“Naked Microvascular Bone Flap” in Oral Reconstruction

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Abstract: Since the 1980s, bone free flaps have been used to reconstruct the maxilla and the mandible. The vascular pedicle, through the supply of nutritional substances and drugs from the bloodstream, ensures the vitality of the flap, rapid bone integration, and reduced risk of infection.

However, due to many surgeons’ concerns about orocervical and orosinusal fistulas and infections, bone flaps are usually buried and protected by mucosal flaps or a second skin flap whenever it is not possible to harvest a skin paddle together with the bone flap.

The authors, convinced that free vascularized bone flaps, if well vascularized, are capable of healing and repairing the osteomucosal deficit on their own, with no risk of infection or fistulas, began to harvest, for oral reconstructions, naked bone flaps, that is, bone flaps covered only by a muscle layer 5 to 20 mm thick.

In this study, the authors present a review of their experience in oral cavity reconstructions by harvesting naked and covered bone free flaps, retrospectively evaluating the occurrence of major and minor, early and late complications, associated with the different reconstructive technique.

Key Words: naked bone flaps, buried bone flaps, mandibular reconstruction, maxillary reconstruction, outcome

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Due to many surgeons’ concerns about orocervical and orosinusal fistulas and infections, vascularized free bone flaps are usually buried and protected by mucosal flaps or a second skin flap whenever it is not possible to harvest a skin paddle together with the bone flap. These procedures (double free flaps, skin paddles, or local flaps) used for covering vascularized free bone flaps notably increase surgical times. In particular, in the case of double flaps, they increase surgical stress, donor-site morbidity, and biological cost to the patient.

The authors, convinced that free vascularized bone flaps covered with a thin layer of surrounding muscle, if well vascularized, are capable of healing and repairing the osteomucosal deficit on their own, with no risk of infection or fistulas, began to harvest, for oral reconstructions, free vascularized bone flaps covered with a thin layer of surrounding muscle, that is, bone flaps covered only by a muscle layer 5 to 20 mm thick (Fig. 1A,B). In this study, the authors present a review of their experience in oral cavity reconstructions by harvesting free vascularized bone flaps covered with a thin layer of surrounding muscle and covered bone free flaps, retrospectively evaluating the occurrence of major and minor, early and late complications, associated with the different reconstructive technique. This study presents novel results for the field of oral cavity reconstructions as no previous author has analyzed the success of reconstructions using free vascularized bone flaps covered with a thin layer of surrounding muscle.

MATERIALS AND METHODS

The term free vascularized bone flaps covered with a thin layer of surrounding muscle is used by the authors to mean bone flaps covered by a muscle cuff 5 to 20 mm thick (e.g., fibula free flap with a peroneus longus and brevis cuff or iliac crest flap with an internal and/or external oblique muscle cuff). Flaps completely buried by mucosa, skin-island compound flaps, and double or pedicled free flaps (fibula + latissimus dorsi or fibula + pectoralis muscle), that is, flaps in which the bony component is completely buried and isolated from the oral cavity, are not included in this group. Evaluated and analyzed data are mean operating time; mean hospitalization time; and early and late, major and minor complications. Early complications are those that develop within 10 days postoperatively, whereas the late one develops after 10 days. A major complication was one that required additional surgery, whereas minor complication was one that resolved on its own or required minimal intervention. The major complications were arterial and venous thrombosis, total necrosis, more than 20% flap necrosis, hemorrhage, plate exposure, bone flap exposure in oral cavity, hematoma, pseudoarthrosis, fistula, and bone flap malacia. The minor complications were minor than 20% flap necrosis, infection, fistulas with a length less than 2 cm, wound dehiscence, small hematoma, and seroma.

Naked Bone Flap Surgical Technique

Deep Circumflex Iliac Artery Harvest

The patient is placed in the supine position with a cushion underneath the buttocks. A straight skin incision is performed, roughly 2 cm medial and parallel to the iliac crest and inguinal ligament, and extended as necessary (roughly 15 cm); the external oblique muscle is identified and also incised. At this stage, unlike the harvesting technique described by other authors, which involves the removal and harvesting of possibly large quantities of internal oblique muscle, the new technique proposed by the authors involves the removal of only a very small amount of muscle tissue (muscle cuff) from the external and internal oblique muscles, no more than 20 mm thick, which will be exposed in the oral cavity and is sufficient to ensure adequate covering and protection for the bony component of the flap. Thus, the exposed surface in the oral cavity will be entirely composed of this muscle cuff. Regarding the identification of the arteriovenous vascular pedicle, the deep circumflex iliac artery and deep circumflex iliac vein, this occurs 1 cm anterior and medial to the anterior superior iliac spine, its course is then followed inferomedially to the origin at the iliac vessels (Fig. 2).

Fibula Harvest

After having performed drainage massage on the leg, a tourniquet is placed around the thigh to ensure hemostasis. Then, with...
the patient in the supine position, the leg is bent to form an angle of approximately 90 degrees with the thigh. A straight skin incision is made along the lateral surface of the leg to expose the muscle fascia, underneath which the peroneus longus and brevis muscles and, posterior to these, the soleus muscle, are easily identified. After having cut the fascia, the space between the peroneus longus and soleus muscles is penetrated. One then proceeds with dissection: anteriorly to detach the peroneus longus and brevis, the extensor digitorum longus, and the extensor hallucis longus muscles from the anterolateral surface of the fibula, taking care to leave a muscle cuff (no thicker than 20 mm) attached to the bone up to the interosseous membrane. Posteriorly, the soleus muscle is separated from the fibula in a similar fashion, to expose the flexor hallucis longus. At this stage, the fibula is cut at its proximal and distal extremities to facilitate exposure of the vascular pedicle. This segment must spare at least 8 cm of distal bone to ensure good functioning of the ankle joint. The segment must also include the middle third of the fibula to keep the nutrient artery intact. By moving the thus-sectioned bone segment anteriorly and laterally and retracting the soleus muscle, the peroneal vessels become visibly deep to the upper margin of insertion of the flexor hallucis longus. This muscle is sectioned while using the fingers to protect the pedicle for the whole length of the bone flap, keeping a muscle cuff attached to the bone. After having thus separated this muscle, the peroneal vessels running along the posterior surface of the bone may be seen. It is isolated and bound distal to the cut fibula. After having sectioned the interosseous membrane, the posterior tibial is cut, leaving, as done previously with the other muscles, a flap of muscle no thicker than 20 mm attached to the bone. At this stage, the entire bone flap is free, except for the vascular pedicle, which may now be detached from its bifurcation from the posterior tibial vessels

**Flap Insetting**

After performing arterial and venous anastomosis, the flap is insetted into the bone deficit. The bone component of the flap is then fixed to the residual mandibular or maxillary bone. After that, the small muscular cuff is sutured to the residual mucosal lining of the oral cavity. Attention has to be paid to not leave residual communication between the oral cavity and the neck.

**Postoperative Management**

To ensure successful transplantation, great importance on the postoperative management of the patients is placed. Indeed, our protocol foresees for all patients who have undergone oral cavity reconstruction with naked bone free flaps: placement of a nasogastric tube for enteral nutrition for an average period of 9 days; administration of broad-spectrum antibiotics effective against gram-positive and gram-negative bacteria for an average period of 4 days; daily cleaning of the oral cavity with antibacterial solution. These procedures were used to reduce the risk of oral cavity infection to a minimum and to allow rapid healing. In addition to these precautions, blood pressure parameters were carefully monitored (thus, avoiding abrupt increases in pressure which could mechanically damage the walls of the microanastomosis), monitoring of blood analyses to maintain hemoglobin values between 8 and 10 g/dL for the first 7 postoperation days, amending any alterations by transfusion should the values fall below 7 g/dL or administering plasma expander should the value exceed 10 g/dL. Our protocol furthermore foresees daily administering of anticoagulants (Clexane) during the period in which patients are bedridden (on average 2 days),

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**FIGURE 1.** A, Schematic drawing of naked fibular flap. B, Schematic drawing of naked iliac crest flap.

**FIGURE 2.** Intraoperative view of naked iliac crest flap.

**FIGURE 3.** Intraoperative view of naked fibular flap.
to be substituted by 100 mg of acetylsalicylic acid daily, once ambulation is resumed, for a maximum period of 30 days. Besides this, great attention is paid to the coagulation parameters, administering AT3 should this parameter drop.

**Patient Population**

From April 2001 to July 2009, at the Department of Maxillofacial Surgery of Umberto I Hospital in Rome, 64 oral cavity reconstructions were carried out using free vascularized bone flaps. Of the 64 procedures, 33 were performed using free vascularized bone flaps covered with a thin layer of surrounding muscle, the remaining 31 were performed using osteomyocutaneous vascularized free flaps. Of the 33 cases using naked flaps, 19 (57.6%) were fibula flaps and 14 (42.4%) were iliac crest flaps. Of the 31 covered flap cases, 18 (58.06%) were iliac crest flaps, 11 (35.48%) fibula flaps, and 3 (9.67%) scapular free flaps. The average operating time using free vascularized bone flaps covered with a thin layer of surrounding muscle was 436.66 minutes, whereas the average operating time with osteomyocutaneous vascularized free flaps was 445.6 minutes. The patient population for free vascularized bone flaps covered with a thin layer of surrounding muscle was made up of 18 men and 15 women. The age range of the patients was 23 to 75 years and the average age was 46.6 years. The patient population for osteomyocutaneous vascularized free flaps was made up of 17 men and 14 women. Their age range was 24 to 70 years and the average age was 47 years. Of the reconstructions carried out using free vascularized bone flaps covered with a thin layer of surrounding muscle, in 28 (84.85%) cases, primary reconstruction was performed; whereas in the remaining 5 (15.15%) cases, secondary reconstruction was carried out. The primary reconstructions using free vascularized bone flaps covered with a thin layer of surrounding muscle included 13 ablations of malignant tumors of which 4 (14.3%) cases were of squamous cell carcinoma, 5 (17.9%) cases of mucoepidermoid carcinoma, 1 (3.57%) case of sarcoma, 1 (3.57%) case of verrucous carcinoma, and 1 (3.57%) case of adenocarcinoma. In the remaining cases, reconstruction followed excision of benign pathologies of which 6 (21.44%) were mandibular ameloblastomas and 4 (14.28%) cases were keratocysts, whereas in 1 (3.57%) case, primary reconstruction was performed for mandibular osteonecrosis. The secondary reconstructions were carried out for 1 (20%) ameloblastoma excision, 1 (20%) squamous cell carcinoma, 1 (20%) osteoma, and 2 (40%) cases of other pathologies.

**TABLE 1. Malignant-Benign Lesion and RT Administration Distribution**

| Buried Treatment, n = 31 | Naked Treatment, n = 33 | P     |
|-------------------------|------------------------|-------|
| Malignant cancers, n (%)| 24 (77.42)             | 14 (42.42) | 0.006 |
| Radiotherapy, n (%)     | 7 (22.58)              | 10 (30.30) | NS    |

*Distribution of malignant/benign cancers and of radiotherapy across the different types of treatment as well as P values for Fisher exact test. NS indicates not significant.*
Of the resected tumors, 13 (41.93%) were squamous cell carcinomas, 4 (12.9%) adenoid cystic carcinomas, 3 (9.67%) sarcomas, 1 (3.22%) adenocarcinoma, and 1 (3.22%) ameloblastoma. The 9 secondary reconstructions were carried out for 3 (9.67%) squamous cell carcinoma, 2 (6.45%) pleomorphic adenomas, 1 (3.22%) squamous cell carcinoma, and 1 (3.22%) adenoid cystic carcinoma.

RESULTS

On harvesting 33 free vascularized bone flaps covered with a thin layer of surrounding muscle, 9 (27.27%) patients developed early complications, of which 3 (9.09%) were major and 6 (18.18%) were minor. Two patients with major early complications required surgical revision of the vascular pedicle due to venous thrombosis; none of these flaps were lost. The third patient to develop a major complication suffered partial necrosis of more than 20%. Of the remaining 6 patients with minor complications, 5 (15.15%) had infections, whereas 1 (3.03%) had dehiscence of the surgical wound. Seven (21.21%) patients developed late complications, of which 3 (9.09%) were major and 4 (12.12%) were minor. One (3.03%) patient with a major late complication developed bone flap exposure, 1 (3.03%) patient developed pseudoarthrosis, whereas 1 (3.03%) suffered osteomalacia and required surgical curettage. The 4 (12.12%) patients with minor late complications developed fistulas. Finally, during follow-up, 5 (15.5%) required orthognathic surgery for definitive remodeling of the free flap. On harvesting the 31 osteomyocutaneous vascularized free flaps, 21 (67.74%) patients developed early complications, of which 9 (29.03%) major and 12 (38.71%) minor. Of the major early complications, 3 (9.67%) resulted in total loss of the flap, of which 1 patient was diabetic and 1 had infection, 4 (12.9%) partial flap losses of which 2 developed infection and 1 (3.22%) hemorrhage. Regarding the minor early complications, 5 (8.07%) patients showed signs of infection and 5 (16.12%) had wound dehiscence. None of the patients developed late bone exposure or osteomalacia, although 1 (3.22%) patient presented pseudoarthrosis. The other minor complications were fistulas and were seen in 7 (22.58%) patients and 1 wound dehiscence. During follow-up, 4 (12.9%) patients required orthognathic surgery for definitive flap remodeling (Table 1).

Table 2 presents the distribution of malignant/benign cancers as well as of radiotherapy across the different types of treatment as well as P values for Fisher exact test on whether these assignments differ across the different treatments. Although the use of radiotherapy is not significantly different for the 2 treatments, malignant cancers were overrepresented among patients undergoing the buried treatment. We are, however, confident that this does not affect our results. Table 3 shows that the reduction in major as well as minor complications that comes with subjecting patients to free vascularized bone flaps covered with a thin layer of surrounding muscle instead of osteomyocutaneous vascularized free flaps occurs equally across both types of cancers.

The reduction in major as well as minor complications that comes with subjecting patients to naked instead of buried flaps occurs equally across both types of cancers.

TABLE 3. Relationship Between Complications of Naked and Buried Flaps and Benign or Malignant Pathology

| Complication          | Buried Flaps, n = 31 | Naked Flaps, n = 33 | P     |
|-----------------------|----------------------|---------------------|-------|
| Bone exposure, n (%)  | 3 (3.03)             | 0 (0)               | NS    |
| Fistula, n (%)        | 7 (22.58)            | 4 (12.12)           | NS    |
| Infection, n (%)      | 5 (16.13)            | 5 (15.15)           |       |
| Revision, n (%)       | 9 (29.03)            | 7 (21.21)           | NS    |
| Flap loss, n (%)      | 8 (25.81)            | 0 (0)               | 0.002 |
| Other complications, n (%) | 11 (35.48)       | 6 (18.18)           | NS    |

Occurrence of different complications among patients subjected to either naked or buried flaps (Fisher exact test).
Table 4 reports the occurrence of different complications among patients subjected to either free vascularized bone flaps covered with a thin layer of surrounding muscle or osteomyocutaneous vascularized free flaps. The equality of these complications was again tested using Fisher exact test. Although naked flaps show lower percentages of occurrence across all measured incidents, the reduction of flap loss was particularly significant ($P = 0.002$). We then classified all complications as being either major or minor and summed them up for each patient. Table 5 reports the mean and standard deviation of major and minor incidents. The difference between these was tested using a Wilcoxon-Mann-Whitney test, which turns significant for minor incidences ($P = 0.021$). Because the incidence of complications is not uncorrelated (eg, infection promotes fistula), we also calculated the probability that any complication happens in the population as a robustness check. The differences between these percentages were tested using a 2 proportions $z$ test. The difference in proportion between the treatments is significant for both major ($P = 0.042$) and minor ($P = 0.001$) complications.

**DISCUSSION**

The history of maxillomandibular bone reconstructions was characterized for many years by bone grafts. These, being devascularized, require careful preparation of the recipient site and meticulous care in covering the graft. A recipient bed, which does not ensure a good blood supply or the occurrence of bone exposure, puts the graft at risk of likely complications such as fistulas, infections, reabsorption, or total failure.

An important innovation in the field of reconstructive surgery was obtained with the introduction of revascularized free flaps. Because of the blood supply ensured by the anastomosis between the vessels of the flap and the vessels of the recipient site, there was a drastic reduction in complications and it was possible to widen the field of application of reconstructions to more varied deficits. However, the memory of the complications associated with incomplete coverage of the grafts today still leads head and neck surgeons and plastic surgeons to carefully cover the revascularized bone flaps. This dogmatic use of covered free flaps often induces the harvesting of osteomyocutaneous flaps or even double flaps, thus lengthening operating times and increasing the biological cost. Furthermore, the skin paddle of osteomyocutaneous vascularized free bone flaps does not present enough mobility in respect to the bony and the muscle components. This fact may lengthen operating time even further and make the reconstructive procedure more difficult.

Is there an effective advantage in this obstinate insistence on the use of osteomyocutaneous vascularized free flaps?

With this question in mind, the authors carried out a careful study of the literature and verified that no reconstructions using free vascularized bone flaps covered with a thin layer of surrounding muscle had been described.

With the conviction that free vascularized bone flaps covered with a thin layer of surrounding muscle, if well vascularized, can heal and repair osteomucosal deficits, from 2001 we began to harvest, in oral reconstructions, such “naked” flaps, that is, bone flaps (iliac crest and fibula) covered only by a muscle cuff between 5 and 20 mm thick. Flaps completely covered by mucosa, skin-island compound flaps, and double or pedicled free flaps, understood to be flaps whose bone component is completely covered and isolated from the oral cavity, are excluded from this definition.

In the authors’ experience, a muscle-cuff thickness of 5 to 20 mm is sufficient to protect the bone tissue from exposure in the oral cavity (Fig. 4) and ensure a guide for mucosal healing by second intention, thus helping to re-form a mucosa similar to that adherent to the oral cavity (Fig. 5A,B). Indeed, quantities less than 5 mm would lead to risk of bone exposure and all the possible consequences of this event. On the other hand, quantities in excess of 20 mm would lead to colliquitative phenomena in the muscles, because these would not be sustained by sufficient vascularization, with a greater risk of infections, fistulas, and increased healing times.

Among the advantages of the free vascularized bone flaps covered with a thin layer of surrounding muscle technique is certainly the reduction in operating times; indeed, in the cases where double free flaps, skin islands, or local flaps were harvested and used to cover the bone flaps, there is inevitably a notable time increase. In the case of double flaps, the surgical procedures double the stress of surgery, donor-site problems, and notably increase the biological cost to the patient.

Furthermore, in the authors’ opinion, the advantage of free vascularized bone flaps covered with a thin layer of surrounding muscle, for the possibility of clinical monitoring of the vitality of the flap, must not be overlooked. Indeed, such flaps allow direct assessment, even without the use of a Doppler probe, of important parameters such as the color of the flap and thus its vitality.

From the data presented in this study, it can be seen that the advantages described for free vascularized bone flaps covered with a thin layer of surrounding muscle are evident in reconstructions after resection of benign pathologies, where the rate of major and minor complications is significantly lower compared to the current rate in osteomyocutaneous vascularized free flaps reconstructions.
This result seems plausibly correlated with improved recipient-site conditions compared to malignant tumor resections. In the case of benign pathologies, indeed, the conditions for flap take are better, and in these circumstances, it seems we can conclude that free vascularized bone flaps covered with a thin layer of surrounding muscle are the best choice due to their greater reliability, lower percentage of complications, and for the reduced operating time, surgical stress, and biological cost.

Regarding reconstruction after the resection of malignant pathologies, from the data presented, the use of osteomyocutaneous vascularized free flaps shows again a major complication rate. This demonstrates that in these cases too, in which the recipient site presents unfavorable conditions, the use of free vascularized bone flaps covered with a thin layer of surrounding muscle represents a valid option, ensuring a higher success rate with a lower biological cost to the patient.

**CONCLUSIONS**

Since the 1970s, vascularized free bone flaps have been used to reconstruct the maxilla and the mandible with progressive better and better results. As shown in this article, the introduction of naked free flaps may represent a reliable option in oral reconstruction with less biological costs for the patients.

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