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The feasibility of rib grafts in long span mandibular defects reconstruction: A long term follow up

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ABSTRACT

Aims: To evaluate the efficiency of reconstruction of long span mandibular defects using split rib bundle bone graft.
Materials and methods: Six hundred patients with long span mandibular defects (more than 6 cm long), following resection of aggressive mandibular tumours, were reconstructed with split rib bundle bone graft technique. Immediate reconstruction was performed in all patients. A reconstruction plate was used to support the graft. Two ribs were harvested from the right side of the chest, split into four halves and used to restore the continuity of the mandible. The inclusion criterion was post-surgical mandibular bony defects without soft tissue deficiency. Defects with a history of previous or need of future irradiation were excluded.
Results: The appearance of the patients was accepted in 550 patients. Functional reconstruction was done in 320 patients by osseointegrated dental implants (after 15 months), and removable prosthesis in 150 patients. Infection was minor in 31 patients, moderate in 47 patients and severe in 42 patients. Partial loss of graft, up to 25%, due to moderate infection was reported. Total or near total loss of graft due to severe infection was corrected by reoperation six months later.
Conclusions: This technique is simple, safe, and can be effectively used to reconstruct long-span mandibular defects with minimal complications in selected patients.

1. Introduction

Mandibular reconstruction has both functional and aesthetic purposes; it provides skeletal support to the lips, the floor of the mouth, and the tongue to restore oral continence, swallowing, control of saliva, and speech. Proper mandibular reconstruction furthermore should provide adequate bone stock for dental rehabilitation either by insertion of a good denture or osseointegrated dental implants. Also, it is performed to restore the contour of the lower facial appearance and avoid the retrogenic and retrognathic profile (Baker et al., 2001).

Mandibular reconstruction can be performed either primary simultaneously with resection or secondary at a later surgery after confirmation of nonrecurrence of pathology. In developing countries, it is preferred to do primary reconstruction to decrease the cost of second surgery and allow the patient to return to work as soon as possible (Ahmad and Choudhary, 2013).

With advancement of microvascular free tissue transfer, vascularized bone flaps (VBFs) are currently the criterion standard for reconstruction of mandibular defects in the developed world (Whitman et al., 1997; Reinert, 2000; Baker et al., 2001).

Nonetheless, in developing countries, VBFs are not the first choice for mandibular bony defect reconstruction because of the lack of financial resources and trained surgical team. Thus, non-vascularized bone grafts (NVBGs), either from iliac crest or rib, still play an important role in mandibular reconstruction in the developing world (Habib, 2016).

When enough soft tissue coverage is present after resection, split ribs can be used to reconstruct mandibular defects in a three-dimensional way (horizontal, vertical, and bucco-lingual) as it is easily contoured to match the original mandibular configuration (El-Skeikh et al., 1992).

In this article, the authors show their experience with the use of non-vascularised split rib bundle graft for mandibular reconstruction, describing its indications, limitations, modified surgical technique, and possible complications.

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2. Materials and methods

We did a prospective observational clinical study involving 600 patients of both sexes and different ages requiring mandibular reconstruction treated in our department between 2007 and 2017 with mandibular defects.

Inclusion Criteria:

1. Patients with benign mandibular tumours planned to be managed by segmental mandibulectomy.
2. Patients with adequate soft tissue coverage after mandibular resection.
3. Patients with malignant tumours those are radio-resistant.

Exclusion Criteria:

1. Patients not suitable for general anaesthesia because of severe systemic medical problems.
2. Patients with soft tissue deficiency after resection, which are better treated by free osseo-cutaneous flaps.
3. Patients planned to have postoperative radiotherapy or with history of head and neck radiotherapy.
4. Patients with obvious preoperative infections at the site of surgical resection.
5. Patients with recurrent lesions where wider resection will necessitate free composite flap reconstruction.
6. Patients with mammary implants for fear of intraoperative injury to the implant or post-operative infection/exposure of the implant.
7. Patients with post gunshot mandibular defects because of the compromised vascularity at the site of injury. They are better treated by free osseo-cutaneous flaps.
8. When immediate dental implant placement is being considered.

All patients were primarily reconstructed for extensive mandibular defects after ablation of aggressive mandibular tumours using split rib bundle graft (SRBG).

The surgical data including the lesions, pathology, location, size, the method of reconstruction, and complications are given in Table 1.

The patient's medical, demographic, surgical, pathological varieties and follow up data were collected (Table 1).

The types of mandibular defects met in this study are:

1. Hemimandibular defect (body, ramus, condyle, and coronoid), 120 patients
2. Hemimandibular defects sparing the condyle, 320 patients
3. Hemimandibular defects extending beyond the midline, 119 patients
4. Subtotal defect (from angle to angle), 21 patients
5. Near-Total Mandibular defect, 20 patients

2.1. Surgical technique

A Preparation of the Oral Cavity;

This was done meticulously before the operation, thorough scaling, elimination of any septic focus, restoration of carious teeth, treatment of any gingival or periodontal infections, removal of remaining roots, etc.

B Adaptation, and Contouring of the Reconstruction Plate:

Maxillo-mandibular fixation (MMF) was adopted using complete upper arch bar and segmental lower arch bar applied to the remaining lower teeth (if any) or by MMF screws fixed to the maxilla and pathological free part of the mandible.

C Surgical Approach and Resection

The operation was done through a combined intra-oral lower sulcus and extra-oral extended submandibular incisions for lateral mandibular resections and a combined intra-oral lower sulcus and transverse collar incision for midline mandibular resections.

A reconstruction plate was adapted to the mandible before resection of the lesion, if this was possible, and at least three holes were drilled on each side of the proposed defect edge. Then the screws were removed, and the plate was put aside. Figs. 1–11.

In some patients, where the shape of the mandible was not significantly changed, the plate was kept in place and the mandible was resected using fine fissure bur. The advantages of this modification in the resection technique are keeping patient's own occlusion and reducing the time of surgery.

When the lesion extends to the angle of the mandible, resection of the coronoid process (even if not involved in the pathological process) was performed to prevent the upward pull of the temporalis muscle that leads to displacement of the proximal segment upwards and inwards. If the lesion approximates or involves the condyle, disarticulation of the temporomandibular joint was performed leaving the articular disc in place.

D Preparation of the Mandibular stumps:

The proximal and distal sharp upper edges of the mandibular stumps were reduced and smoothed to facilitate watertight and tensionless mucosal closure at these critical areas. Also, this prevents the sharp mandibular stumps from penetrating the overlying mucosa.

The outer cortices of the mandible at the recipient sites were removed using a rose-head bur, in the form of a box to expose the spongiosa, and helped bony union and graft take.

E Harvesting the Rib Graft, and Making the Bundle:

A pillow was put under the ipsilateral chest wall facilitating harvesting a long segment of the rib.

Through a curved submammary incision, two alternating ribs, usually the fourth and sixth or the fifth and seventh, were harvested from either side of the chest wall.

We prefer the right side, unless a graft had previously been taken from that side.

When a costochondral graft was desired to replace a resected mandibular condyle, a sheet of periosteum and perichondrium was kept attached to the anterior surface of the costochondral junction of the graft, to minimize the risk of separation at that critical area. After confirming that the pleura was intact, the wound was closed in layers.

The ribs were split, using fine osteotome and manual pressure on an instrument table, using fine osteotome, preserving the bone marrow inside the rib.

F Application of Reconstruction Plate and Screws:

Then the previously adapted reconstruction plate was applied to the remaining mandibular stumps, and utilizing the previously drilled holes, inserting at least three screws on each side of the

Table 1
Patient's characteristics and the surgical data included the lesion's pathology, location, and size, the method of reconstruction, and complications.

Patients characteristics	(A) Lateral defect		(B) Crossing midline		Total
	Without condyle removal	With condyle removal	Without condyle removal	With condyle removal	
Number of patients	320	120	140	20	600
Sex					
Male	200	80	80	10	370
Female	120	40	60	10	230
Mean Age	34.5	26	42.3	33.5	34
Etiology					
Ameloblastoma	150	70	90	10	320
Odontogenic keratocyst	60	30	40	0	130
Odontogenic myxoma	20	10	0	0	30
Trauma	30	0	10	0	40
High flow vascular malformation	20	0	0	0	20
Aneurysmal bone cyst	20	0	0	0	20
Ossifying fibroma	10	0	0	10	20
Central giant cell granuloma	10	0	0	0	10
Rhabdomyosarcoma	0	10	0	0	10
Defect size					
6–10 cm	230	80	90	10	410
>10 cm	90	40	50	10	190
Mean hospital stay (days)	3.4	3.7	4	5.2	3.8
Complications					
Hematoma	20	60	10	10	100
Seroma	30	0	10	0	40
Infection	10	20	50	40	120
Graft failure	0	0	30	10	40
Graft resorption	10	40	20	10	70
Bony nonunion	0	10	20	0	30
Extra oral sinus	10	0	20	0	30

defect. This was done while the teeth are in best occlusion via the MMF previously applied.

G Inserting of the Rib Bundle Graft:

One split rib was fixed at the proximal mandibular stump to the reconstruction plate by screws, placing it in the previously decorticated box. A second split was then placed at the distal mandibular stump, in a similar manner. The other two splits were telescoped to achieve a proper mesio-distal spanning of the defect. The four splits were fixed together as a bundle by screws with or without transosseous-circumferential wires, and to the reconstruction plate by screws. Additional ribs or portions of the ribs are added to obtain more bucco-lingual thickness, and more vertical height. Adequate inter-arch space was maintained to allow for proper dental rehabilitation.

In young patients, when the condyle was resected, one split costochondral graft was used to replace it.

When the central region of the mandible was resected, the genial muscles were suspended to the reconstruction plate by several Vicryl suture (0) sutures, to avoid the need for tracheostomy.

H Closure:

A single layer of continuous or interrupted mattress sutures using Vicryl suture (3/0 or 4/0) closed the oral mucosa. Another

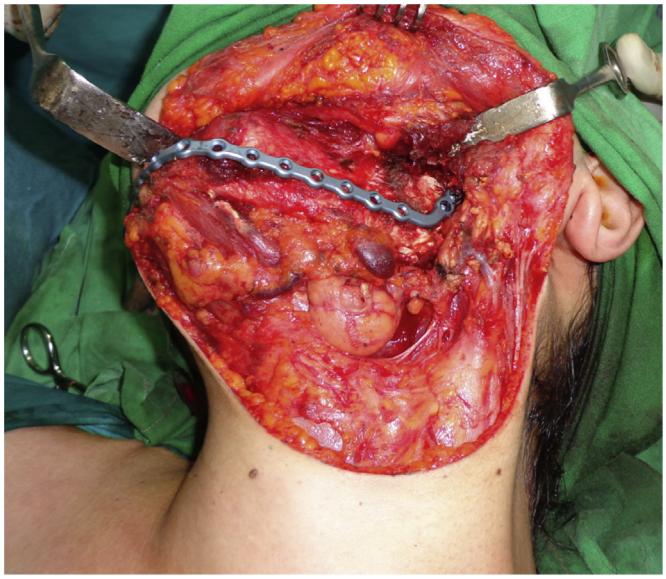

Fig. 1. A reconstruction plate was adapted to the mandible before resection of the lesion.

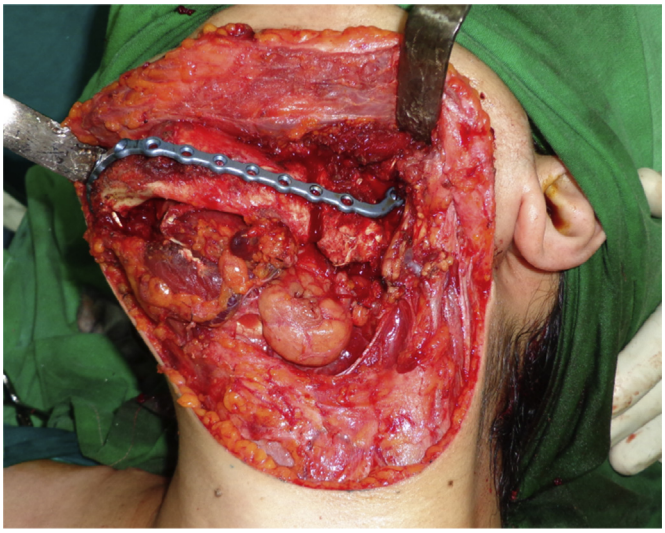

Fig. 2. Mandibular osteotomy lines using fissure bur while the reconstruction plate was kept in place.

Fig. 3. Lateral mandibular defect after tumour resection and reconstruction plate maintaining the original contour of the mandible.

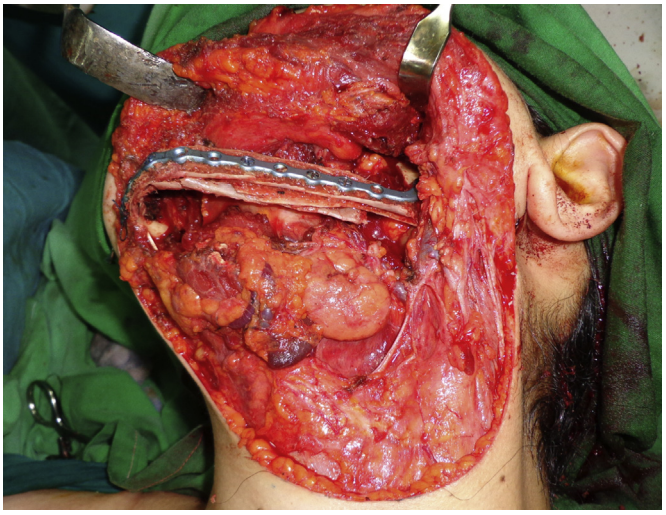

Fig. 4. The split rib grafts were inserted to the reconstruction plate, telescoped to achieve a proper mesio-distal spanning of the defect.

supporting layer was done on the undersurface of the mucosal one, by Vicryl suture (3/0). In addition, suspending the terminal sutures on a nearby tooth, supporting the weight of the flap, provides better healing.

Closure of the external wound in three layers is essential, with suction drainage for 2–3 days.

Early postoperative evaluation (first 2 weeks) included wound healing, hematoma, and infection.

Intermediate postoperative evaluation (2–4 weeks) included SRBG exposure, and infection.

Late postoperative evaluation (1–12 months) included aesthetic deformity, SRBG take, sinus formation, mandibular bony continuity defects, tumour recurrences, and scar appearance.

The Helsinki Declaration guidelines have been followed in this investigation and patients' consents were obtained.

3. Results

Patient age ranged between 3 and 63 years (mean = 34); of these 370 were male and 230 were female. The most common pathology encountered was ameloblastoma (n = 320) followed by odontogenic keratocyst (n = 130).

The defect length ranged from 6 to 18 cm with a mean length of about 8 cm. The indications of the use of the SBRG and the location of the defect to be reconstructed are presented in Table 1.

The duration of operation was three to four hours, with a mean of 3 h and 15 min.

The hospital stay, in the post-operative period, ranged from 3 to 12 days with a mean of 3.8 days. All patients who had difficulties in swallowing and speech initially, improved gradually over the first three weeks post operatively. The follow up period ranged from 6 months to 60 months with a mean period of 34.6 months.

None of the patients experienced a life-threatening complication (Table 1).

Partial loss of graft, up to 25%, due to moderate infection was reported. Total or near total loss of graft due to severe infection (7%) was corrected by reoperation six months later.

260 patients (43.3 %) showed excellent results regarding facial symmetry (FS) and posterior facial height (PFH), 300 patients (50 %) showed acceptable results, and the FS and PFH were unacceptable in 40 patients (6.6 %) after rib reconstruction. Of these, 4 patients had inadequate lower facial contour and 3 patients had loss of the mandibular angle. Furthermore, sharp alveolar ridge and shallow buccal sulcus was noted in 4 and 14 patients, respectively.

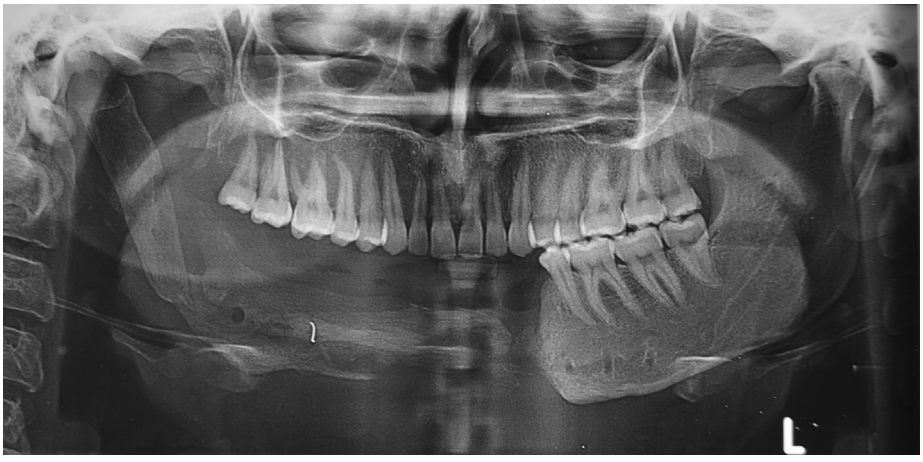

Fig. 5. Costochondral graft was used to replace the resected condyle.

Fig. 6. Genial muscles are suspended to the reconstruction plate by multiple sutures for airway patency.

Fig. 7. Total loss of rib graft after infection.

Reconstruction plate fracture occurred in eight patients in either double mini-reconstruction plates or single high-profile reconstruction plate six months postoperatively, which was mostly due to excessive muscle forces loading on the plate; reconstruction plate and screws were removed leaving the healed rib graft in place, and ipsilateral coronoidectomy was done to decrease the muscle pull action exerted by temporalis on the graft.

Dental rehabilitation was performed in all patients in the form of removable denture in 150 patients and osseo-integrated dental implants in 320 patients. The overall success rate of dental implants was 87%.

4. Discussion

When undertaking mandibular reconstruction, the restoration of bony continuity alone should not be considered the measure of success. The functions of chewing, swallowing, speech articulation and oral competence must also be addressed. The goal of mandibular reconstruction is to return the patient to their previous state of function. To achieve this goal, the reconstructive surgeon must attempt to restore bony continuity and facial contour, maintain tongue mobility, and attempt to restore sensation to the denervated areas (Gadre et al., 2011).

The reconstruction should provide the possibility for successful insertion of dental implants to allow for rehabilitation of occlusion and articulation (Banerjee and Westmore, 1995 and Balaji, 2009).

Unfortunately, none of the presently available techniques can meet all of these needs, and so the search for a better means of reconstruction should continue.

Variable methods are available for mandibular reconstruction including vascularized bone grafts (VBGs), non-vascularized bone grafts (NVBGs), reconstruction plates, and distraction osteogenesis. However, each technique has its advantages and disadvantages.

Reconstruction plates have high complication rates. The use of reconstruction plates only (as a space maintainer) has many drawbacks. The plates are not denture bearing, can fracture, the screws can loosen and more seriously can easily penetrate the oral mucosa (Boyd et al., 1995; Van Minnen et al., 2002).

Bone distraction for mandibular reconstruction is time consuming, annoying to the patient, and the curvature of the mandible makes it difficult to maintain the correct vector during the distraction process (Rubio-Bueno et al., 2005; Goh et al., 2008).

Mandibular reconstruction using VBF is considered by many surgeons as the state of the art and best option for reconstructing

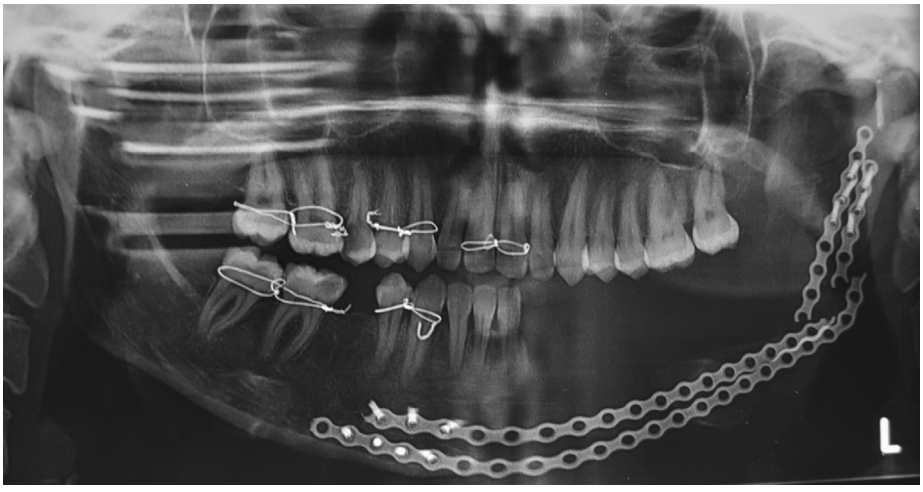

Fig. 8. Double mini reconstruction plates fracture.

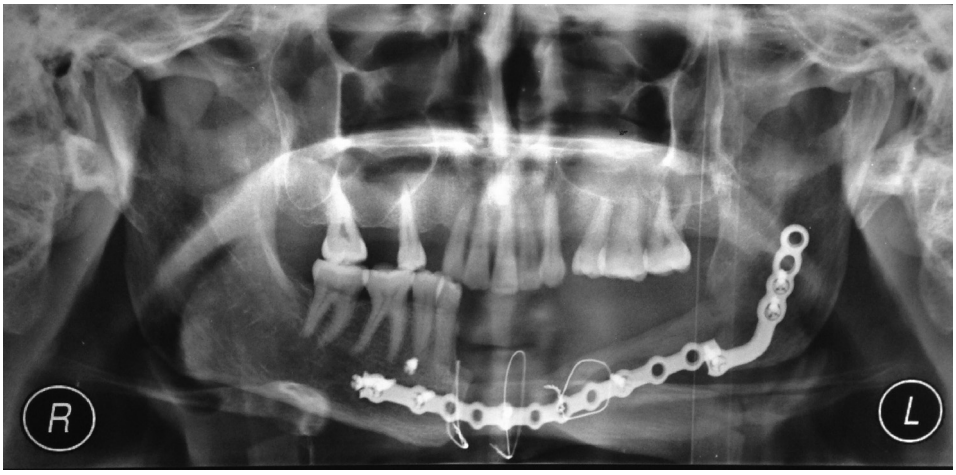

Fig. 9. High profile reconstruction plate fracture with nicely healed rib graft.

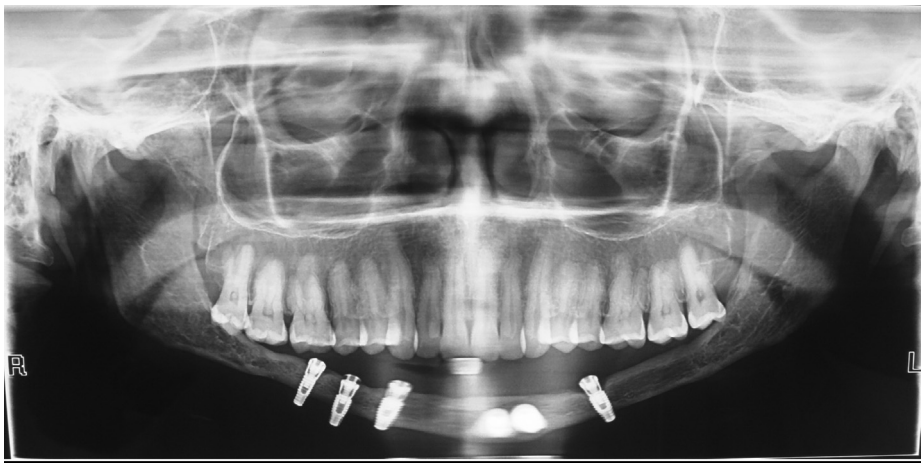

Fig. 10. Four osseointegrated implants in healed rib graft reconstructing the mandibular defect.

mandibular defects in terms of form, function and aesthetic appearance (Disa and Cordeiro, 2000; Chana et al., 2004; Mehta and Deschler, 2004).

VBGs can provide a large segment of bone as well as soft tissue when an osteocutaneous flap is harvested and it is the preferred option when reconstructing the anterior region of the mandible. On the other hand, VBFs are time-consuming, associated with donor-site morbidity, and place a heavy burden on hospital resources. VBFs sometimes show a volumetrical mismatch between transplanted bone and size of the remaining mandible (Gadre et al., 2011).

When soft tissue is adequate at the recipient site, NVGs are a good alternative as its harvesting is simple and can be easily structured with minimal donor site morbidity. Due to its rich blood supply, the head and neck region can provide rapid revascularization to the graft in addition to resistance against infection. Iliac crest is considered by many authors as the first choice of NVBGs when reconstructing a short segment (<5–6 cm) bone defect of the mandible without soft tissue defect (Gadre et al., 2011).

In developing and underdeveloped countries, many factors hinder the use of VBF. Among these factors are the poor lower socioeconomic strata patients, limited treatment financial resources and facilities, and lack of enough expertise in microvascular surgeons. Thus, when the soft tissues are in good condition and enough to provide a sound, leak-proof closure and postoperative radiotherapy is not planned, the use of nonvascularized bone grafts for reconstruction of mandibular continuity is still an accepted

Fig. 11. Complete mouth rehabilitation by an implant supported fixed prosthesis.

method of reconstruction in developing and underdeveloped countries (Gadre et al., 2011).

The transplanted cortico-cancellous block graft acts only as a supporting structure and their mineral matrix is resorbed gradually and replaced by newly formed bone arising from the process of osteoconduction and osteoinduction. This mechanism of creeping substitution relies heavily on the cellularity and vascularity of the recipient site and rigid fixation of the graft (Abbott et al., 1947; El-Skeikh et al., 1992; Marx, 1993).

In the current study, all of our patients had SBRG for primary reconstruction of large mandibular defects (>6 cm) and 160 of them had symphyseal involvement with an overall success rate of 93.4%. Our results are not in line with the literature recommendations and this may be due to the use of split bundle rib graft (SRBG), which provided a large area of exposed cancellous bone for its rapid revascularization and/or due to the expertise of our department in using the SRBG which goes back to the early 1980s (El-Skeikh et al., 1992).

The bundle should not be more than three half ribs in thickness, and ribs were arranged in different vertical planes for easy revascularization of the intermediate splits. A watertight closure of the intraoral wound was mandatory before rigid fixation of the graft by reconstruction plate.

We did not experience any complication at the donor site except in one patient who had a hypertrophic scar. The main donor site complication is pleural injury, which did not occur in this study because of our experience in rib graft harvesting. The most frequent complication encountered at the recipient site was infection, which was severe in 42 patients (7%) and was associated with intraoral wound dehiscence and total loss of graft. This was managed six months later after resolution of the infection by insertion of another rib graft in medically fit patients seeking optimal results. On the other hand, the partial loss of 25% of grafts was managed similarly by debridement and conservative wound care methods followed by reconstruction after 6 months with another rib graft.

It is likely that the infection was related to the intraoral contamination, the general condition of the patient, lengthy procedure and the presence of dead space. Therefore, we recommend a watertight closure of the intraoral wound before graft fixation and applying a suction drainage to reduce the dead space.

Early reports in the literature on mandibular reconstruction of irradiated patients with NVBGs are disappointing. Adamo and Szal (1979) reported a high (81%) incidence of complications in previously irradiated patients, of which 63% were major. However, later reports in the literature like that by Lawson et al. (1982) reported 90% success of delayed mandibular reconstruction after a full course of radiotherapy.

Van Gemert et al. (2009) mentioned that only 5 (19%) of the 27 irradiated patients had a complication. They explained the low incidence of complications in irradiated patients in their study by the fact that almost all irradiated patients had a delayed reconstruction through an extraoral approach. All irradiated patients in their series received HBO_2 therapy and intravenous antibiotic therapy continued 10 days postoperatively.

In accordance with the aforementioned results, we believe that for a successful take of NVBGs, the reconstructions should be secondary after a considerable gap after radiation, which might have allowed recipient site revascularization. The lower rate of complications in recent reports also may be attributed to the use of strong intravenous antibiotic and HBO_2 therapy. Although the use of HBO_2 therapy is disputed, it is the only known modality that can revert the delayed radiation changes in tissues (Peleg and Lopez, 2006).

In our study, all reconstructions were primary, thus patients with irradiated mandibles were excluded. We prefer to use VBG in these circumstances to give the patient the best treatment modality.

Gadre et al. (2011) stated that when severe soft tissue deficiency is present, the intraoral defect can be covered by local or regional flaps such as nasolabial (without cutaneous element), buccal fat pad, temporalis muscle, pectoralis major myocutaneous flaps, sternomastoid, or platsymal muscle.

In these circumstances, we believe like many other reports (Pogrel et al., 1997; Foster et al., 1999; Kademani and Keller, 2006) that the main advantage of NVBG, which is being simple and time saving, is lost, therefore we revert to VBF in cases of extensive soft tissue defects.

In our series, the NVBG was able to reconstruct these anatomic alterations resulting from resection of the central region of the mandible by suturing the muscles of the floor of the mouth and tongue to the reconstruction plate. This is similar to the work of Gadre et al. (2011) in which they fixed the soft tissue beneath to the graft or hardware with sutures. We agree with them that this suspension has many advantages. It reduces the dead space, hematoma formation, additional weight development beneath the reconstruction, pull and drag on the intraoral suture line, and therefore risk of dehiscence.

Van Gemert et al. (2009) stated that NVBG should be used only for lateral mandibular defects because in central defects the muscles of the floor of the mouth and tongue lose their insertion to the mandible with loss of support of the lower lip and the chin. They concluded that this might cause plate exposure and failure in anterior mandibular reconstruction. They also added more mucosal wound mobility in the anterior mandible as an additional reason for graft exposure and failure.

We overcome more mobile anterior mandibular mucosa movements by multiple layers of tension free watertight closure of the intraoral wound with suspending the terminal sutures on a nearby tooth after thorough irrigation with povidone-iodine and saline solution before graft placement. Our protocol of successful management of midline mandibular defects with NVBGs goes in line with Gadre et al. (2011), who had successful reconstruction of 27 of 29 defects (93.1%) that crossed the midline using NVBGs in their series.

The overall success rate of dental implants in this series was high (87%) due to enough buccolingual width obtained by multiple split ribs augmented together in the reconstruction. The main cause of failure was infection around the implants.

To the best of our knowledge, reviewing the literature does not reveal enough data on significant numbers to compare with ours.

5. Conclusions

This technique is simple, safe, and can be effectively used to reconstruct long-span mandibular defects with minimal complications in selected patients.

Splitting of ribs helps early revascularization, lesser extent of resorption, decreases the sequelae of infection, and restores both the width and length of the defect.

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This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2018.11.002.

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