

Costal Grafting in Mandibular Reconstruction

Jean-Thomas Bachelet, MD*
 Jérôme Bourlet, MD*
 Joseph Château, MD†
 Mathieu Jacquemart, MD‡
 Clémence Dufour, MD§
 Ali Mojallal, MD, PhD†
 Arnaud Gleizal, MD, PhD*

Background: Reconstruction of mandibular bone defect is a common indication in craniomaxillofacial surgery, and free fibular flap is the gold standard for this indication. However, there are alternatives; nonvascular bone grafting is one of them, and we present the costal grafting for mandibular reconstruction, a classic technique that is reliable, efficient, and produced less morbidity than the technique of using composite free flaps.

Method: A 9-year retrospective review of 54 patients treated surgically for mandibular reconstruction was performed. The criterion mainly analyzed was graft survival. The surgical technique was described in detail.

Results: A total of 54 patients with mandibular bone defect were identified. Five symphysis, 46 corpus, and 20 ramus defects were considered. These patients underwent reconstruction by costal grafting, and the engrafting was successful in 92.6% of cases. Dental rehabilitation with dental implants was realized in 70% of cases.

Conclusions: The approach described in this article allowed the authors to obtain good results with costal grafting for mandibular reconstruction and dental rehabilitation. Costal grafting is a good alternative for fibula free flap in specific indications. Reconstruction of mandibular bone defect is a common indication in craniomaxillofacial surgery. Since the 1980s, the gold standard for these defects is the use of free fibular flap.¹ In some cases, this technique is contradicted; the surgeon then has several possibilities for the use of free osteomyocutaneous flaps (iliac crest, scapula, and serrato-costal flaps).²⁻⁸ (*Plast Reconstr Surg Glob Open* 2015;3:e565; doi: 10.1097/GOX.0000000000000544; Published online 20 November 2015.)

Our team of microsurgical reconstructive surgery, mastering these techniques, features a classic alternative using the nonvascularized

bone graft (NVBG), particularly the costal graft,⁹ which is reliable, efficient, and produces less morbidity than the composite free flaps.

*From the *Service de chirurgie maxillo-faciale, †Service de chirurgie plastique reconstructrice et esthétique, Hôpital de la Croix-Rousse—CHU de Lyon, Lyon, France; ‡Service de chirurgie maxillo-faciale, Centre Hospitalier Lyon Sud—CHU de Lyon, Pierre-Bénite, France; and §Service de Radiologie pédiatrique, Hôpital Femme Mère Enfant, Bron, France.*

Received for publication March 5, 2015; accepted September 2, 2015.

Copyright © 2015 The Authors. Published by Wolters Kluwer Health, Inc. on behalf of The American Society of Plastic Surgeons. All rights reserved. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially.

DOI: 10.1097/GOX.0000000000000544

Through the description of this classic maxillofacial reconstructive surgery technique, we present a series of 54 patients who underwent reconstruction of mandibular defect by costal transplant in indications for mandibular tumors, craniofacial malformation, mandibular osteonecrosis, and traumatology, with or without fibula free flap contraindication, through targeted indication for isolated mandibular bone defect reconstruction, without indications of adjuvant radiotherapy. We describe the evolution of these patients from a single-center series of 54 patients operated on from 2005 to 2014 by the maxillofacial surgery team of the Croix Rouse Lyon University Hospital.

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*

METHODS

Patients

Between 2005 and 2014, costal bone grafts were used to reconstruct mandibular segmental defects in 54 patients. Reconstruction was realized in the case of tumor resection performed at the same time.

Inclusion criterion was patient with isolated mandibular bone defect. Information considered was sex, age, pathological diagnosis (Table 1), surgical approach endo-/exo-oral, surgical technique, anatomical mandibular area (Fig. 1), evolution/complication of graft, evolution/complication of donor site, dental prosthetic rehabilitation, and additional bone graft time.

All patients were reviewed at 1 year of surgery; a good outcome was defined as continuity, integration, and consolidation of the rib bone graft, without signs of infection after clinical examination and interpretation of orthopantomogram.¹¹ A poor outcome was defined by the appearance of early or late complications.

Surgical Indication

We present a series of 54 patients with isolated mandibular bone defects. The etiology of defects was diverse: ameloblastoma, aggressive fibromatosis, giant mandibular cyst, trauma, mucoepidermoid carcinoma, osteochemonecrosis, and syndrome of the first arch.

Mandibular reconstruction with rib bone graft was indicated for isolated mandibular bone defect, interrupted or not, without involvement of soft parts and without indication of adjuvant radiotherapy.

Reconstruction was realized at the same time excision through oral and/or cervical approach.

Patients with a history of irradiation, skin or mucosal defect, or infection were contraindicated.¹⁰

Surgical Technique

The costal graft harvesting has been used since the 1950s in maxillofacial reconstructive surgery,⁹ and various techniques described in the literature are broadly similar and differ only by the associated sampling of costal cartilage (in the context of temporomandibular joint [TMJ] reconstruction)¹² or by the shaping of the graft.^{13,14}

Installation

The patient is placed supine with a block under the ipsilateral shoulder. The upper limb is bent at 90 degrees and fixed on a rigid support. Access to the face is preserved. Anatomical landmarks considered for the incision are medial axillary line, midclavicular line, and the relief of the 6th or 7th costal arch,¹⁵ and we consider the costal arch located under the breast to disguise the ransom scar (Fig. 2).

Dissection

The incision is obliquely downward and forward. Along the landmarks for 10 cm,¹³ the incision passes through the fibers of the rectus abdominis inside and comes into contact with the rib periosteum, and dissection is circumferential from inside to outside in contact with the bone to preserve the vasculonervous pedicle. Using a Doyen rib dissector to strip soft tissues, dissection is carried out medially and laterally.¹⁶ Once the bone size needed is exposed, osteotomy is performed with a costotome. Hemostasis of costal edges is achieved with Horsley's wax. A sealing test is done to detect pneumothorax. If it is clear, the incision is closed in 2 layers on a drain (Fig. 3).

Shaping

Once the graft is released, it can be made to comply with the requirements of the recipient site; the length is adapted to the measure of the mandibular defect. The costal graft is split into 2 to allow vascularization of the graft; a custom-made shape adapted to the morphology of the patient's mandible is realized.

The graft fragments are joined together by a bicortical bone screw (Fig. 4).

Implementation at the recipient site

The graft is introduced at the recipient site immediately after excision (in case of the mandibular tumors) (Fig. 4), and the incision is endo- or endo-/exo-oral. The graft is attached to the mandible by plates and by bicortical screw fixation (Fig. 5). On the mandible level, external decortication is performed to bring together the spongy parts of the 2 bones as described by El-Sheikh et al.¹³

Method

Our major criterion was graft survival by analyzing 1-year results of 54 cases of rib bone graft. We analyzed each of the failure potential links with indication, surgical approach, and patient's age.

Secondarily, donor-site morbidity was assessed based on the percentage and type of secondary complications in the costal harvesting site. We also highlighted the number of second-time bone grafting actions necessary for the functional rehabilitation of the patient.

Table 1. Pathological Lesions of Mandible

Type of the Lesion	No. of Patients
Ameloblastoma	27
Aggressive fibromatosis	12
Giant mandibular cyst	5
Trauma	4
Mucoepidermoid carcinoma	2
Osteochemonecrosis	2
First arch syndrome	2
Total	54

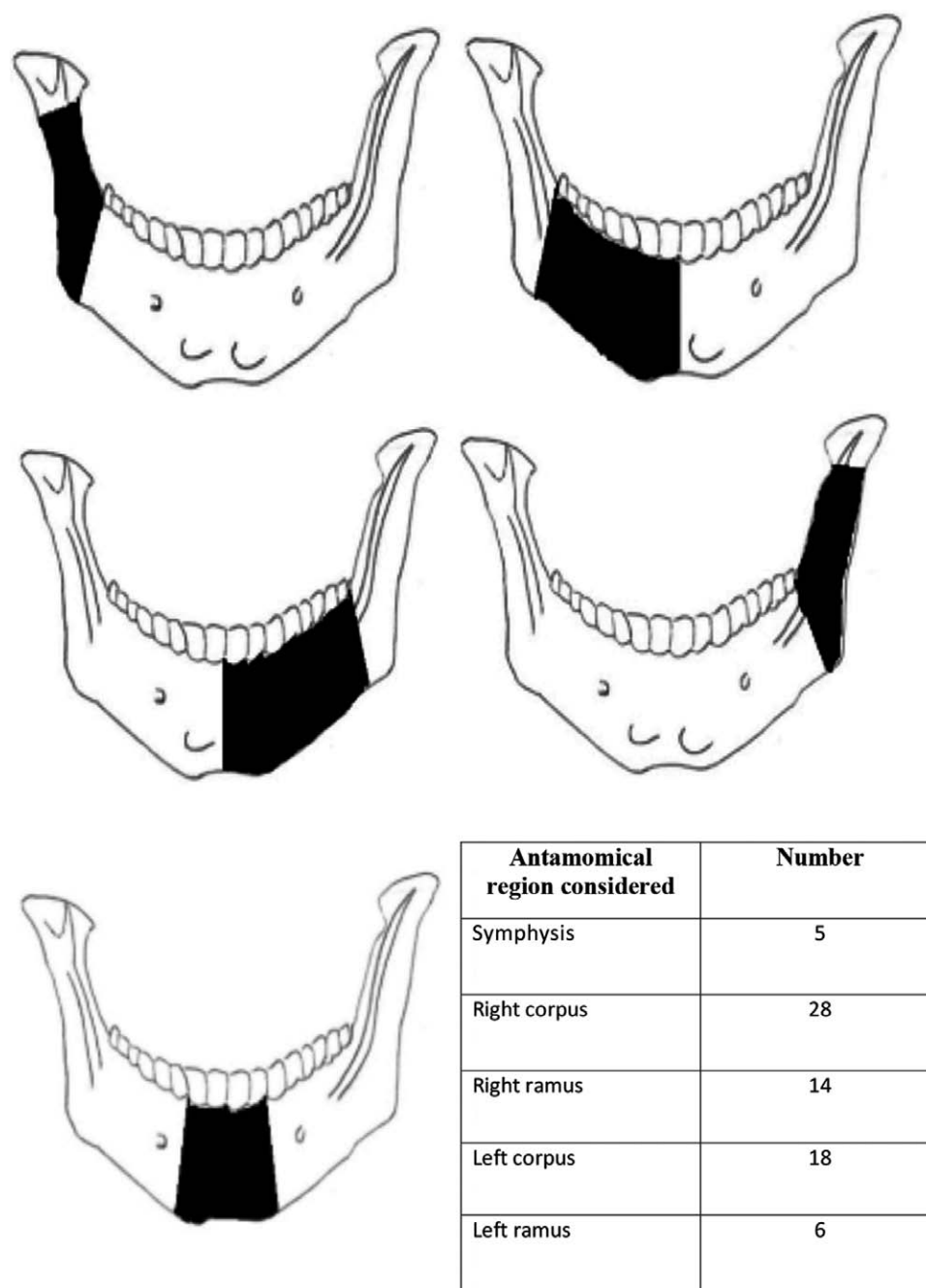


Fig. 1. Types and number of mandibular defects.

RESULTS

Between 2005 and 2014, we treated 54 patients: 44% were women (24/54) and 56% were men (30/54); the average age was 31 years. In 50% of cases, the indication was mandibular ameloblastoma (27/54), and in the other 50% it was found that 22.2% was aggressive fibromatosis (12/54), 3.7% osteochemonecrosis (2/54), 9.2% giant cyst of the mandible (5/54), 3.7% first arch syndrome (2/54), 7.5% complex trauma (ballistic) (4/54), and 3.7% mucoepidermoid carcinoma (2/54).

Interruptive mandibulectomy was performed in 72.2% (39/54); noninterruptive mandibulectomy was performed in 20% (11/54) for the case of complex trauma (ballistic) and the first arch syndrome; there was no mandibulectomy gesture, and the graft was performed directly on the mandibular bone defect.

Regarding anatomical areas, reconstructions were of 5 symphysis, 28 right corpora, 14 right rami, 18 left corpora, and 6 left rami.

The endo-oral approach was used in 79.6% of cases (43/54). Exobuccal approach was not used. In

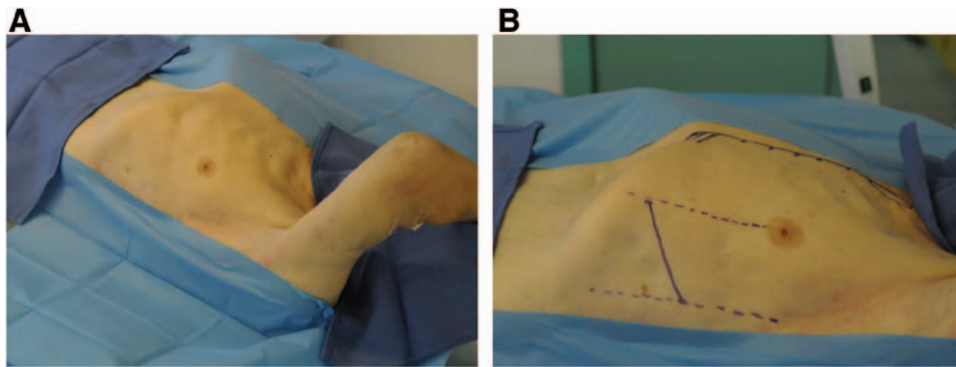


Fig. 2. Surgical installation and landmarks: (A) installation and (B) skin markers.

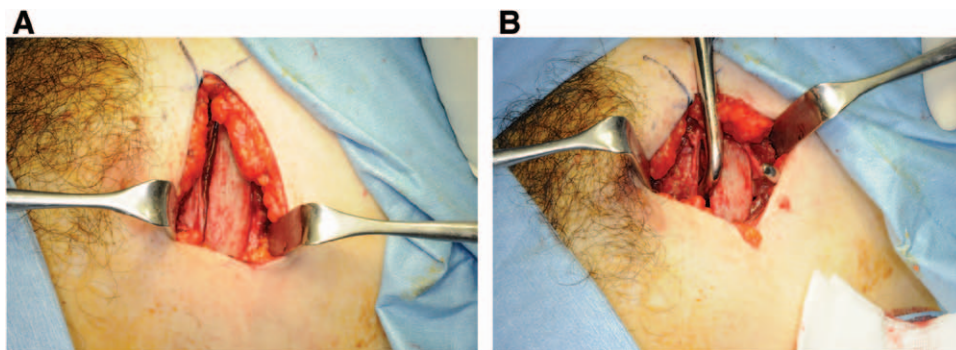


Fig. 3. Costal graft harvesting: (A) bone exposition and (B) costal dissection.



Fig. 4. Establishment of the costal graft.

20.4% of cases, a mixed approach endo-/exo-oral was realized.

Evolution of the Graft

From the 54 patients who underwent reconstruction of mandibular defect by NVBG, the evolution of the result was judged clinically and radiographically at 1 year of surgery. The outcome was successful in 92.6% (50/54) of cases.

Eighty-five percent of cases (46/54) showed no complications. In 15% with complications (8/54), 7.4% (4/54) cases of graft infection, 3.7% (2/54) cases of graft harvesting site hematoma, 1.8% (1/54)

cases of costal graft fracture, and 1.8% (1/54) cases of pneumothorax were found. In these 8 cases of complications, the graft was lost in 4 cases (infection), amounting to 7.4% (4/54) failure. The infections occurred in 3 cases of 4 from endobuccal approach; the other one occurred in mixed endo-/exo-oral approach; the indications were aggressive fibromatosis in 2 cases, osteochemonecrosis in 1 case, and giant cyst of the mandible in 1 case. All the 4 patients were male: two of them were aged 7 years and the other two were aged 56 years. Complications were treated by surgery.

Donor Site Morbidity

We found 96% (52/54) satisfactory results on the donor site, with an absence of physical and/or functional signs. Complications included 1.8% (1/54) cases of hypertrophic scar and 1.8% (1/54) cases of postoperative radiological pneumothorax without clinical impact, treated by pleural drainage with simple suites.

Complementary Surgical Time

To consider an implant rehabilitation gesture for optimal functional result, additional bone graft (allograft bone) was performed in 37% of cases (20/54).

Dental Rehabilitation

The rehabilitation was carried out for the second time once the evolution of the graft was stabilized.

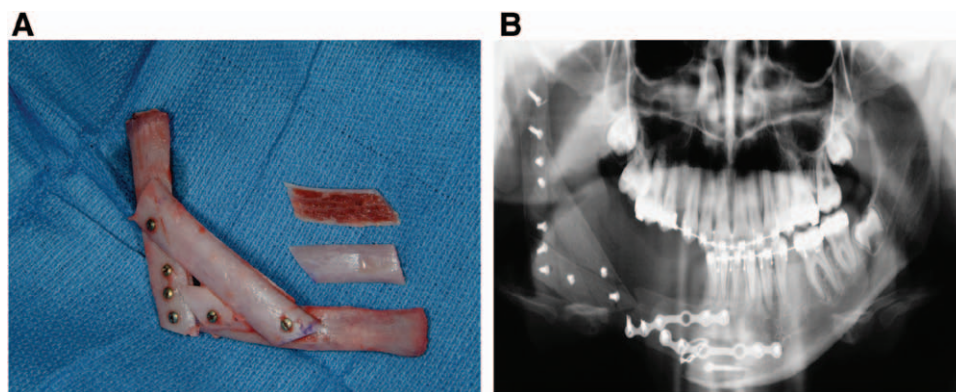


Fig. 5. Costal graft shaping: (A) costal graft split and shaped, set by bicortical screws and (B) postoperative orthopantomogram.

The implant rehabilitation was financially worn by the patient, so it was not systematic. It was performed in 70% (38/54) of the cases; in 37% (20/54) of cases, patients underwent dental implants without additional bone graft time, and 33% (18/54) of patients received an additional bone graft before dental implantation time. Patients received between 2 and 6 implants, and the implants were 5 or 7 mm long (Table 2). We have not lost any dental implant after 1-year follow-up.

DISCUSSION

Mandibular bone defects are common in maxillofacial surgery, and there are several methods of reconstruction. In specific cases, the nonvascular costal graft reconstruction shows good results. This is a reliable technique with 92.6% success rate, as shown by 85% success without complications in our series of 54 cases, for selected cases.

Advantages of Nonvascularized Bone Grafts

Bone graft is a classic technique for segmental mandible defect reconstruction. This conventional technique in maxillofacial surgery is often performed from iliac crest; the results are excellent¹⁷⁻¹⁹; the costal graft has the same reliability¹²; the reference technique for reconstruction of TMJ^{16,20-22} costal graft is also very effective in the treatment of nonarticular mandible defect.^{13,14} Costal bone graft has some major advantages for mandibular reconstruction; the shape of the graft is favorable, the harvesting is simple and fast, and it does not require cervical incision; there

are almost no donor-site sequelae (Fig. 6); esthetic result achieved is very satisfactory (Figs. 5,7,8)¹⁶; the bone graft allows dental prosthetic rehabilitation for functional recovery (Fig. 9). Tahiri et al¹⁶ present a series of 22 patients with hemifacial microsomia treated by costal osteochondral tissue graft with a success rate of 100%. The success of the graft was defined by a radiological and clinical stabilization of the graft at 1 year postoperatively. The success rate in our series was 92.6%, which is comparable with the results obtained in reconstruction with fibula free flap.

The important points describing the costal graft versus fibula free flap are as follows:

Postoperative suites are less painful either at the donor site or at the recipient site because the approaches are less invasive. The duration of the surgery is shorter, which represents an advantage both in terms of reduced morbidity and lower total cost of care.

The total duration of postoperative stay is shorter: the patient will be discharged conventionally on postoperative day 3, and hospitalization time is greatly reduced when reconstruction is done using costal grafting when compared with using a fibula free flap, which is economically advantageous and reduces the risk of nosocomial infection.

These points are important arguments for the choice of the costal graft relative to the free fibular flap, considering segmental mandibulectomy interruption or not, without involvement of soft tissues.

The conditions of the prosthetic dental rehabilitation are the same for the rib grafts as for free fibular

Table 2. Patients' Postoperative Evolution

Coastal Graft Evolution	No. of Patients	Needed Additional Bone Graft	Patients with Dental Implants	No. Implants
Good	47	13	33	2-6
Complication	7	5	5	2

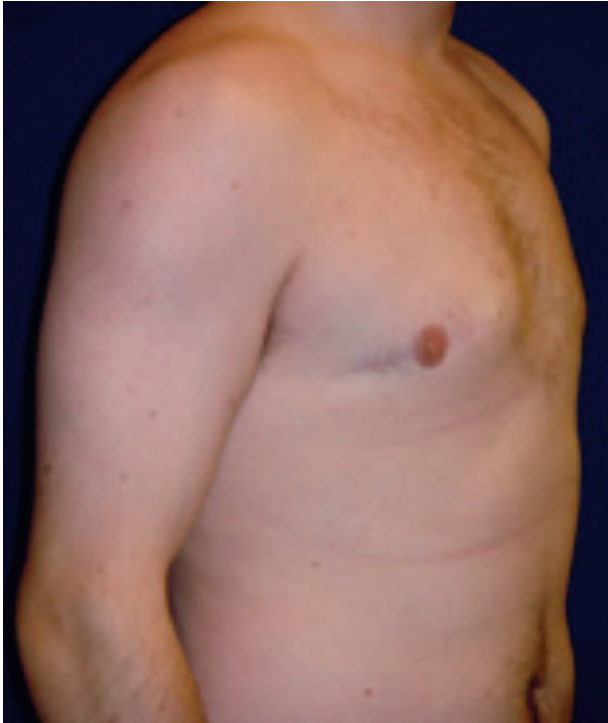


Fig. 6. Donor-site scar.

flap, thanks to short implants; the implants are placed during a second operating time between 4 and 12 months after the mandibular reconstruction.^{23,24}

Disadvantages

The main disadvantages of this technique are related to the selection of surgical indications; indeed, our team contraindicates costal bone graft when adjuvant radiotherapy is indicated or when the patient is older than 65 years. Active smoking is also considered as a failure factor by our team; therefore, the mandibular reconstruction by costal bone graft is for a selected patient pool.

The rib graft is fragile and liable to fracture (Fig. 10). In our series, we had a 15% rate of complications, including complications of the donor and recipient sites. Ultimately, on these 8 cases of complications, 4 were complications of graft loss, which were the cases of infection. Indeed, the rib bone graft is susceptible to infection. Concerning the approach, if we consider a surgical approach excluding exobuccale, we raise the risk of microbiological contamination from endobuccal flora and hopefully decrease the rate of septic complications; however, one advantage of this technique is absence of facial scar.

Alternatives

Costal graft alternatives for mandibular defect reconstruction are fibular free flap and musculoskeletal free flaps, such as iliac crest flap, scapula-dorsal flap, and serrato-costal flap

These classical techniques may seem heavy for indications used by our team in mandibular reconstruction, in regard to the donor-site morbidity, systematic cervical incision. Furthermore, the conformation of a free musculoskeletal flap is more difficult and tends to give esthetic results less favorable than the costal graft.

Donor-site morbidity on the dorsal, iliac, or leg sites is important, and the harvesting of the flap is not exempt of risks due to complications.

The study of Vu and Schmidt²⁵ evaluated patients' quality of life from a series of patients who have benefited by mandibular reconstruction, that is, fibular free flap versus NVBG. The bone graft group presented better results in chewing, swallowing, tasting, and speech.

Other alternatives considered are bone distraction and heavy machinery in terms of septic morbidity risk. Moreover, the mandible shape is difficult to reproduce with the distraction vectors; reconstruc-

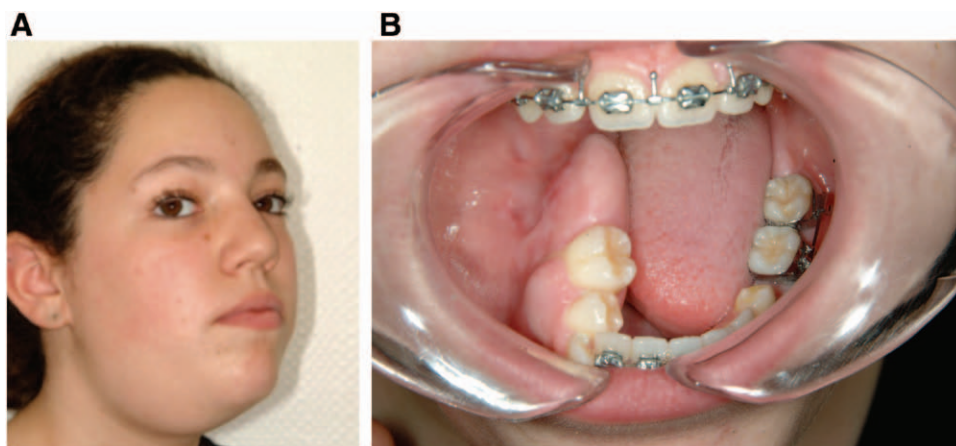


Fig. 7. Aggressive fibromatosis: (A) external view and (B) endobuccal view.



Fig. 8. Aggressive fibromatosis: postoperative external view.



Fig. 9. Implanted costal graft.



Fig. 10. Costal graft, fractured.

tions by metal plates are at risk of exposure, disassembly, nonintegration, and fracture.²⁶

A frequent and reliable alternative to the costal bone graft is iliac bone graft. Although a very popular technique in the literature, it has some limitations compared with the costal bone graft: donor-site

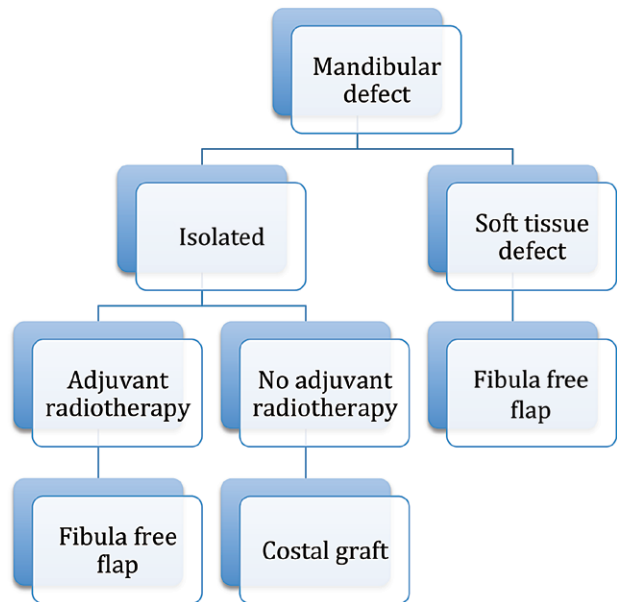


Fig. 11. Decision algorithm of the costal graft for mandibular reconstruction.

morbidity, more difficult shaping of the graft, graft length-dependent reliability according to Pogrel et al,²⁷ and inability to rebuild the TMJ. Moreover, we find nucleus growth in the costal bone graft, which is not found for iliac graft.^{16,28}

The indications for iliac bone graft used by our team are mandible noninterruptive defect, vertical insufficiency, and preimplantal graft (Fig. 11).

Limitations of Our Series

In our series of 54 cases operated on from 2005 to 2014, we find 4 failures without statistically established links between them; in 3 of 4 cases, the incision was endobuccal strict, and in 2 cases lesions were localized in the left corpus and in 2 cases localized in the left corpus + ramus. The 4 patients were men. The only link uniting them is their extreme age, 2 patients were 56 years old and 2 patients were 7 years old.

There is no link between the nature of the pathological lesion and evolution. There is no link between the need for additional bone graft and age.

CONCLUSIONS

We have shown that costal bone graft itself is a reliable alternative for mandibular bone defect reconstructions for specific indications, requiring no adjuvant radiotherapy. This technique brings good results not only in terms of efficiency but also in esthetic and functional level.

The graft harvesting is simple and fast, and the suites at the donor site are simple, without scar ran-

som. In our series, we present 54 cases of costal bone graft with a success rate of 92.6% graft. The variables of this study, age, sex, lesion diagnosis, and surgical approach, do not significantly affect the results of our costal bone grafts. This conventional technique should be readily considered for selected cases of mandibular bone graft.

Jean-Thomas Bachelet, MD

Service de chirurgie Maxillo-faciale
Hôpital de la Croix-Rousse—CHU de Lyon
103 Grande Rue de la Croix-Rousse
69004 Lyon, France
E-mail: jtbachelet@gmail.com

ACKNOWLEDGMENT

We thank Mr. Pascal and Mathilde Luce.

PATIENT CONSENT

Patients provided written consent for the use of their images.

REFERENCES

- Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. *Plast Reconstr Surg*. 1989;84:71–79.
- Iconomou TG, Zuker RM, Phillips JH. Mandibular reconstruction in children using the vascularized fibula. *J Reconstr Microsurg*. 1999;15:83–90.
- Cordeiro PG, Hidalgo DA. Conceptual considerations in mandibular reconstruction. *Clin Plast Surg*. 1995;22:61–69.
- Netscher D, Alford EL, Wigoda P, et al. Free composite myo-osseous flap with serratus anterior and rib: indications in head and neck reconstruction. *Head Neck*. 1998;20:106–112.
- Thomas WO, Harris CN, Moline S, et al. Versatility of the microvascular serratus anterior muscle vascularized rib flap (SARIB) for multifaceted requirements reconstructions. *Ann Plast Surg*. 1998;40:23–27.
- Tobin GR, Moberg A, Ringberg A, et al. Mandibular-facial reconstruction with segmentally split serratus anterior composite flaps. *Clin Plast Surg*. 1990;17:663–672.
- Brown J, Bekiroglu F, Shaw R. Indications for the scapular flap in reconstructions of the head and neck. *Br J Oral Maxillofac Surg*. 2010;48:331–337.
- Yamamoto Y, Sugihara T, Kawashima K, et al. Anatomic study of the latissimus dorsi-rib flap: an extension of the subscapular combined flap. *Plast Reconstr Surg*. 1996;98:811–816.
- Longacre JJ, Destafano GA. Further observations of the behaviour of autogenous split-rib grafts in reconstruction of extensive defects of the cranium and face. *Plast. Reconst. Surg*. 1957;20:281–296.
- Schlieve T, Hull W, Miloro M, et al. Is immediate reconstruction of the mandible with nonvascularized bone graft following resection of benign pathology a viable treatment option? *J Oral Maxillofac Surg*. 2015;73:541–549.
- Foster RD, Anthony JP, Sharma A, et al. Vascularized bone flaps versus nonvascularized bone grafts for mandibular reconstruction: an outcome analysis of primary bony union and endosseous implant success. *Head Neck*. 1999;21:66–71.
- MacIntosh RB, Henny FA. A spectrum of application of autogenous costochondral grafts. *J Maxillofac Surg*. 1977;5:257–267.
- el-Sheikh MM, Zeitoun IM, Medra AM. The split rib bundle graft in mandibular reconstruction. *J Craniomaxillofac Surg*. 1992;20:326–332.
- De Riu G, Meloni SM, Raho MT, et al. Complications of mandibular reconstruction in childhood: report of a case of juvenile aggressive fibromatosis. *J Craniomaxillofac Surg*. 2006;34:168–172.
- James DR, Irvine GH. Autogenous rib grafts in maxillofacial surgery. *J Maxillofac Surg*. 1983;11:201–203.
- Tahiri Y, Chang CS, Tuin J, et al. Costochondral grafting in craniofacial microsomia. *Plast Reconstr Surg*. 2015;135:530–541.
- van Gemert JT, van Es RJ, Van Cann EM, et al. Nonvascularized bone grafts for segmental reconstruction of the mandible—a reappraisal. *J Oral Maxillofac Surg*. 2009;67:1446–1452.
- Tidstrom KD, Keller EE. Reconstruction of mandibular discontinuity with autogenous iliac bone graft: report of 34 consecutive patients. *J Oral Maxillofac Surg*. 1990;48:336–346; discussion 347.
- Xingzhou Q, Chenping Z, Laiping Z, et al. Deep circumflex iliac artery flap combined with a costochondral graft for mandibular reconstruction. *Br J Oral Maxillofac Surg*. 2011;49:597–601.
- Obwegeser HL. Correction of the skeletal anomalies of oto-mandibular dysostosis. *J Maxillofac Surg*. 1974;2:73–92.
- Karagoz H, Eren F, Sever C, et al. Mandibular reconstruction after hemimandibulectomy. *J Craniofac Surg*. 2012;23:1373–1374.
- Breton P, Souchère B, Bancel B, et al. [A case of aggressive juvenile fibromatosis of the mandible]. *Rev Stomatol Chir Maxillofac*. 1997;98:272–274.
- Chiapasco M, Abati S, Ramundo G, et al. Behavior of implants in bone grafts or free flaps after tumor resection. *Clin Oral Implants Res*. 2000;11:66–75.
- Taylor TD, Worthington P. Osseointegrated implant rehabilitation of the previously irradiated mandible: results of a limited trial at 3 to 7 years. *J Prosthet Dent*. 1993;69:60–69.
- Vu DD, Schmidt BL. Quality of life evaluation for patients receiving vascularized versus nonvascularized bone graft reconstruction of segmental mandibular defects. *J Oral Maxillofac Surg*. 2008;66:1856–1863.
- Goh BT, Lee S, Tideman H, Stoeltinga PJ. Mandibular reconstruction in adults: a review. *Int J Oral Maxillofac Surg*. 2008;37:597–605.
- Pogrel MA, Podlesh S, Anthony JP, Alexander J. A comparison of vascularized and nonvascularized bone grafts for reconstruction of mandibular continuity defects. *J Oral Maxillofac Surg*. 1997;55:1200–1206.
- Fernandes R, Fattahi T, Steinberg B. Costochondral rib grafts in mandibular reconstruction. *Atlas Oral Maxillofac Surg Clin North Am*. 2006;14:179–83.