Original Article

Iliac crest bone grafting for mandibular reconstruction: 10-year experience outcomes

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ABSTRACT

Purpose: To evaluate 10-year patient data related to mandibular reconstruction with NVBG at a tertiary academic center.**Patients and Methods:** Sixty patients with mandibular reconstruction were included. Patients were divided to continuity defect and non-continuity defect. Pathology lesion, immediate reconstruction, smoking habit, medical comorbidities, site and size of the defect, surgical approach, intraoperative perforation, cadaveric bone use, and maxilla-mandibular fixation use were analyzed as factors of influence on success. Success was defined as maintenance of more than 50% of graft for non-continuity defects (NCD) and bone continuity and stability for continuity defect (CD), and absence of infection on last follow up upon clinical and radiographic examination. Complications were classified as minor or major.**Results:** The reconstruction was successful in 28 (87%) of CD patients and 23 (82.1%) of NCD patients. Analyses showed that the size of defect was significantly associated with failure. All 4 failed cases of CD had defects more than 9 cm. Four patients had major complications and 43 minor complication.**Conclusions:** Nonvascularized iliac crest bone grafts are highly successful in mandibular continuity reconstruction for non-Cancer patients and should be considered as first choice for defects less than 9 cm. They are less predictable for defects larger than 9 cm but can be considered in these cases with osteoconductive cribs. Symphysis involvement may or may not be associated with lower success rate if our protocol is followed.

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1. Introduction

Restoration of form and function with like tissues are critical tenets of any form of maxillofacial reconstruction. Composite defects following malignant tumor extirpation led to the advent of microvascular tissue transfer. While this technique has revolutionized the reliable reconstruction of complex craniofacial defects, its application as a panacea for bony reconstruction of the mandible has left much to be desired. Isolated bony defects of the jaws resulting from tumor resection, trauma, infection, or other causes can lead to problems with mastication, swallowing and speech. If these defects are not reconstructed appropriately,

esthetic, functional, and social problems can impair quality of life.^{1,2}

Both vascularized and non-vascularized techniques are well-accepted treatment strategies for reconstruction of the jaws. Several criteria to help identify the type of bone graft reconstruction that is optimal for mandibular reconstruction.³ In cases of primary reconstruction for segmental defects, patient's with preoperative radiation therapy, defects >6 cm, and where composite hard/soft tissue is required, vascularized bone flap (VBF) is indicated. Despite the great advantages they offer, free tissue transfer is time-consuming, associated with donor site morbidity, require longer hospital stay, require larger surgical dissection and surgical airways, necessitate monitoring in intensive care unit and place a heavy burden on hospital resources.⁴

In cases of shorter defects (<6 cm), non-continuity defects, defects with no soft tissue requirement, and ability for secondary reconstruction, many defects are amenable to reconstruction with non-vascularized bone grafts (NVBG).^{1,3} These procedures are shorter, allow for faster recovery, and better facilitate reconstruction with dental implants. The anterior and/or

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Fig. 1. a: Institutional protocol for reconstruction of mandibular defects based on characterization and size of the defect. b: Institutional protocol for reconstruction of post-ablative defects of the mandible based on the status of mucosal perforation at the time of resection.

posterior iliac crest is a commonly used donor site as it offers a large amount of bone and high concentration of osteocompetent cells to be transferred.⁵ At out institution, VBFs are the first choice treatment for mandibular reconstruction for all cancer patients and many larger defects, while NVBG are preferred for most defects due to benign pathology, trauma, and non-continuity defects.

The purpose of our study was to retrospectively evaluate the success and complications of lower jaw reconstruction with NVBGs at our center, and to refine treatment strategies and indications. We expected a high rate of success of NVBG for mandibular reconstruction utilizing our institution's protocol (Fig. 1-a and b). The specific aims of our study were to evaluate the effect of various factors such as size, site, timing of reconstruction, use of maxillomandibular fixation, and other factors on success of graft in continuity defects.

2. Patients and Methods

2.1. Study Design and Sample

To evaluate the outcomes and factors that contribute to success or failure of non-vascularized reconstruction of mandibular defects, a retrospective cohort analysis was performed. Approval for the study was obtained from the Institutional Review Board at Boston University. The study population includes all patients who underwent mandibular reconstruction with iliac crest bone grafting between 2001 and 2011. Patients were separated into the following two groups based on the type of defect: Group 1 included continuity defects (CD) and was further sub-classified depending on the anatomical location of the reconstructed site as true lateral, partial symphysis involvement, and complete symphysis involvement (Table 1) while Group 2 patients included large 1- or 2-wall defects (e.g.: post traumatic defects, defects post osteomyelitis debridement), augmentation of free fibular reconstructions for prosthetic purposes and marginal mandibulectomy defects, all of which required iliac crest bone harvest due to the large volume of bone required. Patients were included in the study if they underwent mandibular reconstruction with iliac crest bone grafting for management of ablative defects of the mandible from pathology, trauma, infection, and significant mandibular atrophy. The goals of reconstruction in continuity defects was restoration of mandibular continuity, and in non-continuity defects was to allow for dental rehabilitation or to strengthen the native mandible. Patients were excluded if insufficient records for analysis, had less than 6 months clinical and radiographic follow up, defects from malignant disease with extraperiosteal extension, need for

Table 1
Patient demographic information.

Gender	Number (%)
Male	37 (61.6)
Female	23 (37.4)
Age	
Range (years)	13–67
Mean (years)	36
Dental Status	
Dentate	41
Partially Dentate	13
Edentulous	6
Pathologic Disorder	
Benign Tumor/Cyst	30
Trauma	2
Infection	9
Malignancy	1
Others	18

adjuvant radiation or chemotherapy, and preprosthetic bony defects fewer than 3 walls.

2.2. Description of surgical treatment

In Group 1 (CD), all patients underwent harvest of autogenous cancellous marrow/corticocancellous bone grafts from the anterior and/or posterior iliac crests. The bone grafts were milled in the operating room and stored in iced-saline until ready for transfer into the ablative defect from a strictly, extraoral approach. Harvested bone was packed directly around the periosteum in the ablative defect for defects less than 6 cm. For defects >6 cm and/or those with any symphysis or condylar region involvement, an osteoconductive crib was used. The milled corticocancellous bone grafts compressed and packed into the cribs, which had previously been prepared (thinned and perforated using rotary instrumentation). In Group 2 (NCD), bone was harvested as a corticocancellous block which were secured by lag-type screws into the recipient bed which was perforated to improve local vascularity and incorporation. Cancellous bone particles were packed in the margins to fill in any voids, from either an intraoral or extraoral approach. All patients had similar surgical protocol including perioperative and postoperative antibiotics, surgical approach, and postoperative care.

2.3. Variables

Parameters evaluated included patient factors, surgical factors, graft success, and complications. Patient factors (Table 1) included

demographics, dental status, pathologic disorder, medical co-morbidities including daily smoking and diabetes, size and site of defect. Surgical factors include type of reconstruction (immediate vs delayed), surgical approach, method of graft fixation, use of maxillomandibular fixation, intraoperative perforation, use of cadaveric bone, and type of airway. Complications were classified as major (those requiring return to the hospital or operating room) or minor (requiring only medical treatment such as antibiotics or minor office procedure).

2.4. Data Analysis

Success of the graft was evaluated clinically and radiographically. Success was defined radiographically as maintenance of >75% of the graft based on comparison of preoperative, immediate postoperative (T1) and last postoperative visit (T2) clinical examinations, restoration of mandibular continuity, and CT scan and plain film panoramic radiographic consolidation. Criteria for radiographic consolidation included progressive ossification of the junction between native mandible and graft, no increased radiolucency at the graft/native mandible interface, no increase in radiolucency around fixation or other signs of hardware failure to indicate lack of continuity. Clinical success was defined as absence of infection, complete mucosal closure, no interfragmentary mobility on examination restoration of mandibular form, and intelligible speech. Student's t-test was used for statistical analysis of results.

3. Results

A total of 69 patients underwent mandibular reconstruction with iliac crest non-vascularized bone grafts at Boston Medical Center between 2001 and 2011. Nine patients did not have sufficient records or follow up for inclusion in the study. The triage of patients was based on a standard protocol, which is shown in Fig. 1. Overall success of grafts was 85%. When separately analyzed, success was 87.5% in continuity defects, and 82.1% in non-continuity defects (Fig. 1).

Patient related factors are demonstrated in Table 1. Gender showed a slightly male predilection for reconstruction and mean age was 36 years (range 13–67). Most patients were dentate and no patients had any uncontrolled medical co-morbidity. Specific assessment of patient's smoking status and diabetes were noted because of the relative immunosuppression and risk to graft success. As seen in Table 4, results showed a 15% reduction in success from 90% to 75% in patients who smoked daily and all 4 patients with diabetes had successful graft. Location of continuity defect is described in Table 2. True lateral defects (n = 24) had 95%

success whereas defects that involved the entire symphysis had 62% success. Intraoral or combined approach was used in 27 with 4 failures (85% success) and all 4 failures were in non-continuity defects. Size of the defect was divided in to <6 cm, 6–9 cm, and >9 cm; 100% success was 100% with defects <9 cm and 55.5% when >9 cm (Table 3). Table 4 demonstrates factors related to graft success. Immediate reconstruction was performed in 12 non-continuity defects and 6 continuity defects. Although the overall success in immediate reconstruction was 89%, the two failures were in defects greater than 9 cm. Extraoral approach was used in 33 with 5 failures (85% success). Use of cadaveric cribs had an overall 89% success with only 1 failure out of nine cases. Postoperative maxillomandibular fixation was used in 29 patients with 2 failures (93.1% success), and not used in 31 patients with 7 failures (77% success). Choice of airway was endotracheal intubation for 59 patients and only 1 patient had a tracheostomy. There were 4 major complications in the study. Three patients required return to the OR for debridement and 1 developed a seroma requiring return to the OR perioperatively and subsequently developed exposed cadaveric bone 2 years after procedure requiring debridement. Minor complications occurred including 8 patients with dehiscence (7 recipient; 1 donor site), persistent hip pain in 3 patients, and transient cranial nerve VII weakness in 7 patients. One patient had persistent open wound and a related small sequestrum, that had to be debrided at the site of a previous draining fistula.

4. Discussion

The specific aim of our study was to evaluate the success of non-vascularized bone grafting for mandibular reconstruction in continuity and non-continuity defects of varying, sizes, sites, stages, and indications. In the current study, our overall success rate was 85%, success in continuity defects was 87% and 82% in non-continuity defects. Defect size is one of the critical considerations when planning reconstruction of continuity defect of the mandible. In our study, the only failures were in defects >9 cm with 45% failure rate. There was 100% success in those <6 cm and between 6–9 cm. Use of cadaveric crib can also be considered in defects of >9 cm. Of the 9 patients with successful reconstruction of continuity defects >9 cm, 8 of them were done with cadaveric cribs. The single cadaveric crib failure (1/9, 89% success) was in a defect >14 cm.

Location of continuity defects in our series are seen in Table 1. Failure of defects involving the symphysis occurred in 3 of 8 patients compared to 1/24 patients with true lateral defects (38% failure compared to 5% failure). Although this may seem to imply that the symphysis area had greater failure rate, when we scrutinize this patient population closely, each of the three failed grafts in the symphysis involved greater than 9 cm defects and in none of these was cadaveric crib used. If we consider the results of NVBG in the symphysis area in the other 5 patients where defect size was <9, the success rate was 100% and in 3 of these 5, cadaveric crib was used. Failure in the symphysis is multifactorial given the various muscle attachments and multiple vectors of soft and hard tissue mobility. In our opinion, defects involving the symphysis can be effectively treated with VBF; if NVBG are to be

Table 2
Location of mandibular continuity defects.

Bone Defects	Patients	Failure
True Lateral (n = 23)		
Ramus	0	
Body	11	0
Ramus-Body	12	1
Hemisymphysis (HS)		
Ramus-Body-HS	0	
Body-HS	0	
Complete Symphysis (CS)		
CS only	0	
Unilateral Body-CS	3	1
Bilateral Body-CS	2	0
Ramus-Unilateral Body-CS	1	1
Ramus-Bilateral Body-CS	1	0

Table 3
Size of mandibular continuity defect relative to success rate.

Size of Continuity Defect	N with success	N with failure
<6 cm	12	0
6–9 cm	11	0
>9 cm	9	4

Table 4

Graft Success with related factors.

Factors	Variables	Number (n)	N with success (%)
Immediate Reconstruction	Yes	12 + 6 ^a	12 + 4 ^a (88.9%)
	No	42	35 (83.3%)
Smoking	Yes	20	15 (75%)
	No	40	36 (90%)
Diabetes	Yes	4	4 (100%)
Surgical Approach	Extraoral	27 ^a + 6	23 ^a + 5 (85%)
	Intraoral/Combined	5 ^a + 22	5 ^a + 18
Intraoperative Perforation	Yes	1	1
Osteoconductive Crib	Yes	9	8 (88.8%)
MMF Used	Yes	29	27 (93.1%)
	No	31	24 (77%)

^a Continuity Defects.

used in this area, success rate and predictability rises with the use of any type of osteoconductive crib which supports and prevents micromotion of the graft particles during early healing phases. Timing of reconstruction and indication for reconstruction must be carefully considered when determining treatment for mandibular reconstruction. One of the main benefits of VBG is immediate reconstruction however, we have demonstrated successful primary reconstruction in 18 patients with only 2 failures (88% success). At our institution, continuity defects of the mandible from malignant tumor resection are invariably reconstructed with VBG regardless of size of bony defect; in the current study sample, the only patient with malignant disease was a patient with central mucoepidermoid carcinoma of the left mandible without any extracortical extension.

In this study, we specifically evaluated a number of factors seen in Table 4. An extraoral or combined approach was used for all continuity defects. Closure of dead space and prevention of seroma/fluid collection is critical to success of grafts. In non-continuity defects, an intraoral approach was used most commonly and there was no difference in success rates. Use of maxillomandibular fixation in our study was shown to influence success rates (93% vs 77%). MMF was used in all continuity defects for total of 4 weeks. The ability to reduce micromotion in the graft during vascular ingrowth and graft maturation is likely the reason for improved outcome with use of maxillomandibular fixation. Major and minor complications from NVBG for mandibular reconstruction were evaluated. Total of 4 patients developed major complications. Three required return to the operating room for debridement, and one developed seroma with return to OR for drainage. There were minor complications including dehiscence in 7 recipient sites/1 donor site, persistent hip pain in 3, and 7 with temporary paresis of facial nerve.

In this series, all patients had either continuity defects, non-continuity defects of 3 or more bony walls, or severely atrophic mandible and our success rates are consistent with those other series.^{3,6} Other studies have also shown increased failure in defects 9 cm or greater.^{3,5} August and others in 2000 evaluated mean length of mandibular defect and found that 7 cm was the mean for those grafts that succeeded within one year and 9.9 cm among those that failed.² Use of crib can also be considered in defect length >9 cm as it minimizes micromobility, which is a factor in NVBG failure, especially in large defects. Of the 9 successful patients with reconstruction of mandibular defect >9 cm, 8 of them were done with cadveric cribs and 3 of these 8 involved the symphysis.

Based on experience at our center and in agreement with most of the existing literature, we don't primarily recommend NVBG in malignant disease, unless the lesion is completely intrabony and no postoperative radiation is required. This is to facilitate adjuvant

therapy and accommodate for soft tissue loss, which often accompanies malignant lesion extirpation, and additionally, because there is low rate of dental implant rehabilitation in this population.^{7,8} In patients who have had radiation therapy, there is controversy regarding success of NVBG.^{9,10} No patients in our study had radiation therapy, and our preference is to use VBG in radiated fields. Consistent with others, we also prefer to use NVBG in benign disease.^{5,6,9,10} Based on our findings, we recommend use of NVBG alone in continuity defects <9 cm, and with an osteoconductive crib in defects >9 cm.

Multiple medical and surgical factors have been associated with graft outcome. These factors include blood loss/volume replacement, smoking, diabetes, postoperative antibiotics, recipient site complications, fixation, and drain placement.^{2,13,14} In our study, in addition to the factors already discussed, Smoking has variable association with graft success in other studies.^{5,14,15} In the current study, patients who did not smoke had increased success of engraftment (90% vs 75%). Minimizing risk of perforation is critical to success of reconstruction. In the current study, patients with primary reconstruction had extraction of teeth 8–12 weeks prior to resection to maximize keratinized tissue and minimize perforation risk. Flap design to maximize keratinized tissue is going to help prevent perforation and improve prosthetic rehabilitation. In our experience, intra-operative perforation does not doom a reconstruction to failure and we recommend adherence to Carlson's protocol to maximize graft success.^{11,12}

Choice of airway is a factor to consider when anticipating mandibular reconstruction particularly for benign disease. Elective tracheostomy is recommended for most vascularized bone grafts, particularly lateral defects and with bilateral neck dissection.¹⁶ At our institution, tracheotomy is advocated when VBG is used for reconstruction regardless of etiology of disease but not for NVBG unless specific airway protection is anticipated postoperatively. Complications from VBG are well-known and may include flap failure, hardware failure, inability to reconstruct, infection, donor site complications, need for debulking, and often require longer hospitalization.^{3,17} Morbidity associated with the ICBG donor site include pain, gait disturbance, scarring, and neurosensory disturbance.¹⁸

The main limitation of this study is that it is a retrospective cohort analysis of a limited number of patients. The strengths of the study are that it highlights the benefits of non-vascularized grafts alone and in conjunction with a crib demonstrating good success. It is critical to have multiple tools in the reconstructive armamentarium and this study offers many considerations, advantages, and factors to weigh in choosing the type of mandibular reconstruction for continuity and non-continuity defects of varying types.

5. Conclusions

Non-vascularized iliac crest bone grafts are highly successful in mandibular continuity reconstruction for non-cancer patients and should be considered as first choice for defects less than 9 cm. Based on our experience, they are less predictable for defects larger than 9 cm but can be considered in these cases with cribs and MMF. Symphysis involvement may not be associated with lower success rate if the criteria for selection of patients for bone grafting mentioned in Fig. 1 is followed as long as the soft tissue is of adequate quality and quantity. Complications and morbidity with NVBG were relatively minor and within acceptable range.

Conflict of interest

None.

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