The Multiple Osteotomized Free Iliac Osteocutaneous Flap for Reconstructions of Complex Maxillofacial and Oromandibular Defects

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Abstract: The vascularized iliac osteocutaneous flap has been used successfully for jaw reconstruction. To obtain a better contour of the reconstructed area in large upper and lower jaw resections, the transferred bone actually needs to be osteotomized. Single closing-wedge osteotomy of the iliac flap for mandibular reconstruction has been previously described. In this article, the modified multiple osteotomized perforator-based versatile free iliac osteocutaneous flap is described. Eleven cases were enrolled. Seven patients had wide anterior mandibular resections due to oral cavity and mandibular tumors; 3 patients had a defect due to explosive injury and 1 patient had complicated orbitomaxillary defect due to blast injury. Skin paddle was based on the perforators. In 8 patients, the bony segment was divided into 3 segments by 2 osteotomies, whereas in 2 patients the bony segment was divided into 4 segments by 3 osteotomies. In 10 cases, the flap was used for anterior mandibular defects, whereas in 1 case the flap was customized to fit an L-shaped defect at the naso-orbito-maxillary region. The overall flap success rate was 100%. No resorption or morbidity related to the osteotomy of the bony segments was observed. The size of perforator skin paddle was 6 to 8 × 15 to 18 cm. Physical and radiologic examinations showed proper bone healing without any additional complications. The modified multiple osteotomized free osteocutaneous iliac flap can provide a safe and versatile bony segment to be arranged and adapted to reconstruct complex mandibular and maxillofacial defects.

Key Words: Multiple, osteotomized, free, iliac

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As Gump was caricaturized in the 1930s,[1] mandibular reconstruction became an important part in the evolution of head and neck reconstructive surgery. Osteocutaneous flaps, including vascularized fibula, ilium, scapula and radius flaps, provide the standard solution for reconstructing mandibular and oral cavity defects with acceptable aesthetic and functional results.[2–7] The vascularized iliac osteocutaneous flap has been used for jaw reconstruction since 1979.[8] A sequence of modifications has been proposed to improve its surgical application.[9–12]

To obtain a better contour of the reconstructed area in large upper and lower jaw resections, the transferred vascularized bone actually needs to be osteotomized.[3,7,9,10,13–17] Although multiple segmental osteotomies for fibula flap can be safely performed depending on its segmental blood supply,[5–7,16,17] there have been few reports and clinical series to date regarding the osteotomized vascularized iliac flap.[3,9,10,13,18] Although the iliac crest bone flap provides a natural contour for the lateral segment of the lower jaw, for the anterior segment en bloc or for the upper maxilla and orbital region, the use of the iliac flap, even harvested or designed in a V shape,[4] fails to yield a custom natural shape.

Moreover, in modern surgery, three-dimensional modeling poses a great deal of sophistication in preoperative planning that may give rise to the need for more detailed tailoring of the insetted bone flap.[19] In addition to patient preference of the donor site selection, and of the surgeon having experience with the surgery, the iliac crest flap could be the standard choice for reconstruction in the head and neck region.[4,9,15,17,18,20–24]

As it is known literally, the iliac bone flap manipulation is not easy and the periosteal branches to the bone are not macroscopically obvious; hence, it is actually not secure to osteotomize the iliac bone as it is as safe as in the more popular fibula flap.[1,25–27] Several authors have described multiple closing-wedge osteotomies for mandibular reconstruction.[3,7,9,10,13–15] In addition, Ozkan[18] had previously reported the experience of reconstructing the anterior mandible using a single osteotomized free iliac crest flap in a series of 5 patients.

The objective of this study was to present our modified surgical technique, adaptations of the flap at the recipient site, and the follow-up procedures.

PATIENTS AND METHODS

All patients included in this series were informed about the operative procedure and undergone treatment in accordance to the

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TABLE 1. Patient Summary

Patient Age, Sex	Etiology	Soft Tissue Defect	Flap Length	Osteotomies	Length of Segments	Recipient Pedicle	Vein Graft	Complications	Secondary Procedures
52, F	Oral cavity tumor (T3N3M0)	Oral cavity	11 cm	2	3 cm, 5 cm, 3 cm	Right facial vessels	None	None	Flap debulking
55, F	Oral cavity tumor (T3N2M0)	Oral cavity	14 cm	2	4 cm, 7 cm, 4 cm	Right facial vessels	None	None	None
31, M	Mandibular tumor	Oral cavity	9 cm	2	3 cm, 2 cm, 4 cm	Right facial vessels	None	None	None
27, M	Explosive injury, three-dimensional defect of orbitomaxillary region	Orbit, malar, nose	12 cm	2	5 cm, 6 cm, 3 cm	Left facial vessels	Cephalic vein	Avulsion of skin paddle perforators	Flap debulking Orbital socket reconstruction Nasal Reconstruction
65, M	Oral cavity tumor (T4N3M0)	Oral cavity	16 cm	3	3 cm, 4 cm, 6 cm, 4 cm	Right facial vessels	None	None	None
33, F	Explosive injury	Oral cavity, chin	9 cm	2	3 cm, 3 cm, 3 cm	Left facial vessels	None	Arterial insufficiency	None
56, F	Mandibular tumor	Oral cavity	12 cm	2	6 cm, 3 cm, 3 cm	Right facial vessels	None	Wound dehiscence at donor site	None
34, M	Explosive injury mandibular defect	Oral cavity, chin	14 cm	3	4 cm,3 cm, 5 cm, 2 cm	Bilateral facial vessels	None	None	Flap debulking
61, M	Mandibular tumor	Oral cavity	12 cm	2	3 cm, 5 cm, 4 cm	Right facial vessels	None	None	None
24, M	Explosive injury mandibular defect	Lower lip	16 cm	3	4 cm, 3 cm, 5 cm, 4 cm	Bilateral facial vessels	None	None	None
37, M	Oral cavity tumor	Oral cavity and lower lip	12 cm	2	3 cm, 5 cm, 4 cm	Radial artery, cephalic vein of FRFAF as chain flap	None	None	Flap revision for lower lip reconstruction

FRFAF indicates free radial forearm flap.

declaration of Helsinki. Between 2006 and 2011, surgery was performed on a total of 11 consecutive cases with different etiologies and tissue defects (Table 1). There were 4 female and 7 male patients, and their ages ranged from 23 to 65 years. Of these, 7 patients had wide anterior mandibular resections due to oral cavity and primary mandibular tumors; 3 patients had a vast defect due to explosive injury and close-range gunshot and 1 patient had complicated orbitomaxillary defect due to blast injury. In 10 cases, the free composite perforator-based iliac crest osteomusculocutaneous flap was selected for reconstruction of the anterior mandible, whereas in 1 patient a free iliac crest bone flap was used for orbitomaxillary reconstruction. The preference of the flap selection was based primarily on the need of high volume of composite tissue, versatility of the perforator-based skin paddle, and surgeons' experience with the flap. In 9 patients, the bony segment of the flap was divided into 3 segments by performing 2 osteotomies, whereas in 2 patients the bony segment was divided into 4 segments by performing 3 consecutive osteotomies (Table 1). In 9 cases, the flap was used for anterior defects that laterally extended to the mandible angle, which could not be reconstructed with a nonosteotomized iliac flap, whereas in 1 case the flap was customized to fit an L-shaped convex defect at the naso-orbito-maxillary region.

SURGICAL TECHNIQUE

In 9 cases, composite iliac perforator-based osteomusculocutaneous flaps were harvested on the deep circumflex iliac artery and vein in the standard manner. In 2 cases, the flap was harvested on both the standard pedicle and the iliolumbar vessels in a bipedicled fashion (Fig. 1). The size of the bony part was measured, and a paper template was used to perform the osteotomies. An oscillating saw was used to cut the external cortex of the bony segment, and care was taken not to harm the inner surface and vascular pedicle (Fig. 2). Afterward, by using 2 forceps graspers, the segments were bent to create a green stick fracture at the inner cortex to avoid harm to the inner periosteal layer. This procedure was performed before the pedicle separation of the flap. The shape and curvature of the bony segments were molded according to defect reconstructed. The bony segments were then fixed orderly using miniplates and lag screws. The facial artery was used as the recipient artery in 5 patients, the superior thyroid artery in the 5 patients, and the radial artery (using coupler device 2.5 mm; Synovis Inc, Birmingham, AL, USA) in 1 patient where the flap was chained to a free radial forearm flap that

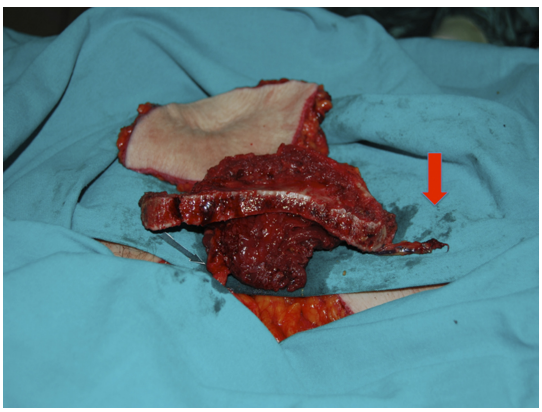

FIGURE 1. The free iliac bone flap harvested in a bipedicled design. The green arrow indicates the deep circumflex iliac pedicle; red arrow, the iliolumbar pedicle.

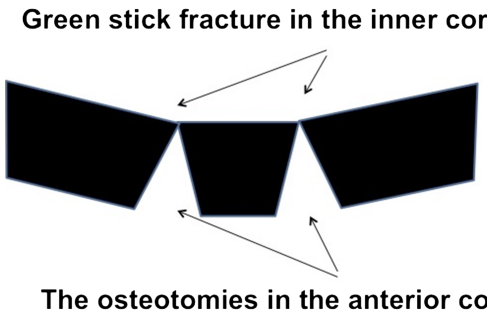

FIGURE 2. Schematic representations of the multiple osteotomized iliac bone flap. Note that the outer cortex is osteotomized using oscillating saw, whereas the inner cortex is in-fractured with the aid of graspers.

was anastomosed to the carotid artery and jugular vein in an end-to-side fashion because of previous failed free fibula flap and lack of appropriate recipient vessels in the neck region. The external jugular veins, which are branches of internal jugular vein, were the recipient veins. However, in one patient, the cephalic vein of the free radial forearm flap was used. After performing the anastomoses, active bleeding from the osteotomized bony segment edges was the confirmation of the vascularity of all segments. An interpositional saphenous vein graft was used only in the naso-orbito-maxillary reconstruction case. All patients were medicated with a 5-day protocol of low-molecular-weight heparin of 0.4 U and 500 mL per 8 hours of dextran per intravenous infusion. Postoperatively, patients were followed up clinically, using radiographs, bone scintigraphy, and three-dimensional computed tomography.

RESULTS

All flaps were monitored using clinical evaluation traditionally including examination of flap color, temperature, capillary refill, and skin turgor from surgeons up to seventh postoperative day regularly. One flap required reoperation for anastomosis revision because of arterial insufficiency, and the flap was rescued with a successful arterial anastomosis. Another flap required a salvage of re-anastomosing the perforator vessels of the iatrogenic avulsion of skin paddle during flap harvest. Therefore, the overall flap success rate was 100%. Osteotomized iliac bone flap was used for mandible reconstruction in all but one case. One flap was used for a complex reconstruction of nasoorbital and maxillary region. The soft tissue was harvested on perforator vessels of the deep circumflex iliac artery and vein. The skin paddle was used to reconstruct the oral cavity floor in 9 cases; the orbital socket, malar region, upper lip, and intraoral lining in 1 case. The size range of the harvested skin paddle was 6 to 8 $\times$ 15 to 18 cm. One patient had wound dehiscence in the donor site, which was treated with Vacuum Assisted Wound Closure or Negative-pressure wound therapy and conventional wound care until primary closure. Physical examination, x-rays, bone scintigraphy, and three-dimensional CT scans showed proper bone healing without any additional complications. Two osteotomies were performed in 9 cases, whereas 3 osteotomies were done in 2 cases. The resulting bone segment numbers and lengths are summarized in Table 1. During the 1 to 5 years follow-up period, 2 patients underwent surgery for bulky flap and 1 patient underwent 4 consecutive surgeries to refine the skin paddle for the planned facial structures. All patients healed in the 2-year postoperative period. Two patients had pulmonary and cranial metastasis and died at 26 and 31 months after surgery.

PATIENT REPORTS

Clinical Report 1

A 55-year-old female patient presented with a squamous cell carcinoma of the oral cavity, which involved the anterior floor of the mouth with multiple invasions of the mandible and base of the tongue. There was a 3-cm palpable fixed mass in the left submandibular level with additional multiple lymphadenopathies of less than 1 cm in the neck bilaterally. No accompanied systemic diseases were present. Bilateral modified radical neck dissection was performed, after performing a tracheotomy, via an apron incision. Afterward, a split-lip approach was used to dissect the anterior cortex of the mandible and a bilateral mandibular osteotomy near the angle region was performed to resect the affected mandibular segment. To retain safe tumor margin, a wide excision of the oral cavity and inferior part of the tongue was included. The defect was reconstructed with a perforator-based free iliac osteomusculocutaneous flap (Fig. 3). The bone was osteotomized into 4–7–4 cm segments and was replaced in the resected mandibular defect (Fig. 4). After rigid fixation of the boney segments, skin paddle was used to furnish the oral cavity floor and the incisions were properly closed. The patient recovered after 2 weeks postoperatively with no complications .The bone flap healed with a perfect remodeling, and the patient was followed up for 5 years with no tumor recurrence (Figs. 5 and 6). Finally, the oromandibular rehabilitation was completed with insertion of osteointegrated dental implants and with use of dental prostheses (Figs. 7 and 8).

Clinical Report 2

A 27-year-old male patient was seen 2 years after a blast injury in Iraq that resulted in severe facial deformity (Fig. 9). After removing all hard wares and obtaining a steady clinical course and normal blood count levels, the patient was rescheduled for surgery. The preoperative scans showed a tissue defect in the maxilla and orbital bones pertinent to be reconstructed with a molded free iliac bone flap. Moreover, soft tissue was needed for reconstructing the right orbital socket and lateral nasal region. During operation, a free perforator-based iliac osteocutaneous flap was performed. Because of the abdominal scar in the left side, a right iliac bone flap was preferred. Inadvertently, during dissection, the perforator vessels were avulsed and the skin paddle was detached. A salvage anastomosis of the perforators was successfully accomplished. The bone part was osteotomized into 3 segments and transferred to the orbitomaxillary region to adapt the defect, and fixation with miniplates was performed (Fig. 10). A cephalic vein graft harvested

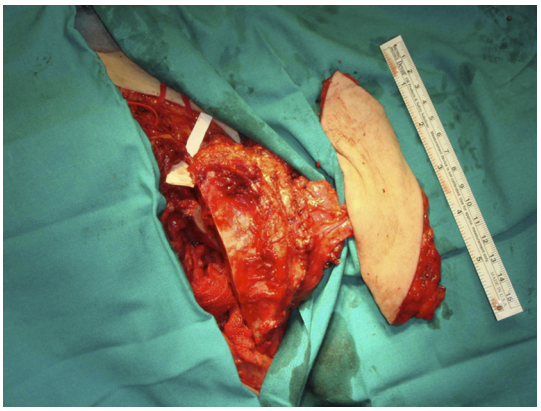

FIGURE 3. The harvested perforator-based free iliac osteomusculocutaneous flap.

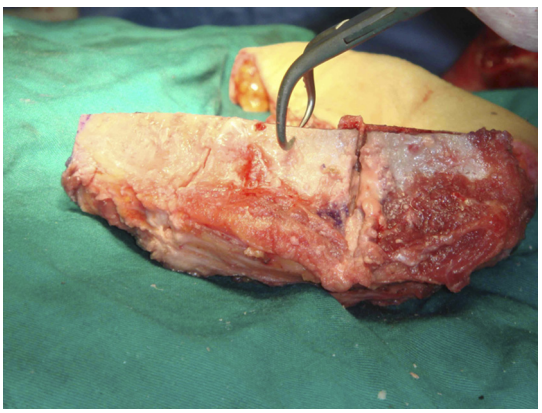

FIGURE 4. The osteotomized free iliac flap.

FIGURE 5. Postoperative view after 5 years. A, Anterior view. B, Intraoral view retracted with the aid of mouthpiece. C and D, lateral views.

from the right forearm was used to bridge the vessels of the free iliac flap and recipient facial vessels. Afterward, the skin paddle was used to cover the deficiencies in malar, upper lip, orbital socket, and intraoral regions, respectively. A spherical implant was inserted as preparation for the future orbital reconstruction. The postoperative period was uneventful, the viability of the transferred tissues was followed up clinically, and vascularization of the transferred bone was confirmed by bone scintigraphy. In addition, postoperative CT scan was performed (Fig. 11). Refinement surgeries were performed later to adapt the soft tissue to the defective facial structures (Fig. 12).

DISCUSSION

As microvascular tissue transfer and perforator flaps became popular in the reconstructive era, various flaps have been described and proposed for mandibular and maxillofacial reconstruction.[1–8]

FIGURE 6. Postoperative three-dimensional CT scans after 5 years. The red lines show the borders of the bony segment of the free perforator-based osteocutaneous iliac flap.

Since the first report by Taylor et al in 1979,[8] the free vascularized iliac osteocutaneous flap based on the deep circumflex iliac artery has become one of the most commonly used flaps for reconstruction of the mandible. Its anatomy, and a sequence of refinements and modifications added to its harvest, was introduced by several authors.[9–12] Because of its consistent vascular pedicle, strong thick cancellous bone content allowing excellent dental implant osteointegration, acceptable donor site morbidity, and reliable overlaying cutaneous area, the free iliac bone flap gained popularity in reconstruction of the maxillofacial region.[1,20–22]

The need for osteotomy of the bone flap used in maxillofacial reconstruction is of certain importance in improving the functional and cosmetic outcome of the regarded reconstruction.[2,3,5,6,17] Permitting segmental osteotomies by means of its segmental vascular supply, the osteocutaneous fibula flap has become widely used for this purpose.[2,3,5,17,25–27] Besides the other alternative radial forearm and scapular bone flaps,[22–24] the quality of the bony segment in the fibula and iliac flap remains superior to them.

As with the fibula flap, the iliac crest flap can also be reliably used as an alternative for maxillofacial reconstructions.[4,9,10,15,18,19] Although the iliac bone has excellent cancellous bone content and a large volume, the fibula offers a long bone stock including a thick cortical bone structure as a great advantage for mandibular

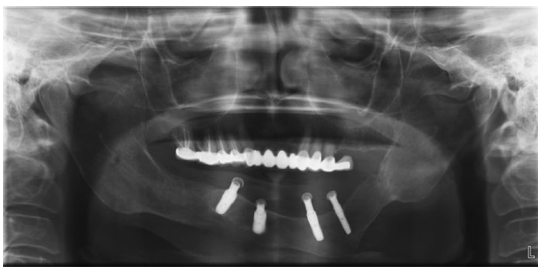

FIGURE 7. An orthopantograph demonstrating the dental implant after 5 years of surgery.

FIGURE 8. An intraoral view demonstrating the adapted dental prosthesis.

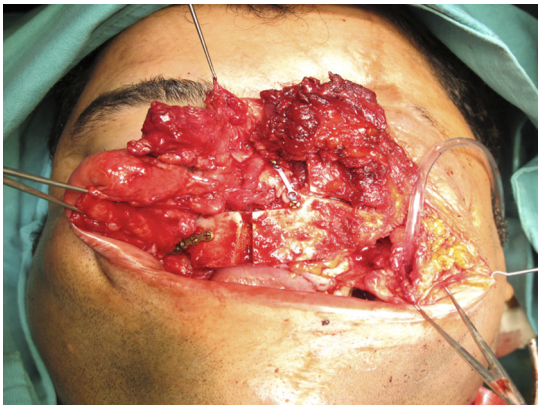

FIGURE 10. Intraoperative view demonstrating the osteotomized free iliac bone flap that has been inset to the defective region in convex reverse "L" fashion.

reconstruction. In general, anterior composite oromandibular and complex three-dimensional maxillofacial defects require large volume of high-quality bone in addition to the soft tissue. Yet, to obtain the natural contour, a three-dimensional configuration with multiple osteotomies becomes necessary.

The osseous blood supply of the iliac crest is robust, incorporating both nutrient perforators and periosteal vessels, but its vascular pattern is rather nonsegmented as it is in the fibular bone flap, which renders the flap less tolerable to multiple osteotomies.[28] Previous studies have reported the application of single closing-wedge osteotomies and split inner segmented iliac bone flap for mandibular reconstruction.[3,7,9,10,13–15,18]

Although Ozkan[18] had successfully reported the single osteotomy technique, which involved breaking the bone into 2 vascularized segments, it is well known potentially that multiple osteotomies can damage the blood supply of the bone in return. The periosteal blood supply of iliac crest is not as certain, which is obvious macroscopically as that in the fibula. Therefore, hypothetically, small segments of iliac crest could be devascularized consequently after multiple osteotomies and act as a nonvascularized graft instead of a vascularized bone. By contrast, reports regarding the fibula,[16,17,25–27] radius,[29,30,34] scapula,[31] and rib[32], [33] flaps used as osteotomized bone flaps showed no detrimental effects of osteotomy on bone union.

As a major benefit of our surgical technique, we show that performing a true-cut osteotomy of the external cortex while making a green stick fracture to the inner cortex can successfully protect the inner periosteal layer from damage. Hence, despite the multiple osteotomies, vascularity in each bone segment was preserved.

The free iliac osteomusculocutaneous flap can provide superiority in complex maxillofacial defects compared with the other flaps as a large size of skin paddle can be included.[28] However, Miyamoto et al[35] discouraged the use of skin island of the iliac crest flap for intraoral lining, if adequate circulation of the skin cannot be ensured. In our experience, a reliable skin paddle based on a major perforator or multiple segmental perforators can be designed reliably prepared.

FIGURE 9. A 27-year-old patient who had blast explosive injury in the maxillofacial region. The preoperative views after removing the titanium hard wares from the orbital region.

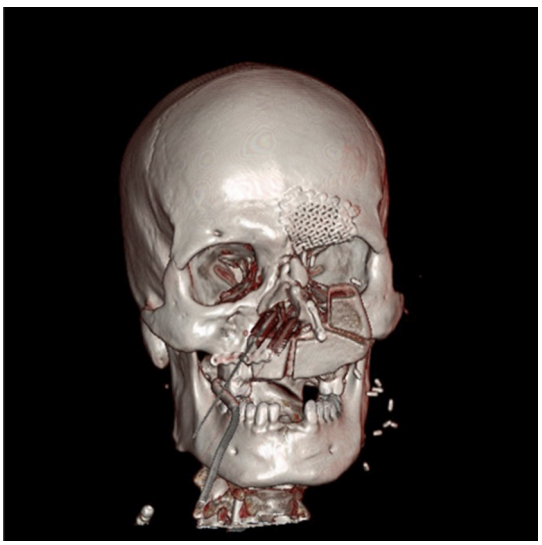

FIGURE 11. The postoperative three-dimensional CT scan after 1 month of surgery, demonstrating the adapted free osteotomized iliac bone flap.

FIGURE 12. Postoperative and intraoperative views after multiple refinement surgeries. The patient was prepared for definitive reconstruction as soft and skeletal tissue was restored and the orbital socket was ready for a prosthetic application per se.

The potential drawback of the bulky skin paddle in the iliac flap has been overcome by perforator-based dissection, which was previously described by Safak et al.[12] In our case series, all flaps were similarly designed on perforator basis, which provided versatility to the harvested skin paddle and the adaptation of the osteotomized iliac bone flap in the reconstructed region.

Ting et al[36] proposed the use of computed tomographic angiography to safety plan the deep circumflex iliac artery perforator flap. Yet, in our series, perforator identification was performed preoperatively by using a handheld Doppler device.

After giving off the ascending branch, the deep circumflex iliac artery pierces the transversalis fascia and enters a fibroosseous tunnel traveling in the inner surface of the iliac crest. In its course, multiple musculocutaneous perforators rises. Finally, it terminates approximately 6 to 9 cm from the anterior iliac spine anastomosing with the iliolumbar, superior gluteal, and intercostal systems.

Literally, a maximum length of 14 cm bone can be harvested from the iliac crest with a reliable vascularity in accordance to the pedicle course.[1,28] Yet, as presented in the 2 cases of our series, the bipedicled design of free iliac flap created by including the iliolumbar pedicle may have provided an extra vascularity and an additional 2 to 4 cm length of harvested bone.

It seems that the disadvantage of using multiple fixation plates might be tolerated in the expense of the desired shape obtained in the iliac bone after multiple osteotomies.

The fate of the bony segments were followed up with scintigraphy at the early postoperative period of 3 weeks, and long-term postoperative three-dimensional CT scans demonstrated no signs of resorption. Moreover, 4 of 10 patients underwent successful surgery for dental implants at 2 years postoperatively in which the bony segments were apparently vital and were bleeding during the surgical procedure.

In all cases, the iliac crest flap was used for osteomusculocutaneous composition. Basic elements influenced the decision to use the flap, that is, the experience of the surgeons with the flap and the amount of soft tissue offered for proper reconstruction.

In summary, this case series presents the experience of application of a multiple osteotomized iliac flap without jeopardizing vascularity.

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