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Review

Extended and unusual indications in jaw reconstruction with the fibula flap: An overview based on our 30-year experience

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ABSTRACT

Since the introduction of fibula flap as a reconstructive technique, an evolution of indications has been observed. Our first report of a traumatic mandibular reconstruction using fibula flap was in 1992. The vast majority of indications for surgery, are: malignant tumors, benign neoplasms, osteoradionecrosis and traumas. Nevertheless, extended indications have been described such as the treatment of dentoalveolar defect without bone discontinuity or reconstruction of maxilla defect up to type III (A and B), according to Cordeiro's classification. Unusual indications include cleft palate malformations with bone discontinuity less than 6 cm. Moreover, a particular attention should be focus on fibula flap harvest with more innovative technologies than traditional use of monopolar or bipolar and their advantages in pre and postoperative management.

1. Introduction

Since the introduction of fibula flap as a reconstructive technique, an evolution of indications has been developed. The first indication found in literature is related to the use of fibula flap for reconstructions of extended bone defects in the extremities, using a posterior approach for flap harvesting. It was Taylor, in 1975, who performed the first fibula flap using a vascularized myosseous segment of the fibula to treat a post-traumatic defect of the tibia [1].

Since fibula graft can provide skin island, up to 25 cm and 14 cm wide, it can be suitable for reconstruction of soft tissue defects; this was firstly experienced by Chen and Yan who described the osteocutaneous fibula flap in 1983, using a lateral approach for harvesting the bone flap, that has the advantages to be easier to perform and to allow a better visualization of the cutaneous branches of the peroneal artery [2]. The dual endosteal and periosteal blood supply guarantees bony viability despite multiple osteotomies.

The fist jaw reconstruction using fibula flab is dated in 1989 from Hidalgo who used osteotomies to mimic the shape of the mandible after oncological or traumatic defects [3].

Even if at the beginning of the 1990s, many surgeons didn't trust in the use of osteocutaneous flap because of poor skin vascular reliability, a better understanding of the vascular anatomy enhanced the skin paddle survival.

Fibula graft gives the chance to harvest multiple skin islands providing an osteomyocutaneous flap, including those based on septocutaneous as well as on musculocutaneous peroneal perforators [4].

Even if the most reliable septocutaneous perforators have been observed in the middle and distal third of the fibula [5], currently, a second skin island based on proximal perforators of the peroneal artery has been reported [6].

This flap has shown the lowest complication rate among osteocutaneous flap. It can provide the simultaneous reconstruction of bone and soft tissue defects both inside and outside the oral cavity, providing healthy tissue to an area which is often contaminated and irradiated [7, 8].

Fibula vascularized flaps withstand irradiation much better than bone grafts or plates by providing tissue with a new blood supply in those areas that have been previously irradiated. [9].

Since its first description [3] for head and neck reconstruction, technical development about fibula flap harvest and inset has been possible thanks to the improving experience and a better understanding of the physiology of the flap. An example of the improvement of the technique is the use of the soleus muscle connected to motor branches at

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the recipient site in order to restore the motor function or the use of the sural cutaneous nerve together with a skin island to restore sensory function [10].

Another great achievement was reached in 1988 by Jones et al. who described a modified flap called "the double-barrel flap" for lower limb reconstruction that gave the opportunity to overcome the limited height of the fibula. With this technique, the thickness of the bony part of the flap can be doubled, and it is nowadays fundamental in mandibular reconstruction to obtain a flap size similar to the native mandible [11].

Another technique is to use flap combinations by anastomosing a second free flap to the distal peroneal artery and vein, which do not significantly reduce in caliber, giving many advantages at the recipient site like sliding more freely and facilitating the setting of the osteocutaneous flap [12].

The use of free vascularized fibula has become over the years the gold standard for large mandibular and maxillary defects. The aim of this paper is a review of the literature including through our 30-year published experience with the fibula flap. We will focus the attention on unusual and extended indications in jaw reconstruction and on the use of new technologies.

2. Extended and unusual indications

Traumatic injuries, congenital defects, oncologic resections (for either benign or malignant tumor), osteoradionecrosis, osteomyelitis, and large vascular malformation of the head and neck are the widely used indications for mandibular or maxillary reconstruction [8].

Fibula flap is usually used to reconstruct bone discontinuity greater than 4–6 cm, for defects of mandibula or upper maxilla [13, 14].

The first report of a traumatic mandibular reconstruction with fibula flap has been described in our center in 1992 [15]. From February 1989 to January 2019, a total of 520 free vascularized fibula flaps has been transferred for composite soft-tissue and jaw bone defects. According to the literature, the vast majority of our indications for surgery were malignant tumors, benign neoplasm, osteoradionecrosis and traumas.

Nevertheless, we have extended indications to the treatment of other conditions such as dentoalveolar defect without bone discontinuity; this condition includes all cases where, although there are no discontinuities, a bone augmentation is necessary because the height of the native bone is not sufficient to ensure the stability of the dental implants; this happens in classes V and VI of Cawood's classification of jawbone atrophies [16]. Thanks to its morphological properties, fibula seems to be the ideal bone for alveolar ridge augmentation and its donor site morbidity is the lowest among vascularized bone flaps [17]. Our study from 2002 was the first study that reported the successful treatment of extreme atrophy of both jaws by simultaneous bony augmentation of the maxillary and mandibular alveolar ridges with just one free fibula flap [18]. Furthermore, in 2004, we reported a multidisciplinary treatment protocol for the rehabilitation of extreme mandibular and maxillary atrophy with respect to bone augmentation, implant surgery, soft-tissue management and prosthetic restoration [19].

Fibula flap has become fundamental in maxillary defects resulting from tumor or trauma; since these defects can lead both to severe cosmetic and functional deformities, maxillary reconstruction is more challenging rather than the reconstruction of the mandible. Maxillary bone provides height and width to the midface defining the aesthetic facial contour, and moreover it divides the oral from the nasal and orbital cavities; it also represents the skeletal support to the orbital contents. Given that, maxillary defects involve speech, swallowing and mastication and can cause dystopia. When demanding structures such as the orbit, the globe and the cranial base are resected, the reconstruction of maxillary defects can become really challenging and it often requires the use of distant tissues. While the loss of the vertical component impacts on aesthetic features, the horizontal component loss involves functional aspects. The two goals of maxillary reconstruction are functional preservation, including orbital contents' support and optimization of feeding and speech, and secondly aesthetic restoration of patient's appearance with right midfacial projection and vertical facial height. It is not fundamental to reconstruct all the walls of the maxilla, but it is mandatory to give midface contour, to ensure orbital floor support and to replace the missing alveolar bone as the base for dental implants [20].

Different classification systems classify the defects from their functional and/or aesthetic effects. According to Cordeiro's classification [21], we are now able to reconstruct maxilla defects of type III (A and B) and type IV, evaluating the preoperative findings. In our opinion, when the orbit is involved the aim is not only to cover the defect but also to accommodate the orbital contents or an epithesis when warranted. In our study from 2015 it has been described the use of fibula flap for the near-anatomic reconstruction of the orbit and for the obliteration of dead space [22]. The orbital depth is created by the bony fibula, whereas the fascio-cutaneous part of the fibula flap such as another fascio-cutaneous or muscular free flap allow to line the orbit, to fil skull base or maxillary region, or to resurface the palate and/or the nasal cavity. Latissimus dorsi flap, rectus abdominis free flap and deep inferior epigastric perforator flap are then performed to refill the midface contour and to seal the nasal fossa and oral cavity thanks to their great volume [23].

Fig. 1(a and b,c,d) shows a patient affected by a right minor salivary gland carcinoma (Class 3b according to Brown and Shaw Classification) [24]. We describe a successful reconstruction of composite orbital defect performing a single segmentalized fibula flap. We recreated a new orbit with a good depth and shape in order to accommodate the eye bulbus. We also obliterated orbit dead spaces and reconstructed soft tissues. If the eye is intact but there is a lack of a normal surrounding orbit, this condition can affect the eye position and may even lead to diplopia. The use of alloplastic materials has the advantages to fulfill the above requirements and to mimic a perfect anatomical shape but there can be problems when patients undergo radiotherapy. Segmentalized bony fibula is used to create the orbital rims and/or walls as well as the maxilla, ensuring the re-creation of the most projected part of the facial skeleton and minimizing the use of foreign materials [22].

A study from Santamaria et al., in 2012 shows how fibula flap can be used also for the treatment of palate cleft malformations [25]. Patients often suffer from tooth loss, due to the atrophy of the edentulous alveolar crest. These patients can't undergo oral rehabilitation with conventional prostheses so the only way to avoid tooth loss is to support prostheses with bone augmentation through fibula free flaps, which have a high success rate in patients with cleft lip and palate malformation, especially if prelamination of fibula with split-skin grafts is used

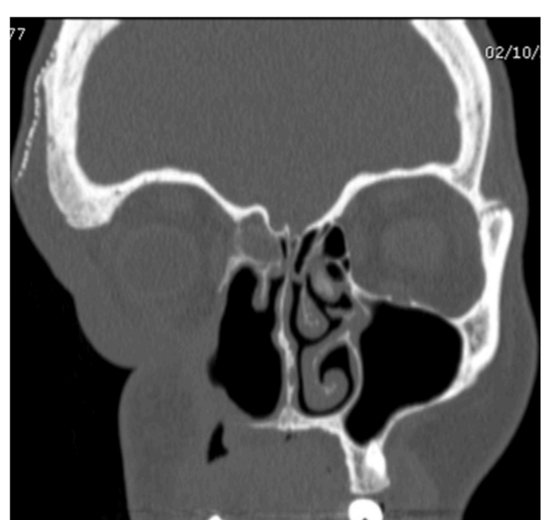

Fig. 1a. Right minor salivary gland carcinoma: CT finding.

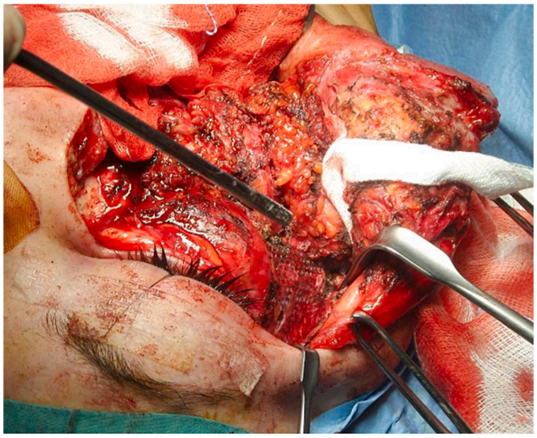

Fig. 1b. A resection of the right maxilla, the alveolar process, the nasal fossa, the pterygoid process of the sphenoid, the floor and the medial and lateral sides of the orbit was performed.

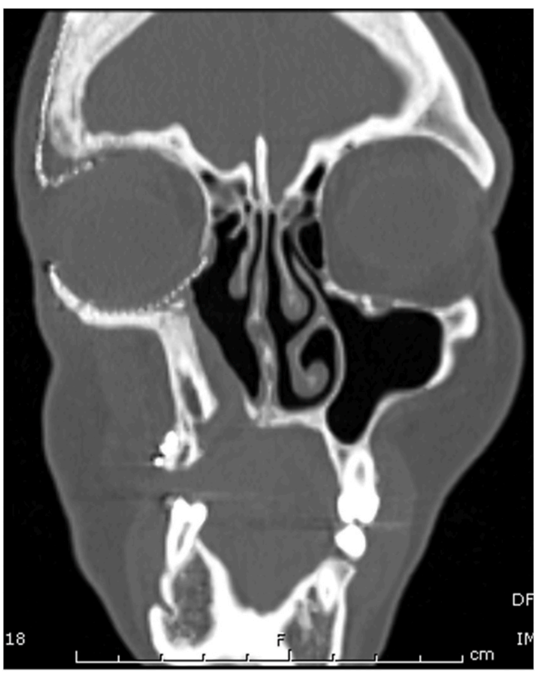

Fig. 1c. CT finding. The reconstruction included the use of a fibula free flap U-shaped (three bony segments U shaped) and the reconstruction of orbital walls and floor with titanium mesh and bone graft. Rectus abdominis muscle was used to fill the residual maxilla.

[25]. Even if fibula flap is usually performed to reconstruct bone discontinuity greater than 4–6 cm, in our experience, this flap can be used for bone discontinuity less than 6 cm. Bone defects resulting from oncological resection of the upper and lower jaw or congenital malformations such as cleft palate, even if smaller than 6 cm, can be treated through fibula flap: this is an unusual indication that in selected patients can be taken into consideration. Fig. 2(a and b,c,d) shows the case of a 16 years-old man with a small bone defect due to cleft palate which we successfully treated with a free fibula flap. The patient was previously treated with conventional bone graft (7 surgeries) but unsuccessfully. We performed a fibula flap that allowed subsequent implant surgery(see Fig. 2e).

Fig. 1d. After radiotherapy the patient developed a moderate lower eyelid ectropion.

Fig. 2a. A 16 years-old man affected by cleft lip and palate.

Fig. 2b. Pre-operative Intraoral view.

Fig. 2c. Fibula flap harvest. Note the long pedicle and the peg-type modelling.

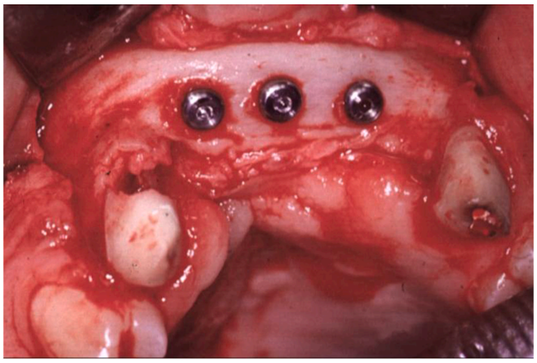

Fig. 2d. Implants after 6 months.

Fig. 2e. Post-operative intraoral view after definitive dentures.

3. Technical refinements

During the last years, technical refinements have been developed with respect to fibula flap harvest, planning and fixation techniques, allowing to reduce complications and achieve optimal results. Computer-aided design (CAD) and computer-aided manufacturing (CAM) are recently used by many surgeons. CAD/CAM procedure has become really helpful in mandibular reconstruction to guide the surgeon to correctly position the residual bone and fibula free flap. In this procedure, high-resolution CT allows to get a virtual surgical plan. As a virtual surgical guide this technique allow bone segments repositioning, and a computer reconstruction bone plate is provided to support the fibula free flap (CAD). The stereolithographic files of the guide and plate are then printed three-dimensionally (CAM) [26]. This recent technology allows the right bone-plate relationship, a good functional outcome and a correct occlusion [27,28].

Traditionally, osteotomies are performed using templates based upon a pre-operative CT scan and lateral cephalogram of the patient. This method is reliable and efficient and added cost or time are not necessary. Virtual surgical planning has inherent advantages in all cases in which reliable measurement of the specimen cannot be performed because of tumor distortion or for delayed reconstruction. Its disadvantages include the substantial added cost of this technology and a time-consuming pre-operative planning. According to our experience, generally the clinical difference between the use of CAD/CAM and traditional methods is not so meaningful to justify the high additional cost. Nevertheless, in selected cases of significant specimen distortion, virtual surgical planning can be very useful [27,28]. It is important for the plastic surgeons to be familiar with both methods so that pros and cons of the two techniques can be evaluated in each patient in order to select the more cost-effective one.

We described in our study from 2019 that fibula free flap elevation could not necessarily be performed under tourniquet, as it is historically done, since there are not specific advantages [29]. Tourniquet is known to be a risky procedure because it can induce micro-thromboses, muscle edema and nerve-related injury due to local compression. In addition, no pulse of the skin paddle perforators is visible and the selection of the most suitable vessel can be difficult. In the perfused leg, anatomic structures are easily identified and bleeding is controlled permanently.

Thanks to the use of CAD-CAM technology and the harvest of fibula without tourniquet, the flap can be modelled in the donor site without any interruption of the vascularization: it means that there is not ischemia time.

Moreover, we described how fibula flap harvest can be performed with more innovative technologies rather than traditional use of monopolar or bipolar [29–31]. Harmonic scalpel shears and J-plasma device present a few advantages including simultaneous tissue dissection and hemostasis, no eschar formation over the blade, minimal thermal damage, no smoke formation and the possibility to be used in patients with pacemaker. These alternative methods of free flap harvesting are reliable and safe and they have advantages such as reduction of the operation time, fast drain removal and less serum drainage.

Furthermore, in our division piezosurgical devices have been used to perform osteotomies instead of rotary instruments in order to obtain more advanced stages of bone healing. Even if more powerful, these devices do not alter the process of bone healing. The application of Piezosurgery to segment fibula flap has proved to be more suitable compared to traditional cutting methods, because it improves the intraoperative safety of the procedure giving also minimal periosteal elevation [32,33].

4. Discussion

The use of new technologies can be very useful to perform fibula flap reconstruction [26–33]. Nevertheless, limitations and challenges can be encountered. The added cost of the described technologies is substantial [26–28]. In our Teaching Hospital additional costs are allowed as part of the Resident Educational Program. Nevertheless, it is mandatory for inexperienced surgeons to be familiar with both traditional and innovative methods because they might go to work to peripheral hospitals where the choice of the method is based on the cost-effectiveness. Every surgery should be performed with a good result apart from the possibility to use additional helpful instruments [27–32]. Moreover, with any new device there is a required learning curve to achieve reliable, predictable, and reproducible results. It is important to underline that only after a great experience with traditional methods, the application of new technologies can significantly improve clinical outcomes. In case of relatively intuitive new methods, the performance of surgeons without great experience can be simplified. Nevertheless, unknown risks and complications can discourage newcomers. To overcome these limitations, in our hospital the surgical team include a senior consultant, a surgeon without great experience and a resident. Surgeries are performed with traditional techniques [34–43] and innovative methods [44–53] according to characteristics of the patient. An accurate selection of the case [54] is the key for successful application of new methods in terms of cost-effectiveness.

5. Conclusion

In conclusion, we would like to underline how the current use of 3D computed tomography planning, virtual surgical planning and the new technologies of surgical modelling and harvest allow the integration of the reconstruction with the planned defect, it gives the chance to perform precise bone cuts and to get the right orientation of the vascular pedicle; it allows to model the flap in the donor site without ischemia time and, therefore, it leads to an important reduction of complications. When performing bone augmentation (double barrel technique or use of non-vascularized graft), we recommend the use of piezosurgical device and new harvest technologies for improved bone healing due to the great respect of vascularization.

In the last year we have tried to improve surgical techniques and to reduce all of the possible complications in order to achieve optimal results throughout: the possibility to perform multiple osteotomies and to double barrel the flap without risk of vascular impairment, a better chance of reliable implant-supported dental rehabilitation, the ability to reconstruct small bone defects and last but not least the chance to reduce donor site morbidity.

Ethical aproval

No ethical approval needed. We describe a review of the literature.

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No study sponsors

Author contribution

Giorgio De Santis: study concept, data interpretation, writing the paper.

Massimo Pinelli: data collection, data interpretation.

Marta Starnoni: study concept, data interpretation, writing the paper.

Conflict of intret

No conflict of interest.

Trial registry number

The research does not involve human participants but it is a review of the literature.

Guarantor

Giorgio De Santis; Massimo Pinelli; Marta Starnoni.

Consent

The study is a review of the literature.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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