Innovative Method of Titanium Plate Use for Morphological and Functional Human Face Recontruction

ZORIN CRAINICEANU[1]*#, EMILIA IANES[2#], PETRU MATUSZ[3], VLAD BLOANCA[1], ELENA SELEACU[1], VIVIANA NARAD[1], GAURAV NARAD[1], GHEORGHE NODITI[1], TIBERIU BRATU[1]

[1]Victor Babes University of Medicine and Pharmacy, Department of Plastic and Reconstructive Surgery, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

[2]Victor Babes University of Medicine and Pharmacy, Department of Maxillofacial Surgery, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

[3]Victor Babes University of Medicine and Pharmacy, Department of Anatomy, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

Morphological restoration of the face in complex tissue defects involving midface remains a great challenge for any surgeon. Tridimensional tomographic analyze gives excellent quality images of the defect and modern technology can provide prosthesis for skeletal replacement at least. Prelaminated free flaps are a method to reestablish morphological aspect and restore lost functions. We describe here a case of 30 years old male patient, victim of a self-inflicted gunshot wound, with a complex defect of the midface. A three-dimensional skull reconstruction was performed in order to restore the midface morphology. Following an initial uneventful evolution, at 2 weeks we noticed partial flap necrosis, with a small island of implant denudation in the mouth and significant decrease of the hypodermis, but with the integrity of the skin covering the implant. Despite of this, we observed a good general condition and improvement of patient's mental health, swallowing restoration and phonation improvement.

Keywords: titanium plate, human face restoration, anterolateral thigh prelaminated free flap, face reconstruction, microsurgery

Morphology of the face is one of the most complex because of the multitude of anatomical structures involved in its determination. Face has three topographical parts: frontal floor, in the upper part, midface and bucal floor in the lower part. The aspect of the face is completed by 6 prominences: two eyebrow arches, nasal pyramid, two zygomatic arches and menton. Many areas of the skin separated in aesthetic units determined by the natural shape of the face, are described in the face: frontal, orbital, temporal, nasal, infraorbital, zygomatic, labial, buccal, maseteric, auricular, mental (Delmar, 1994 [7]; Fattahi, 2003 [8]; Gruber et al., 2013 [12]).

Subcutaneous tissue is represented by fat compartments surrounding the facial folds with different arrangement patterns of the fat compartments around the facial rhytides (Gireloff, 2012 [11]).

Muscles in the face are highly developed and with skin and bone attachments insures mimics and mastication (Marur and Demirci, 2013 [17]). Their origin is on the visceral cranium, composed by pneumatic flat bones: 2 inferior nasal conchae, 2 lacrimal/nasal bones,1 mandible, 2 maxillae, 2 nasal bones, 2 palatine bones,1 vomer, 2 zygomatic bones, in close relation with cranial bones: frontal bone, ethmoid bone, sphenoid bone and 2 parietal bones.

Branches of the facial nerve, main motor nerve in the region, insure the motility of the muscles and branches of the trigeminal nerve insure sensation of the face.

Three main arteries assure vascularization of the face: facial, transverse facial and infraorbital artery, branches from external carotid artery. (Soikkonen et al., 1991 [23]) As in the hole body different artery supplies a different skin and subcutaneous tissue territory (Cormack and Lamberty, 1986 [5]). The arterial supply dominance varies between facial artery and the other two in different proportions (Cormack and Lamberty, 1986 [5]; Bratu et al., 2010 [2]).

Complex facial tissue defects are difficult to reconstruct due to the multiple structures with various functions involved, and to the morphological, physiological and psychological impact. The reconstruction of the morphology allows functional recovery and improves psychological status. There are a number of reconstructive possibilities, from epitheses and prostheses to free transfer of composite flaps (associated or not with prostheses), and to partial or complete face transplantation.

We describe here a case of 30 years old male patient, who was a victim of a self-inflicted gunshot wound (with hunting rifle), resulting in a complex defect of the midface, including bone and soft tissues. He underwent psychiatric evaluation and treatment and was cleared suitable for reconstruction.

Preliminary morphologic evaluation included photos, skull radiography and tomography, and 3D tomographic evaluation of vascular network. Images showed a left mandibular fracture with bone defect, cvasicomplete defect of left maxilla, including the maxillary dental arch, the orbital floor and medial wall, complete absence of the left nasal bone, frontal bone fracture with defect and opening of the frontal sinuses, absence of the left eye-ball and partially of left eyelid, cvasicomplete defect of the left nasal pyramid,(fig. 1). The lesion is classified as type IV

Fig. 1. A preop clinical aspect – front

Fig. 2A. Defect evaluation - CT with tridimensional reconstruction – front

* email: zcrainiceanu@gmail.com

# Authors with equal contribution

Fig. 2B. Defect evaluation - CT with tridimensional reconstruction - front: vascularization and bone defect

Fig. 2C. Defect evaluation - CT with tridimensional reconstruction - front: left maxilla, left infraorbital floor, left zygomatic process, centrum and left nasal pyramid walls defects, partial mandibular defect plate fixated\

Fig. 2 D. Defect evaluation - CT with tridimensional reconstruction – left semiprofile: left maxilla, left infraorbital floor, left zygomatic process, centrum and left nasal pyramid walls defects, partial mandibular defect plate fixated

according to the classification proposed by Cordeiro and Santamaria (Cordeiro and Santamaria, 2000 [4]) for complex midface tissue defects. The angioCT images showed the absence of the distal portion of left facial artery, (fig. 2).

Results and discussions

In a first step we performed mandible reconstruction with iliac crest bone graft, fixed with plate and screws. A length of about 5 cm from the iliac crest was required to reconstruct the horizontal portion of the left lower jaw.

A three-dimensional skull reconstruction was performed in order to restore the midface morphology. Based on the mirror image, a cast of the absent skeleton was made. The bone defect was including the maxillary bone and it's zygomatic, frontal and palatine process and also left and right paramedian dental arch. Using the mold, customized titanium prosthesis was made, to match the bone defect and which has preformed holes to allow fixation on the remaining skeleton (fig. 3-A). The metal prosthesis perfect reconstructs the skeleton morphology. We decided to create a prelaminated fasciocutaneous anterolateral thigh flap based on perforators from the lateral femoral circumflex artery (fig. 3-B) in order to get in the face region enough skin and soft tissue to reconstruct the hole morphology, including nose and lower eyelid. The metallic prosthesis was sterilized and then it was implanted in the left thigh at suprafascial level, considering the available perforators detected by ultrasound and CT scan and the future position it will take in the face. The device was allowed to integrate for a period of three months – all the prosthesis to be covered by well-vascularized soft tissue.

Fig. 3A.Titanium prosthesis to reconstruct the defect: mashed part - orbital floor; holes for bone fixation – frontal, nasal, zygomatic and right maxila.

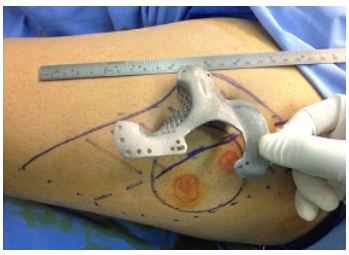

Fig. 3B. Prelaminated left anterolateral tigh flap design and prelamination planned with titanium prosthesis positioning

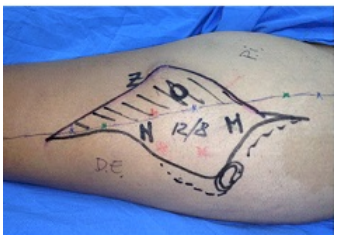

Fig. 4A.The prelaminated anterolateral thigh flap - skin flap planning: N- left nasal, Z- left zygoma, O: orbital floor, M- right maxilla

Fig. 4B. Imediat postop clinical aspect

The prelaminated flap was designed (fig. 4-A) and than harvested based on one muscular perforant only, branch from lateral circumflex femoral artery. The total length of the pedicol was 15 cm and maximum caliber was 2mm. The prelaminated flap was microsurgically transferred to the face, fixing the prosthesis with screws to the remnant bones. The revascularization of the flap was performed at facial artery inframandibular level, with a 3mm caliber, by end-to-end anastomosis and end to side vein suture at internal jugular vein. We use for microsurgery a Zeiss microscope S88, magnification 7 to 21. The retromolar pedicol traiect avoided dental arch contact and trauma. Interdisciplinary team performed surgery: plastic and oro-maxillo-facial surgeons, radiologist. The imediat postoperator aspect was considered good (fig. 4-B).

Following an initial (5 days) uneventful evolution, at 2 weeks we noticed partial flap necrosis, with a small island of implant denudation in the mouth and significant decrease of the hypodermis, but with the integrity of the skin covering the implant. The late postoperative result was acceptable with good general condition and improvement of patient's mental health, swallowing restoration and phonation improvement (fig. 5-A). We also found on CT scan good morphological restauration of the face skeleton (fig. 5- B).

Morphological reconstruction in the posttraumatic face complex defects is very difficult because of multiple structures involved, also hard and soft tissue, with many functional implications and which are also visible, impossible to be hidden, so with great psychological impact. The 3D analysis of the face was mandatory to obtain the missing pieces and to establish the proper way

Fig. 5A. Clinical aspect -2 months postop – front

Fig. 5B CT aspect – prosthesis integrated

to rebuilt them. This should include also to the hard tissue and the soft tissue. Different procedures are described in the literature, but for hard tissue tomography is considered the best way – 3D CT scan – with the variant of CBCT (cone beam CT) combined with optical images (Chiarella et al., 2013[3]).

Considering the particular psychological structure of the patient with intentional self-inflected injury, we estimated him at high risk both preoperatively, amplified by the resulting disfiguration, and postoperatively, due to the difficulty of harmonizing his expectations to the possibilities of reconstruction with imperfect results. Series of patients with complex facial defects produced by shotguns with suicidal purposes are described in literature. They have benefited from free flaps reconstruction, the recommendation being that the reconstruction should be as early as possible (Dean et al., 2011 [6]). Psychiatric evaluation and clearing was considered mandatory, the patient being monitored and treated both with drugs and with counseling. The surgical and the intensive care team were aware about the increased risk of complications in patients with mental and behavioral disorders (Kuo et al., 2008 [15]).

There are various possibilities of reconstruction, due to the complexity of the defect and the imperfection of surgical methods. The need for reconstruction was mandatory, in order to normalize or at least to improve facial morphology and, of course, functions that were affected: breathing, chewing and swallowing. Under the specific circumstances, we considered appropriate to apply the principle of reverse reconstructive ladder, where the microsurgical free tissue transfer is considered as the first option (Dean et al., 2011 [6]).

We appreciated as insufficient the reconstruction with alloplastic device only, such as an external prosthesis. However, a microsurgical autotransplantation alone is also insufficient, due to the complexity of the defect (both oro-facial and midface, but also nose and left orbit) and to the multitude of physiological and morphological aspects to consider (Oladimeji, 2012 [20]; Pribaz and Caterson, 2013 [22]). Partial face transplantation in conditions of a limited defect with moderate degree of mutilation is still a too risky and costly intervention, having a too important impact on quality of life (Oladimeji, 2012 [20]; Pribaz and Caterson, 2013[22]). Three-dimensional reconstruction, with an implantable metal prosthesis and a prelaminated flap was considered the best choice for this case (Kokemüller et al., 2011 [14]).

Three-dimensional CT analysis is essential in all cases of reconstruction of facial complex defects (Gellrich et al., 2002 [10]). This method allowed a mirror reconstruction of the cast of the defect and the making of the permanent titanium prosthesis. The procedure proved extremely accurate in hard, complying with the physiological facial asymmetry (Metzger et al., 2007 [19]). The intraoperative integrated navigation system can further increase the accuracy of the reconstruction (Bell and Markiewicz, 2009 [1]; Zang et al., 2012 [24]).

The prelaminated flap reconstruction chosen in this case can be weighted against pure autologous reconstruction methods, such as radial fasciocutaneous flap or osteo-musculo-fascio-cutaneous fibula flap (He at al., 2009 [13]). Another option would have been the combination of the custom-made implant with a scapular osteo-musculo-cutaneous flap (Mertens, 2012) [18].

The perforator flap, prelaminated by suprafascial implantation of the titanium prosthesis, is at major risk of interruption in blood flow between the subdermal plexus and fascia, due to the placement of the prosthesis at this level. The direction of the blood flow from the perforator artery towards the subdermal plexus and then to the fat and fascia may explain why the flap's suffering occurred as described. Another explanation could be the corrosive action of saliva upon the subfascial plexus, causing its thrombosis. This course of action might explain the sequence of tissue necrosis from deep, fascial level, towards the overlying skin. It would also explain the delay of necrosis, which occurred in more than 5 days from the free transfer, and also the survival of skin that was not exposed to corrosive factors.

For nose reconstruction we benefit from studies that provides dimensions and proportions in the face by race and gender (Leslie et al., 2005 [16]; Ziqing et al., 2010 [25]). Anthropometric analysis will still be necessary. Most of the authors considered optical analysis to be at least mandatory, by digital photographs acquired in frontal, lateral and basal views (Omar et al., 2010 [21]), but combination with 3D CT or CBCT can provide exceptional data for reconstruction. (Chiarella et al., 2013 [3]). Another possibility is to use laser scanner for evaluation (Ramieri et al., 2006 [9]). Images analysis will provide data for amount of soft and hard tissue necessary for nasal pyramid reconstruction; so we can decide if local or regional flap will be sufficient or another free flap microsurgical transfer will be necessary.

Skeletal reconstruction can be achieved with a preoperatively bent titanium sheet mesh on a universal skeletal model. A free flap, preferably anterolateral thigh flap, is used, with a deepithelized part put in front of the mesh to prevent exposure, and the other part is used for palatal reconstruction (Dediol et al., 2013 [26]). The main difference is that we prelaminated the foreign material, and instead of bending we used 3D reconstruction and printing.

Epithesis is another option of reconstruction. By 3D integration of contours it was possible to achieve 3D model of the region and therefore the virtual model of epithesis (ROSU S et al., 2014 [27]). We consider this method to be last solution.

Conclusions

Morphological reconstruction of the face after high-energy trauma with complex tissue defect is very difficult surgical procedure, involving accurate high tech analysis, step-by-step high performance surgical procedures combined with a good psychological assessment of the patient. The prelaminated flap obtained using personalized titanium prosthesis by mirror image cast from the three-dimensional tomographic study, implanted between fascia and skin in the anterior – lateral thigh flap, is a very good method of reconstruction of significant complex midface defects. The presence of foreign material (titanium prosthesis), together with the prelamination procedure, which can compromise the vascular connections between fascia and skin, intraoral environment aggressiveness and patient's peculiar mental status, greatly increases the rate of complications.

We conclude that mashed titanium prosthesis and skin layer inside the oral cavity may avoid partial failure of our complex morphological reconstruction because it allows better integration of the prosthesis in the flap and has higher resistance to the intraoral environment.

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