Evolution of midface microvascular reconstruction: A three decade experience from a single institution

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Abstract

Objectives: Midface reconstruction poses a complex set of challenges for reconstructive surgeons. The optimal midface reconstruction must possess a durable underlying bone construct capable of integrating dental implants. Facial contour is restored by the overlying microvascular soft tissue reconstruction with reestablishment of the oral cavity. A plethora of microvascular flaps used in clinical practice have been described including those harvested from the iliac crest, scapula, fibula, forearm and back (latissimus dorsi). The objective was to share our experiences with each of these treatment options that have continued to evolve over time for the benefit of patients. Design: Our institution has over three decades of experience in reconstructing complex midface defects and this article summarizes midface reconstruction from an evolutionary perspective (for type II, III and IV defect; Browns classification, Supplementary table 1). We broadly divide this into (i) flaps supplied by the subscapular system (ii) autologous reconstruction with titanium mesh and (iii) fibula microvascular flaps using 3D planning. The advantages and disadvantages for each approach are discussed (Supplementary Table 2). Conclusion: In the future, it is expected that 3D planning coupled with rapid prototyping, intraoperative navigation and CT imaging will become standard procedural practice. Our institution has over three decades of experience in reconstructing complex midface defects and this article summarizes midface reconstruction from an evolutionary perspective (for type II, III and IV defect; Browns classification, Supplementary table 1). We broadly divide this into (i) flaps supplied by the subscapular system (ii) autologous reconstruction with titanium mesh and (iii) fibula microvascular flaps using 3D planning. The advantages and disadvantages for each approach are discussed (Supplementary Table 2). In the future, it is expected that 3D planning coupled with rapid prototyping, intraoperative navigation and CT imaging will become standard procedural practice.

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Conclusion: In the future, it is expected that 3D planning coupled with rapid prototyping, intraoperative navigation and CT imaging will become standard procedural practice.

KEY POINTS

1. Midface reconstruction after tumour removal is a highly complex task. This requires careful planning and as such techniques have continued to evolve with time.
2. Trainees should be aware of the options previously practised, as this can still serve as a lifeboat when the gold standard is not possible.
3. Reconstruction requires bone and soft tissue considerations, always consider donor tissues and pedicle carefully and where to find recipient vessels.
4. Obturators and locorgeional flaps provide a poor solution. We consider their use is best reserved for salvage and revisional cases, or when patients comorbidities necessitate expedient surgery.
5. Tissue engineering and 3D scaffolds/printing is an exciting prospect to reduce donor morbidity and should be welcomed to provide patients with a bespoke reconstruction.

Background

Today, microvascular surgery is an essential facet in the treatment of head and neck defects from any cause. The functional morbidity, aesthetic implications and impact on quality of life are universally appreciated. Prosthetic devices and obturators are not well-tolerated by patients and fall short in assisting with speech or mastication, especially in the presence of an oronasal/antral communication.

Prior to addressing this clinical need in midface reconstruction, the emphasis was largely placed on mandibular reconstruction and its associated soft tissue defects[1]. There are several reasons for this. The mandible in essence is largely a pillar, whereas the anatomical features of the midface are highly complex with vital neighboring structures creating its borders. The maxilla forms the anterior aspect of the midface but bridges the floor of the orbit and separates both oral and nasal cavities whilst housing the superior dental arch. Indeed, prosthetic restoration (obturator) first described in the 16th century by Ambroise Paré[2], arguably provide satisfactory results for Brown class I and II defects[3]. Moreover, compared with mandibular reconstruction, the technical challenges posed by midface reconstruction include the consideration of a longer pedicle for anastomosis to vessels within the neck. Vein grafts have been used and increase the risk of microvascular failure[4].

The ideal microvascular flap for the midface relies on a stable bony construct providing adequate bone stock for dental implantation. Soft tissue flaps should aim to restore facial contour whilst compartmentalizing the oral and nasal cavities. We aim to discuss the evolution of midface microvascular reconstruction in our reconstructive head and neck service over three decades that largely mirrors that of clinical practice worldwide.

Surgical evolution

Flaps were classified using the Brown classification *(Table. 1).*

Autologous composite reconstructions using chimeric flaps (bone, skin, muscle)

Flaps most frequently employed for various midface defects (classified by Brown; *Table. 1*) are composite flaps comprising soft tissue and bone. Flaps harvested from the iliac crest[5]scapula[6] and fibula[7] have been well-described, each facilitating dental restoration. In addition, microvascular flaps have been reported from the forearm[8], rectus abdominis[9], latissimus dorsi[10] and the anterolateral thigh flap[11].

The very first microvascular midface reconstructions that we performed (1993) were flaps supplied by the subscapular axis. Our preference was a single pedicale scapula flap perfused on the angular artery, incorporating the latissimus dorsi and serratus anterior (with or without rib) with or without a fasciocutaneous paddle. The main advantage of this composite flap is its freedom of movement to suit most reconstructive needs. Brown type IV defects were reconstructed using this approach enabling us to reconstruct almost any complex defect.

Our technique has previously been described in more detail[12]. In brief, the scapula is positioned vertically, and osteotomies allow for the infraorbital rim and orbital floor to be reconstructed. The LD muscle was incorporated to separate the oral and nasal cavities. Patients had bespoke eye prostheses placed *(Fig 1a,b,c,d,, Fig s4)* . Although this reconstruction provided tremendous benefit for patients with Brown type IV maxillectomies, its drawbacks became evident over time. With the absence of 3D planning and rapid prototyping (unavailable at the time) to aid in scapular osteotomies intraoperatively, longer-term results were unpredictable. Moreover, tumor resection and reconstruction could not be performed simultaneously due to patient positioning, increasing complication rates (longer anaesthesia) and overall operative costs. Despite the operation becoming routine departmental practice, operative times exceeded 7-8 hours.

Combination of soft tissue or bone flaps and 3D shaped titanium mesh

Early in 2000, CT planning and 3D printing became available bringing about a shift in our reconstructive approach. A pedicled buccal fat flap with autologous bone using a prefabricated titanium mesh provided a functional reconstruction, similar to that described by Liu et al.[13]. In our case titanium mesh was used to support orbital contents. ALT flap was partly deepithelialised to cover the titanium mesh and to separate oral and nasal cavity. In cases were microvascular bone was used, afforded a stable construct for alveolar ridge reconstruction. All patients were classified as having Brown class III defects. Titanium mesh provides sufficient material to bridge most large midface defects. Mesh was contoured preoperatively on 3D models to develop a stable platform to support overlying soft tissues[14] *(Fig 2a,b,c,d,e, s5)* . Consequently, we were able to offer a simultaneous two team approach in which operative time was lowered to approximately 5-6 hours. Titanium mesh was also useful in trauma cases and skin tumor surgery when bone was resected. The difference between these cases and midface reconstruction was that these cases did not need postoperative irradiation whereas all midface reconstructions required adjunctive irradiation.

The majority of patients not receiving irradiation experienced no complications. Conversely, those that did need irradiation experienced complications, manifesting up to a year after surgery. More commonly we encountered fistulas and at the extreme end we encountered extrusion of the titanium mesh. In cases of prolong, repeated infection and potential implant extrusion lipofilling helped to mitigate this risk. In two instances, we had to utilize a pericranial flap and full thickness skin graft to reconstruct the infraorbital rim. In three cases we had to perform an additional free flap.

Computer assisted a*utologous 3D modelling utilizing the fibula rather than scapula*

We have found that the adoption of 3D planning for autologous reconstruction has revolutionized head and neck reconstruction in our department and worldwide. Computer assisted 3D planning generates bespoke resection and cutting guides (Fig 3a,b,c,d)[15]. This was a welcome step, giving surgeons confidence in their reconstructive goals. We chose the fibula flap as our workhorse flap. The fibula tolerates multiple osteotomies, and the long pedicle avoids the need for vein grafts when anastomosing to vessels in the neck, lowering any thrombotic risk[16]. All of these cases were classified as Brown class II and III.

Indeed, the reconstructive gamechanger was CT planning for reconstruction (s1,2,3). After many years of practice, we realized we had to adapt to technological advances such as this. Its impact despite skepticism was far beyond our expectations. CT scans fed into computer software to generate a bespoke model to guide surgical resection (Brainlab AG, Germany). We use preplan STL files (Standard Tessellation Language or STereoLithography) positioned according to a patients individualized length and angle. Data is submitted to the CAD Autodesk 123D and Autodex Fusion 360 software program whereby modeling of the resection and cutting guides is performed.

To enable 3D printing, preparations are made using an Autodesk Mashmixer + Ultramaker Cura software. Guides are printed using the 3D printer Ultimaker 2+ (Ultimaker, Netherlands). What is unique is that the majority of the plan and 3D printing is performed within the department. For this reason, patients can be prepared for surgery within 3 to 7 days. Usually, two osteotomies were performed to recreate the alveolar ridge for insertion of dental implants, and distally on the flap to recreate the zygomaticomaxillary buttress. The fibula was fixed with miniplates and 2.0mm screws for the alveolar ridge as well as to the body of the zygomatic bone. Additional stability was achieved using the free fibula bone fixed with miniplates to the bone flap itself and the medial aspect of the infraorbital rim when recreating the nasomaxillary buttress.

We felt that a free bone graft when we started out in 2017, would be a temporary measure and we expected that it would resorb over time. Encouragingly, we have seen that even after three years, bone graft following integration retains its volume. There was no significant inflammatory reaction nor any graft excursion. We position the pedicle in such a way that it is orientated distally, at the level of zygomatic body. Vein grafts are not used in our practice except in one instance when the flow via the facial artery was considered too weak to support the flap and a vein graft used as a precautionary measure. For Brown class III defects, the fibula flap was combined with titanium mesh to reconstruct the orbital floor and infraorbital rim. The reporting guideline has been followed in this study.

Results

Table 1

Table 2

Table 3

Discussion

Anatomically, the maxilla possesses a vital role. It forms the orbital floor, superior dental arch, separates the oronasal cavity and contributes to midface projection. Its proximity to multiple neighboring structures means maxillectomy lends itself to a host of functional impairments, including speech and visual disturbance and impaired swallowing. Unsurprisingly, in addition to the cosmetic implications with loss in midface projection, this has a significant impact on quality of life with psychological sequelae[17]. Obturators provide a poor solution to tackle these issues and locoregional flaps often require staged procedures which correspondingly leave visible donor scars in the head and neck and in such cases leave a paucity of options available. We consider their use is best reserved for salvage and revisional cases, or when patients comorbidities necessitate expedient surgery to mitigate prolonged operative times.

In this paper we have presented our experiences in the evolution of three microsurgical modalities for midface reconstruction over three decades *(Table. 2)* . The aim was to discuss and outline the range and often controversial debate about which techniques and approach deliver the desired patient outcomes. Indeed, we acknowledge these are the views of a single centre but does highlight, especially for trainee surgeons the progressive management of such complex cases and the historical basis behind a shift in practice for midface reconstruction. It also highlights how residents should be open minded about innovation, and to be aware of emerging technologies. Better still would be for the next generation of reconstructive surgeons to collaborate and develop new techniques in their respective field of work.

We are often asked by our residents what is the future of midface reconstruction? In our opinion 3D planning, rapid prototyping and intraoperative navigation will be the golden standard in the near future, especially given the plethora of uses for 3D printing, which has now reached the point of 'in-house' printing. Using tissue engineering departments have 3D printed bioresorbable scaffolds bespoke to the patient for this particular purpose in maxillectomy but the outcomes are yet to be clearly identified[18]. For the meantime, microvascular flap reconstructions will remain the mainstay of management as soft tissue cover is needed and tissue engineering does not have an answer for this at the current time[19-21].

We found that the main advantages of utilizing 3D planning for free fibula reconstruction are that we can plan the resection and reconstruction much more precisely and as a result, we have achieved more predictable outcomes *(Table. 3)* . This addition of this technology to the reconstructive armamentarium has enabled us to provide stable soft tissue support and the ability to accurately place implants for mastication. Preoperative planning (within a week) in concert with a simultaneous two team surgical approach, we have considerably reduced operative time. We have not experienced any major complications using this reconstructive approach. However, one limitation is that the maximum follow-up for this cohort of patients is five years in seven patients. We intend on providing a more definitive answer as we recruit more patients with a longer follow up with more subjective and objective measures with regards to outcomes.

In conclusion, the ultimate paradigm shift in midface reconstruction will arise from tissue engineering, sparing the morbidity and any complications from harvest of autologous tissues using 'in house 3D printing technology'. Tissue engineering represents a promising prospect for the future wherein biological scaffolds and growth factors are combined with autologous cells to engineer a composite tissue construct that integrates with the recipient. The end goal should be to have an incorporated construct that has sensibility, durability and remains viable long-term. The translation of laboratory engineered constructs, bespoke for the individual most likely utilizing 3D printing is very appealing yet still remains at the experimental phases in the basic science literature. Importantly, microvascular reconstruction is still likely to play an adjunctive role to vascularize or supplement biocompatibility with further research required to deliver a solution at human scale[22].

Conflict of interest: None

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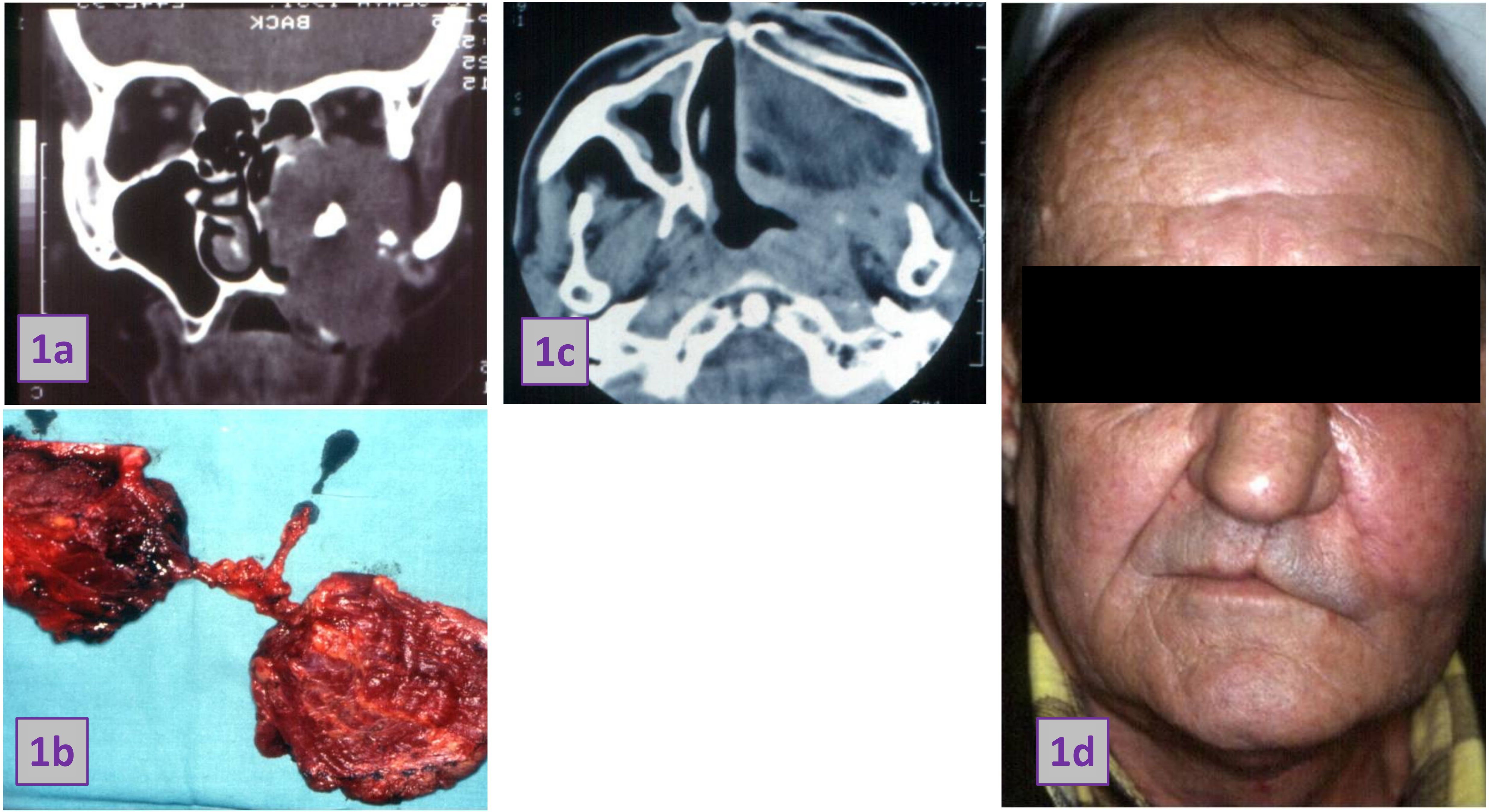
Fig. 1a Maxillary sinus PCC.
Fig. 1b Composite LD and angle of the scapula flap.
Fig. 1c Position of the scapula.
Fig. 1d Patient fitted with custom made eye prosthesis.
Fig. 2a Patient was referred to our department after sustaining a motorcycling accident. He had two previous operations to correct his lid and cheek deformity.
Fig. 2b 3D printing model of the actual defect on the right and mirror image on the left side.
Fig. 2c Four separate pieces of titanium mesh were prefabricated on mirror image model.
Fig. 2d CT scans of the postoperative result. Fibula flap was used for the alveolar ridge reconstruction.
Fig. 2e Preoperative and postoperative look after two years.
Fig. 3a Planned approach for the maxillectomy together with resection of the cheek skin and reconstruction with a local rotation flap.
Fig. 3b Cutting guide for the fibula flap.
Fig. 3c Postoperative CT 14 months after surgery.
Fig. 3d Patient appearance after 12 months post op.
S1. 3D simulation of the Brown class II defect for resection of osteosarcoma.
s2. 3D simulation of fibula flap reconstruction for the alveolar ridge and two free fibula grafts for reconstruction of the nasomaxillary buttresses
s3. Resection and cutting gudies
S4. Maxillectomy type IV, composite LD and angle of scapula, final result with prosthesis
S5. Pre-fabricated titanium mesh, fibula inset for alveolar ridge reconstruction with 6 month post-operative result.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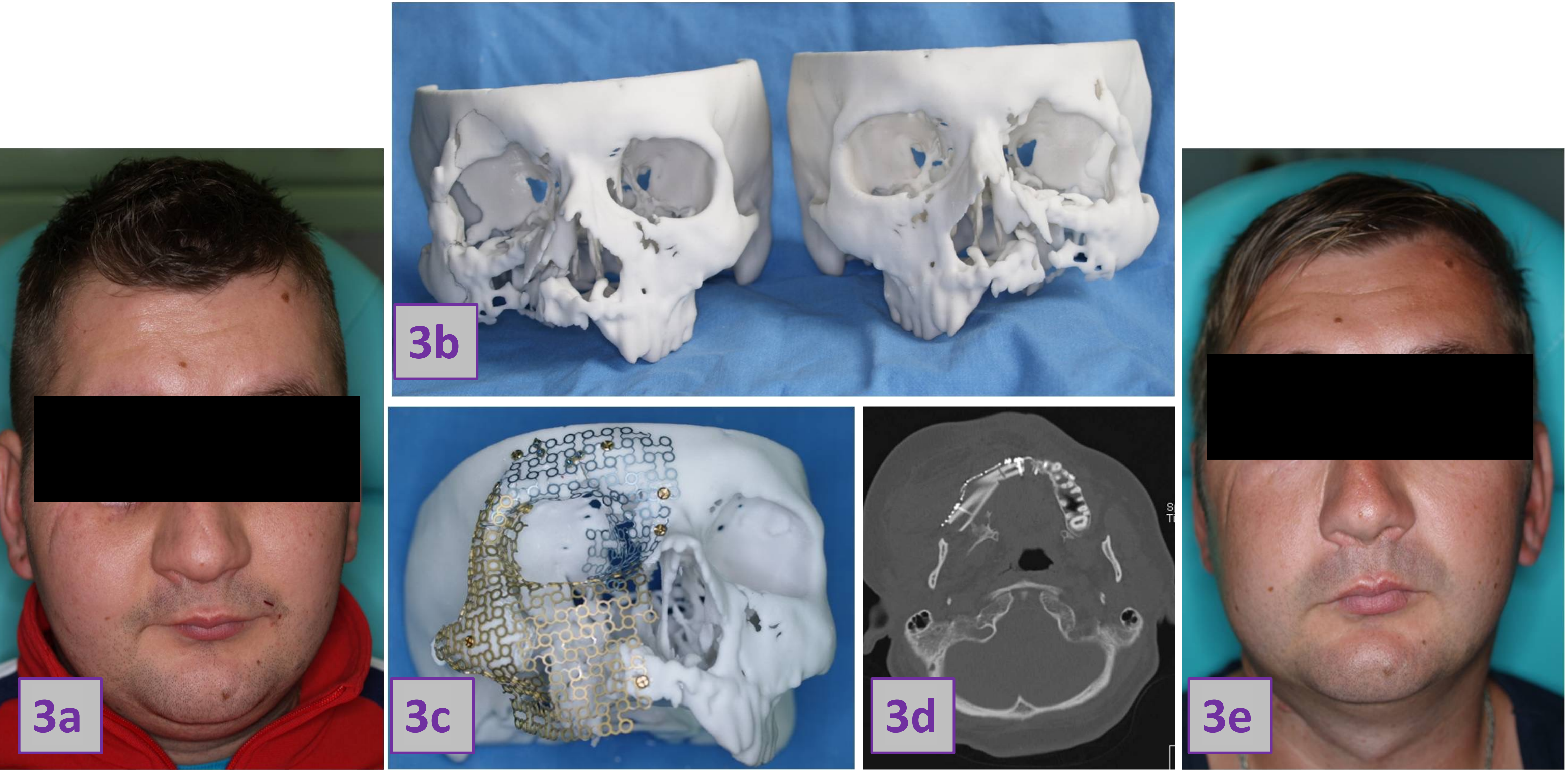
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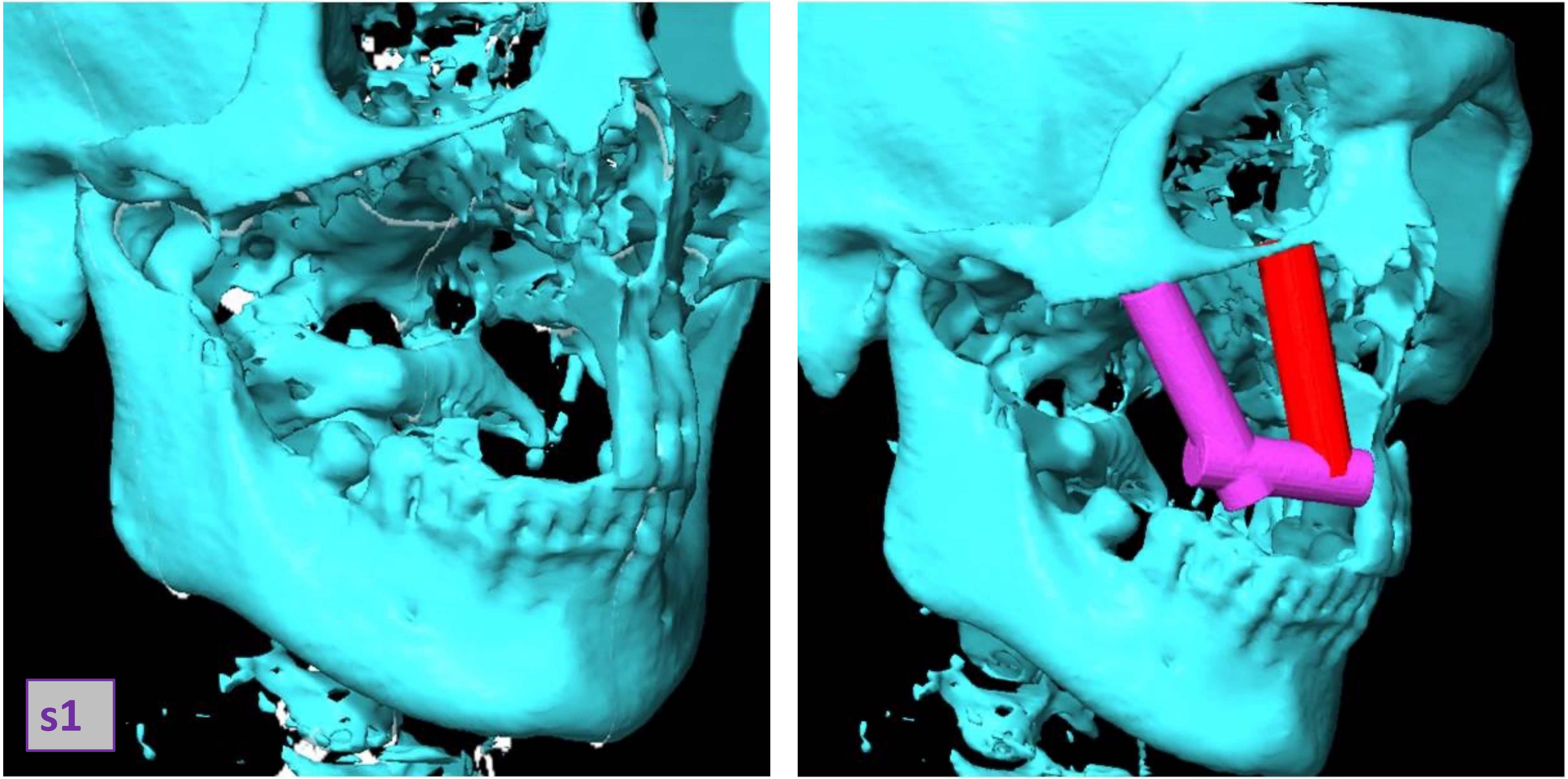
Supplementary Images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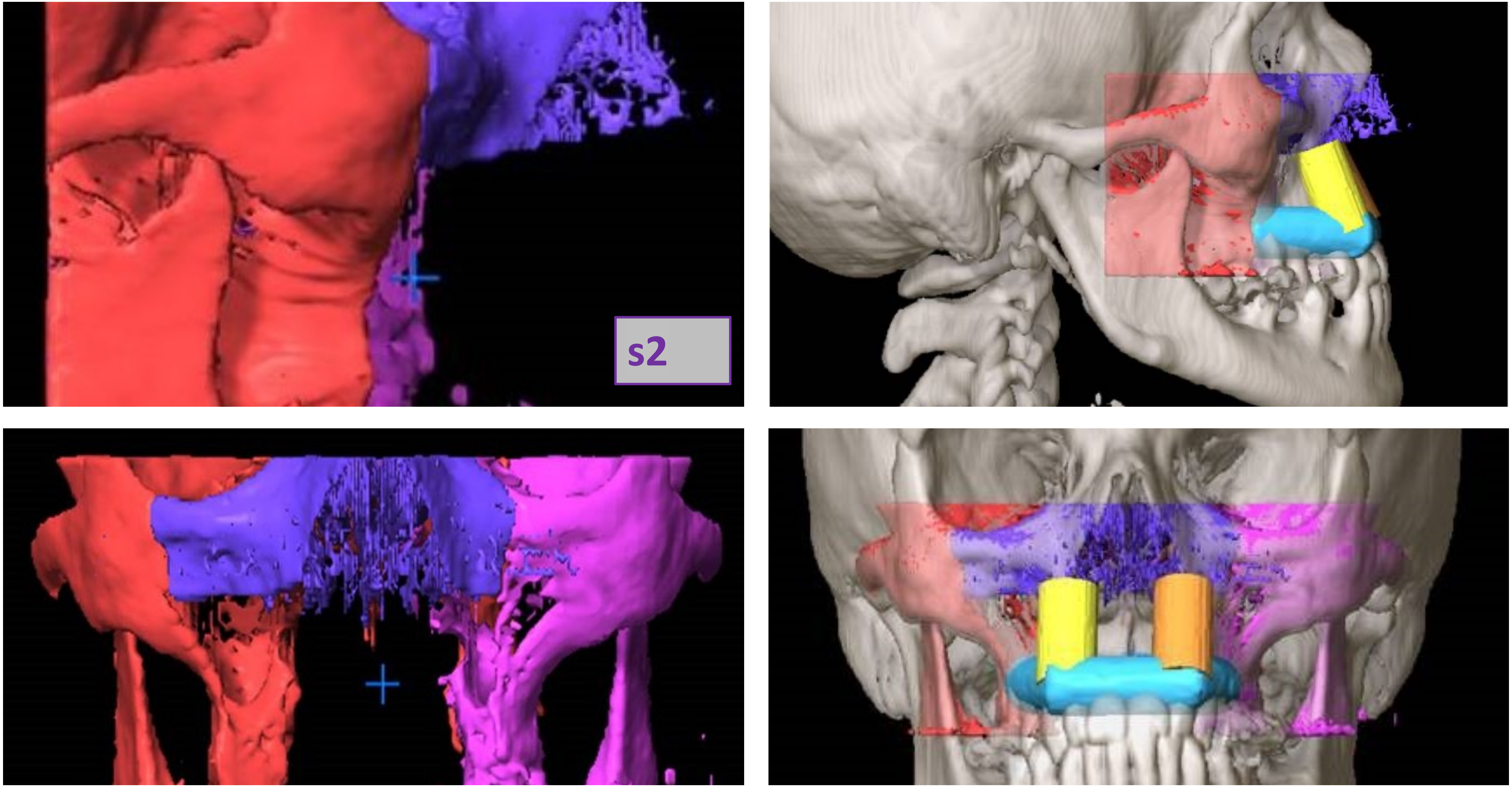
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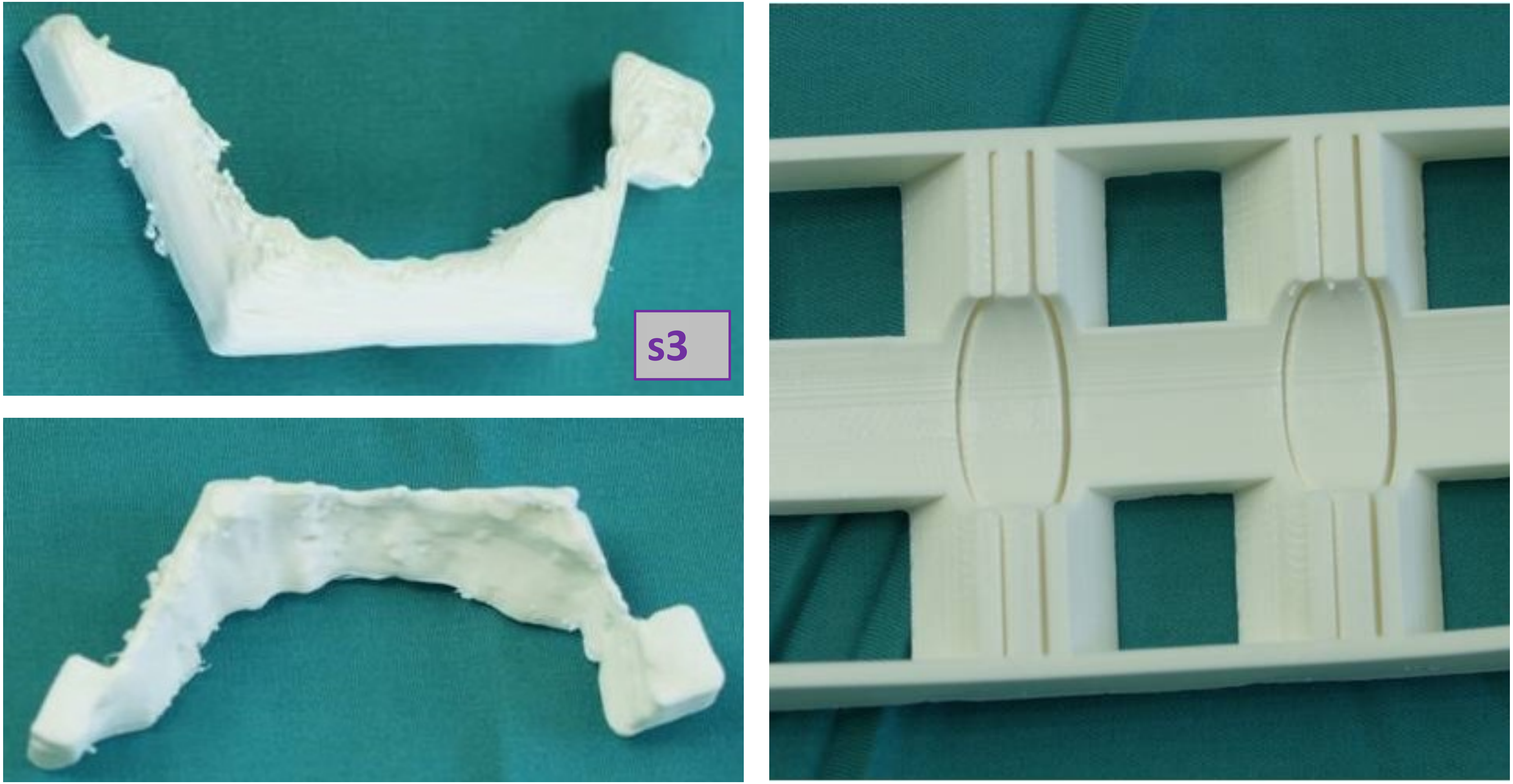
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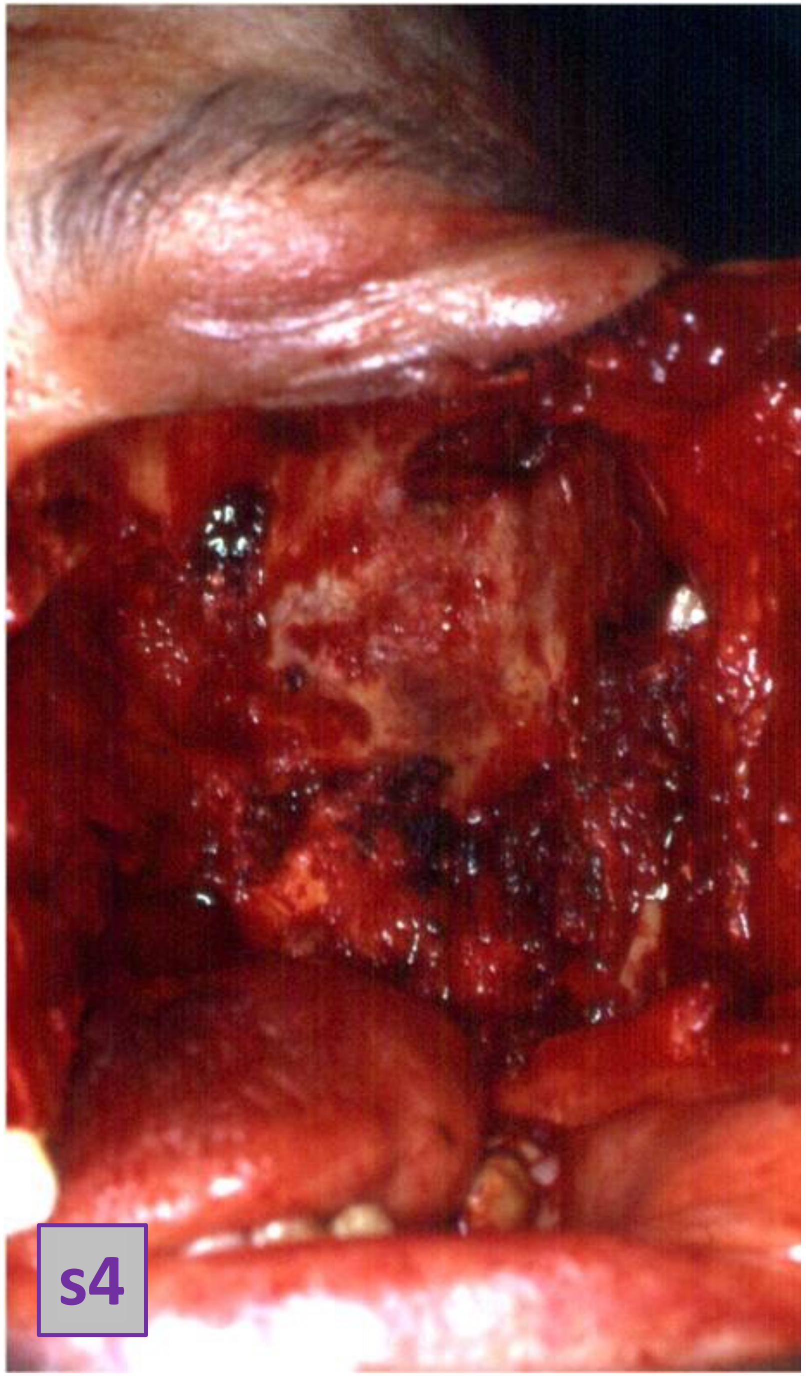
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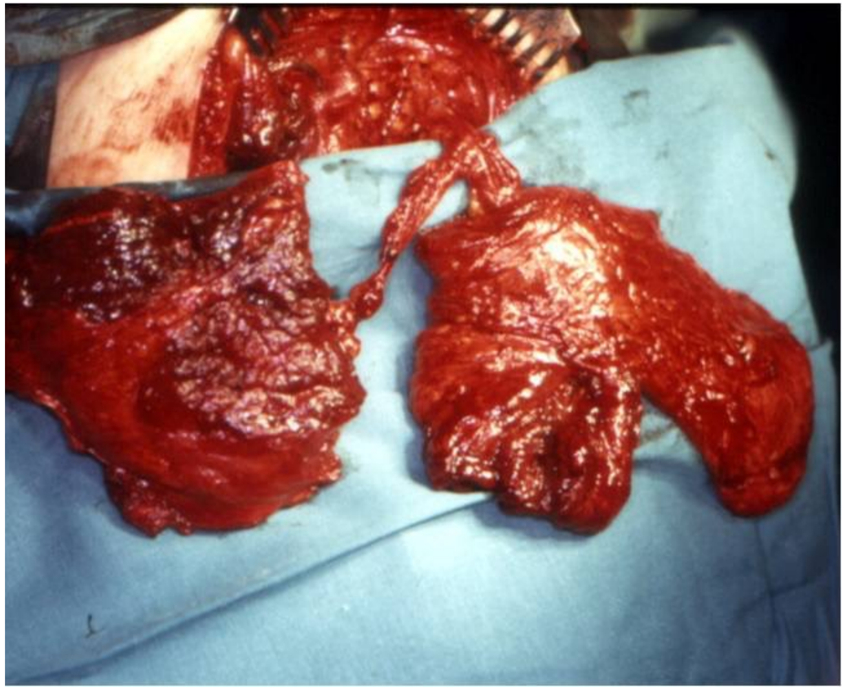

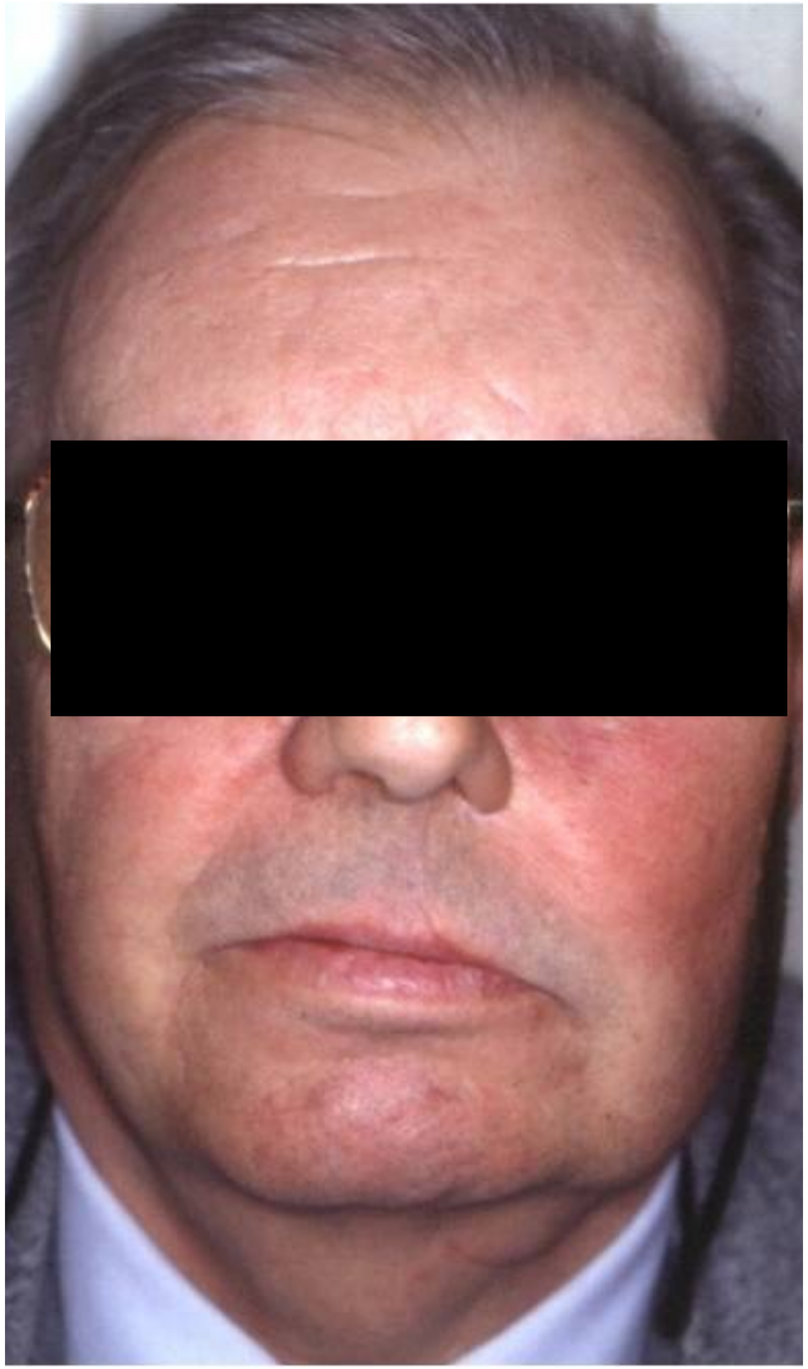


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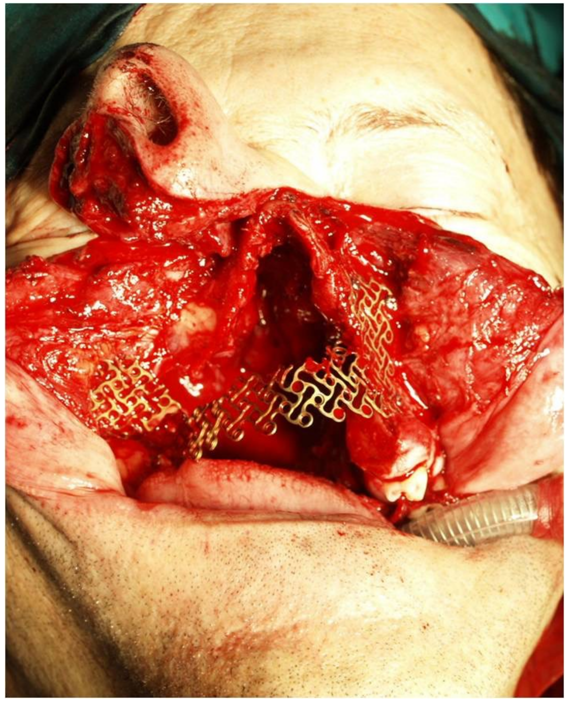
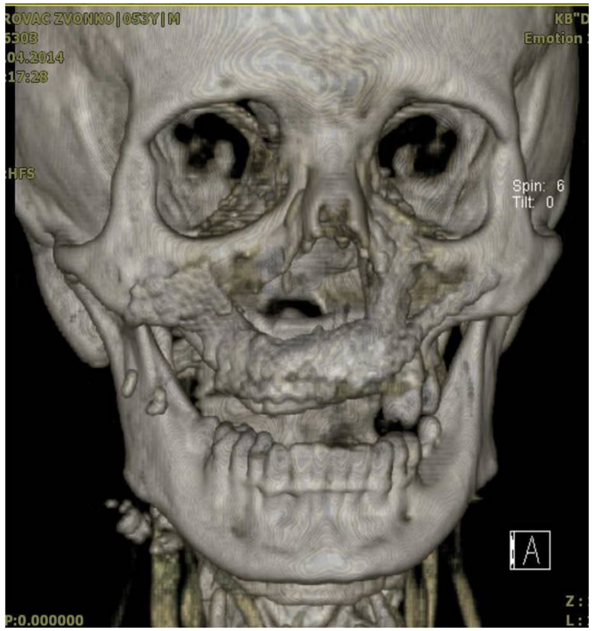
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