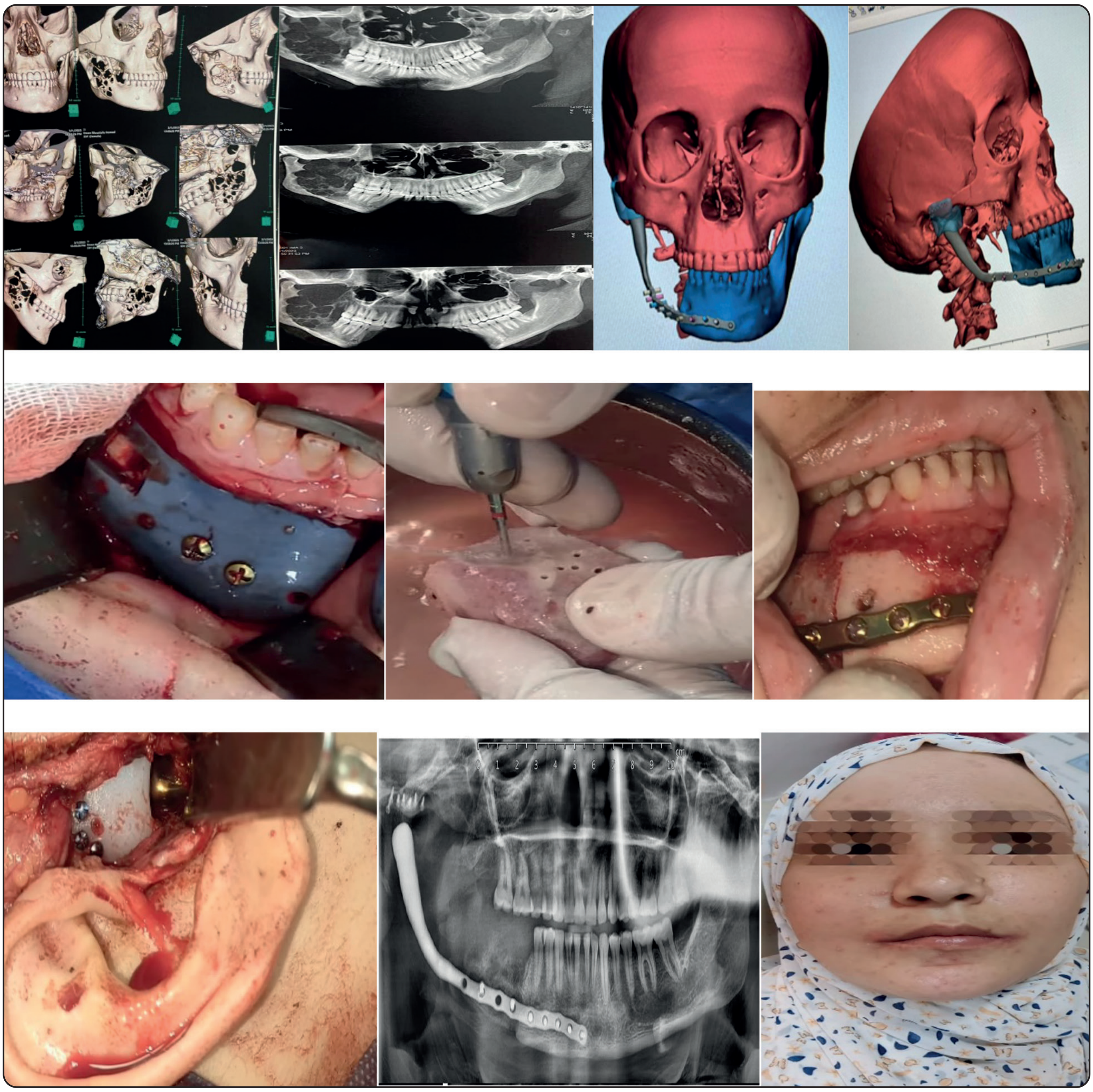
Case 2: An 18-year-old female with left TMJ ankylosis and exactly a replica of case 1, where the same management is done for her.

both functional and aesthetic outcomes for patients with severe TMJ disorders. The findings align with previous studies such as those by Govoni et al.[1], Mommaerts et al.[2], and Zheng et al.(5), which emphasize the advantages of using personalized surgical planning and customized implants in TMJ reconstruction. Additionally, the use of VSP and 3D-printed prostheses has proven to be an invaluable tool in improving surgical accuracy and prosthetic fit, as emphasized by Zheng et al.[5]. Customization ensures a better fit, reduces complications, and enhances long-term outcomes, as evidenced by our study and supported by the work of Govoni et al.[1].

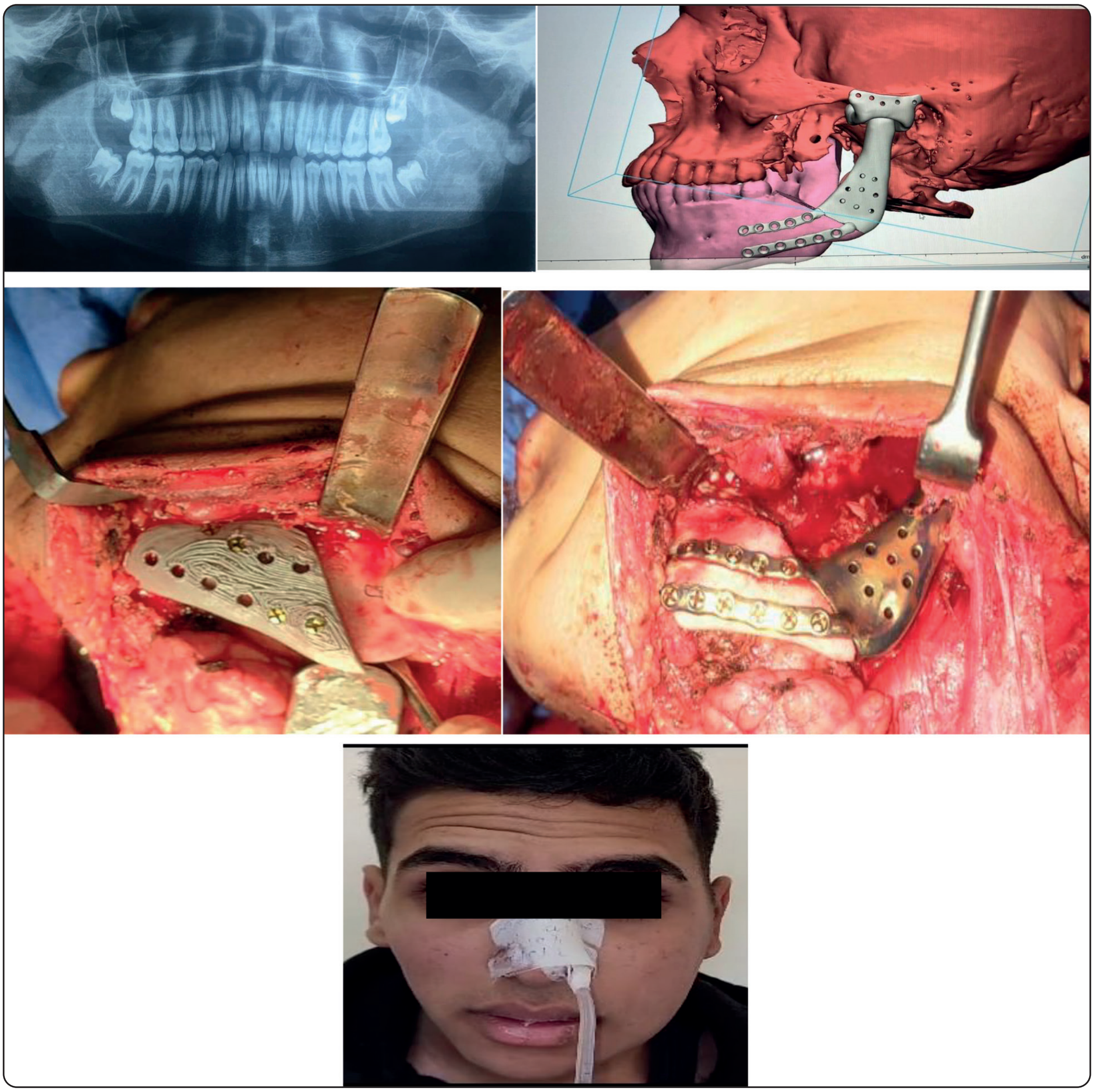


Case 4: A 21-year-old male patient suffering from ameloblastoma of the right-side mandibular body, ramus, and extending to the condyle and articular fossa. He scheduled for free fibula free flap reconstruction using Mimix and Proplan software for reconstruction. Where the right TMG is reconstructed using a custom-made titanium plate while the fossa is made of UHMPE.

Case 5: A 34-year-old female had previous surgery for mandibulectomy due to ameloblastoma with failed reconstruction. A high-resolution Angio-CT (1-mm cuts) of the facial skeleton and lower extremities should be obtained. Computer-guided surgery (Materialise Mimics Software) was utilized for the fabrication of type 4 titanium milled mandible and surgical guide for fibula osteotomy. Mandibular reconstruction by custom-made titanium plate was attached to the remaining part of the condyle bilaterally with no need for fossa reconstruction{F0}



Case 6: A 38-year-old female patient with right mandibular ameloblastoma related to posterior body, angle, and ramus. Surgical excision is done with immediate reconstruction using a titanium plate forming the condylar head as well as the ramus and the body where the iliac crest bone graft is attached to it, while the fossa is made up from UHMPE fixed to the zygomatic arch with screws.



Case 7: A 19-year-old male patient suffering from left mandibular body solid ameloblastoma extending to the TMJ. Excision is done by a combination of intraoral preauricular as well as extended cervical approach and immediate reconstruction is done by prefabricated custom-made titanium plate and UHMPE as fossa fixed by screws.

CONCLUSION

The results of this retrospective case series demonstrate the effectiveness of Virtual Surgical Planning and 3D-printed customized prostheses in the reconstruction of the temporomandibular joint (TMJ). Significant improvements in pain reduction, jaw mobility, and masticatory function were observed in most patients, with low complication rates. This study supports the growing body of evidence that personalized prostheses, designed using advanced surgical planning tools, can lead to superior clinical outcomes in TMJ reconstruction, offering long-term functional and aesthetic benefits.

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