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Reconstruction of isolated mandibular bone defects with non-vascularized corticocancellous bone autograft and graft viability☆

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ABSTRACT

Objective: The aim of this study is to discuss the use of non-vascularized bone grafts in mandibular reconstruction and their viability.
Methods: In this study, 11 patients with mandibular defect treated by surgery using non-vascularized bone grafts between 2011 and 2012 were reviewed. All patients underwent preoperative and postoperative 3-dimensional computerized tomography scan for surgical planning and evaluation of success after surgery. Grafts were used for defects caused by mandible tumors in 2 patients and firearm injuries in 9 patients. Reconstruction was achieved by using various non-vascularized bones, including iliac crest, fibula and scapula. To improve graft supply, periosteum of the grafts was spared and multiple bores were created on the graft during surgery by drilling. At the postoperative period, Dextran 70 and Bencyclane Hydrogen Fumarate was given in order to enhance micro-circulation. On the postoperative day 5, 15 and 30, Tc-99 m methylenediphosphonate scintigraph, blood-pool single photon emission computed tomography and it's bone phase were performed in order to assess viability of bone grafts greater than 3 cm.
Results: Mean age was 32. 27 ± 13.33 (min = 10–max = 56). Of the 11 patients, 10 (90. 9%) were men and 1 (9. 1%) was woman. Mandibular defects were at right corpus in 3 patients; at right ramus and angulus in 1 patient; at left corpus in 1 patient; at left ramus and angulus in 1 patient; at left ramus, angulus and corpus in 1 patient; left parasymphysis in 1 patient; at bilateral corpus in 1 patient; at symphysis in 1 patient and at whole segment from right corpus to left one in 1 patient. The following grafts were used: iliac crest grafts in 9 cases, scapula graft in 1 case and fibula graft in 1 case. The smallest graft used was 1 × 2 cm in size, while the greatest, single piece graft was 7 cm in size. The greatest multi-piece graft was a fibula graft of 14 cm in length. All grafts with a size of 3 and 7 cm had been supplied at the end of first month. No bone resorption or donor site morbidity was observed in any patient.
Conclusion: Non-vascular bone grafts can be successfully used in isolated bone defects of mandible in case of appropriate graft selection for fitting anatomical region. A single piece iliac crest grafts up to 7 cm can be revascularized in long-term.

1. Introduction

Bone grafts are the bone fragments which are removed from a part of skeletal system and used to heal and strengthen the diseased area. The materials used for this purpose may not only be taken from patient himself/herself but also they may also be cadaver-originated or synthetic. These grafts are used to bridge a gap developed in spine disorders such as infection, trauma, tumor, degeneration and deformity or to achieve fusion. Grafts taken from patients' skeletal system itself to achieve fusion are termed as autograft. Hip and extremities are the most frequently used sites as the source of autograft.

Reconstruction in the oral and mandibular region is a difficult task. Anatomical, functional and esthetic aspects have to be taken into account while performing reconstructive surgery [1]. While a lot of alloplastic materials are available for reconstruction of mandible defects, the role of free non-vascularized bone grafts remains to be important [2,3].

There are some points in mandibular reconstructions those have to be emphasized. This important points are the facial skin envelope, neuromuscular dynamic functions, the bony supportive framework and soft tissue volume [4]. In this context, it will fail to

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repair isolated bone defects by using plate alone without bone and soft tissue reconstruction in terms of esthetic and function.

Bone autografts removed from fibula, iliac crest and ribs are widely used at maxillary, mandibular and nasal regions with varying success rate. However, micro-vascular surgery using soft tissue and bone (composite graft) with vessel anastomosis may be a better method but it requires special skills and expensive equipment. While scapula and iliac crest grafts could be selected among alternative grafts, fibula grafts with many advantages seems to be choice of the graft in mandible reconstructions at the present [5]. In the literature, it was demonstrated that fibula has been successfully used as non-vascularized graft since it is a strong, long and tubular bone [2,6]. Moreover, it is also an option to use fibula non-vascularly in structures as mandible without load-bearing.

It has been reported that non-vascularized iliac bone grafts with fixation screws are successfully used in extremity reconstructions [7]. It has been reported that these grafts ware revascularized 2 weeks after cancellous bone operations and up to 8 weeks in cortical bones [8]. Bone scintigraphy is a practical, non-invasive and effective method in the assessment of viability. Single photon emission computed tomography (SPECT) scans have some advantages over planar imaging such as enabling 3 dimensional evaluations, allowing discrimination of superimposed activities and increasing image activity by increasing signal: background rate. Scintigraphic imaging was used in the assessment of graft viability in our patients underwent graft surgery.

In the present study, we aimed to discuss feasibility of non-vascular corticocancellous autogenic bone grafts, graft viability and surgical outcomes in mandibular reconstructions.

2. Materials and methods

Eleven patients underwent mandibular surgery at our clinic between October, 2011 and July, 2012, were retrospectively evaluated. Informed consent was obtained from all patients. Two patients were treated for mandible tumors. The remaining 9 patients were admitted because of firearm injury. Reconstruction was achieved in all patients by using various non-vascularized bones, including iliac crest, fibula and scapula.

All patients underwent surgery under general anesthesia. All patients received 7.5 cc/kg/day Dextran 70 infusion and 2 mg/kg/day Bencyclane Hydrogen Fumarate for 1 week after surgery in order to improve micro-circulation. For prophylaxis, adult patients received Cefazoline sodium (1 g, twice daily for 5 days), whereas a 10-years old patient received 0.5 g twice daily for 5 days. At the postoperative period, food ingestion was abolished for 7–30 (mean = 11.48 ± 7.23) days in cases underwent oral and gingival interventions during surgery. Nutrition was achieved through a nasogastric feeding tube during this period.

Surgery planning and surgical success was evaluated by pre- and postoperative 3-dimensional computerized tomography (3-D CT) scans in all patients.

Radiology, histology, bone scintigraphy, bone densitometry, laser Doppler flow measurements and biomechanical tests have been used in order to assess viability of bone grafts. In our cases, we performed scintigraphic bone studies on the day 5, 15 and 30 after surgery to assess bone viability in bone grafts greater than 3 cm in size. The most widely used evaluation is three phase bone scintigraphy with Tc-99 methylenediphosphonate (MDP) and blood pool and bone phase SPECT in the assessment of blood flow and viability of maxillofacial bone grafts. In the present study, dynamic perfusion and blood pool images from cranium were obtained to assess viability after intravenous injection of 740 MBq (20 mCi) Tc-99 m MDP. Subsequently, blood-pool SPECT scan was performed. After 4 h, delayed static and SPECT images of whole body was obtained. For the publication of this study, consent of all patients and approval of local Ethics Committee were obtained.

3. Results

Mean age of the patients was 32. 27 ± 13.33 (min = 10–max = 56); there was 10 men (90. 9%) and 1 woman (9. 1%). Mandibular defects were detected at right corpus in 3 patients; at right ramus and angulus in 1 patient; at left corpus in 1 patient; at left ramus and angulus in 1 patient; at left ramus, angulus and corpus in 1 patient; left parasymphysis in 1 patient; at bilateral corpus in 1 patient; at symphysis in 1 patient and at whole segment from right to left corpus in 1 patient (Table 1).

For reconstruction, iliac crest grafts were used in 9 cases (Fig. 1), whereas scapula graft in 1 case (Fig. 2) and fibula graft in 1 case. The smallest graft used was 1 × 2 cm in size, while the greatest single piece graft was 7 cm in size. The greatest multi-piece graft was a fibula graft of 14 cm in length (Fig. 3). All grafts with a size of 3 and 7 cm had been supplied at the end of first month. Scintigraphy was not performed in grafts smaller than 3 cm in size, given the observation that even grafts larger than 3 cm in size had been supplied. No bone resorption or donor site morbidity was observed in any patient.

Gargle with polyvidone iodine and to take care for oral hygiene were recommended. No donor site morbidity was observed in any of the patients. An oral-cutaneous fistula was developed in one patient; however, fistula was closed after secondary suture and stopping oral intake. No infection related to bone was detected, while an abscess was found at submandibular region in 1 patient regardless of graft; however, it was recovered by drainage and antibiotic therapy. At the postoperative period, the most common problems were pain and nutritional difficulties. There was no significant bleeding requiring perioperative blood replacement.

4. Discussion

Microvascular osteocutaeneous free flaps provide a powerful tool in the reconstruction of composite defects in mandible. However, this flap technique includes some complications in both donor and recipient sites [9,10]. Sensorial changes, femoral neuropathy and incisional hernia can be observed in iliac crest free vascularized flaps [11], while edema, cold intolerance, sensorial loss and weakness can be observed at the distal to donor site in free fibular flaps [9]. The peroneal artery and vein are divided and ligated in the free fibular flaps. The weakness at lower extremity can occur as a result of failure in arterial blood flow, whereas edema can resulted from failure of venous drainage.

Another problem is the need for external incision at the recipient site to perform micro-anastomosis. These incisions can result in scar tissue as well as facial paralysis risk during surgery [12]. However, a non-vascular graft can be used via transoral route without an external incision if the bullet did not cause a defect other than a small bullet hole.

Non-vascular grafts may be preferred in patients who have circulatory problems or predisposition such as those with varicose veins or in those who refuse external incision at mandibular region. In our study, there was a case, in which a mandibular graft up to 7 cm in size was supplied and we recommend reconstruction with standard vascularized free flaps above this size.

Bone tissue is supplied by 3 different sources including blood flow of periosteum, endosteum and surrounding soft tissue [8]. In the present study, as non-vascular grafting was used, it was attempted to provide blood supply to grafts from all 3 ways by sparing periosteum. Periosteum was spared in all non-vascular grafts other than perpendicular plate and they were sutured to adjacent soft tissue.

Table 1
Distribution of cases reconstructed by non-vascular bone grafts according to defect site, graft used, graft size, type of incision and plates used for fixation.

Age	Sex	Diagnosis	Localization	Diameter of defect	Surgery performed	Graft used	Fixation tools	Incision
51	F	Mandibular Follicular Ameloblastoma	Defect at right mandibular corpus	Segmental defect of 7 cm in length	Segmental resection and grafting in the same session	Non-vascularized full thickness iliac graft	Fixation with 1 angular compression plate and 7 screws	Approach by external incision
10	M	Mandibular giant cell granuloma	A mass along all segment extending from symphisis to left mental foramen and involving external cortex and medulla	A defect of $0.8 \times 2.5 \times 3$ cm in volume involving external cortex and medulla	Mass was excised internal cortex was spared and grafting was performed in the same session	Iliac graft, external cortex and medulla	External and internal cortex fixation with only two 11-mm mini-screw	Approach by gingivobuccal incision
33	M	Firearm injury	Defect at left mandibular corpus	Segmental defect of 3.5 cm in length	Bone fragments were removed and grafting was performed in the same session	Non-vascularized full thickness iliac graft	Fixation with 1 angular compression plate and 6 screws	Approach by external from bullet entry + gingivobuccal
42	M	Firearm injury	Defect at left mandibular ramus, angulus and corpus; fractures at left zygomatic bone and maxilla; disruption at cervicobuccal branch of left facial nerve	Segmental defect of 10 cm in length	Mandibular reconstruction by left scapula graft; in the same session, static facial suspension with temporal fascia for left facial paralysis	Non-vascularized scapula bone graft	1 compression plate, 6 screws, 1 mini-plate and 4 mini screw for mandible; 2 mini-plate and 10 mini-screw for maxilla and zygomatic bone	Approach by external from bullet entry + gingivobuccal
22	M	Firearm injury	Defect at right mandibular ramus and angulus; fracture line at symphysis	Segmental defect of 5 cm in length in angular shape	Bone fragments were removed and grafting was performed in the same session	Non-vascularized full thickness iliac graft was shaped in the form of angulus	1 angular compression plate and 7 screws	Bullet entry was extended by preserving facial nerve. Gingivobuccal incision was done for symphysis fragment
56	M	Firearm injury	Defect at left mandibular ramus and angulus; fracture line at symphysis	Segmental defect of 4.5 cm in length in angular shape	Bone fragments were removed and grafting was performed in the same session	Non-vascularized full thickness iliac graft was shaped in the form of angulus	1 angular compression plate and 8 screws	Bullet entry was extended by preserving facial nerve and approach by external incision
24	M	Firearm injury	Bone defect at bilateral mandibular corpus	Bone defects; 2 cm in size at right corpus and 1.5 cm in size at left corpus	Mini bone fragments were removed and grafting was performed in the same session	Graft removed from right iliac crest was used in 2 pieces	2 linear compression plate and 12 screw	Approach by gingivobuccal incision
34	M	Firearm injury	Bone defect at mandibular symphisis	A marginal bone defect with a base 2 cm in size and inverse V in shape	Soft tissue and bone defect were reconstructed in the same session	Non-vascularized full thickness iliac graft	Fixation with 4 mini-plates and 16 mini-screws	Approach from external skin defect extending from lower lip to mentum
32	M	Firearm injury	Bone defect at mandibular symphysis, bilateral parasymphysis and partially bilateral corpus	Segmental bone defect 14 cm in size that fits to mandibular arc	Mandible was created by structuring fibula graft in 3 pieces via cutting; several bores were created to improve graft supply	Non-vascularized bone graft of right fibula	1 linear compression plate and 10 screws for mandible; 1 orbital, 1 simple, 1 T-type; in total 3 mini-plates and 15 mini-screws	Approach from external skin defect extending from lower lip to mentum
27	M	Firearm injury	Bone defect at right mandibular corpus as mini-fragments; a displaced, comminuted fracture at symphysis and left corpus	Segmental bone defect 3.5 cm in length at right mandibular corpus	Mini bone fragments were removed, grafting was performed in the same session at right and left side was fixed by plates	Non-vascularized iliac graft	1 compression plate, 6 screws; 2 mini-plates and 12 mini-screws	Surgery was performed through gingivobuccal line by transoral approach, graft was screwed through bullet entry
24	M	Firearm injury	Defect at right mandibular corpus	Segmental defect of 4 cm in length	Mini bone fragments were removed and grafting was performed in the same session	Non-vascularized full thickness iliac graft	Fixation with 1 angular compression plate and 7 screws	Approach by external from bullet entry + gingivobuccal

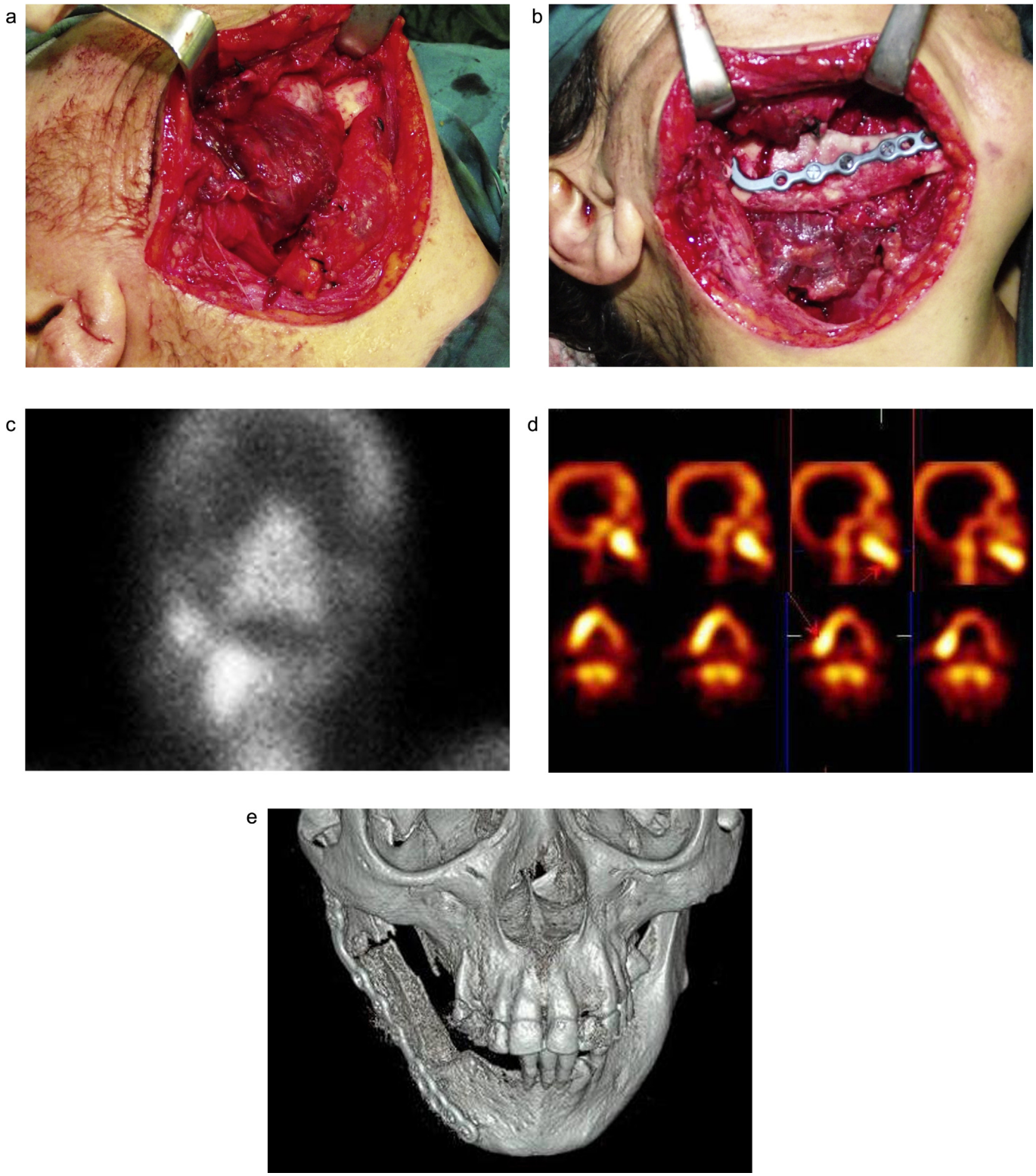

Fig. 1. Ameloblastoma was resected with adequate surgical margins (a). Non-vascular iliac graft was removed with adequate periosteum over it in order to facilitate graft supply (b). On scintigraphy, it was seen that graft that was not supplied on day 5 (c) was supplied on day 30 (arrow) (d). Also, it was seen that no graft resorption at the end of month 6 on 3-dimensional CT (e). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Santorine et al. performed reconstruction at the femur of a dog after 5 cm segmental resection by using alloplastic graft. Even in that alloplastic grafting study, success in terms of biocompatibility, angiogenesis and osteogenesis was demonstrated [13]. Compliance is higher in autogenic bone grafts compared to alloplastic grafts, while it is less likely to have contagious disease.

In the facial reconstructions, best outcomes are achieved in cases with isolated bone defect, which had no soft tissue defect [14]. When compared to reconstructions using bone graft, contour of mandible are sharper in reconstructions performed by using compression plates alone. Also, likelihood of protrusion is higher with plates. There are different opinions regarding the

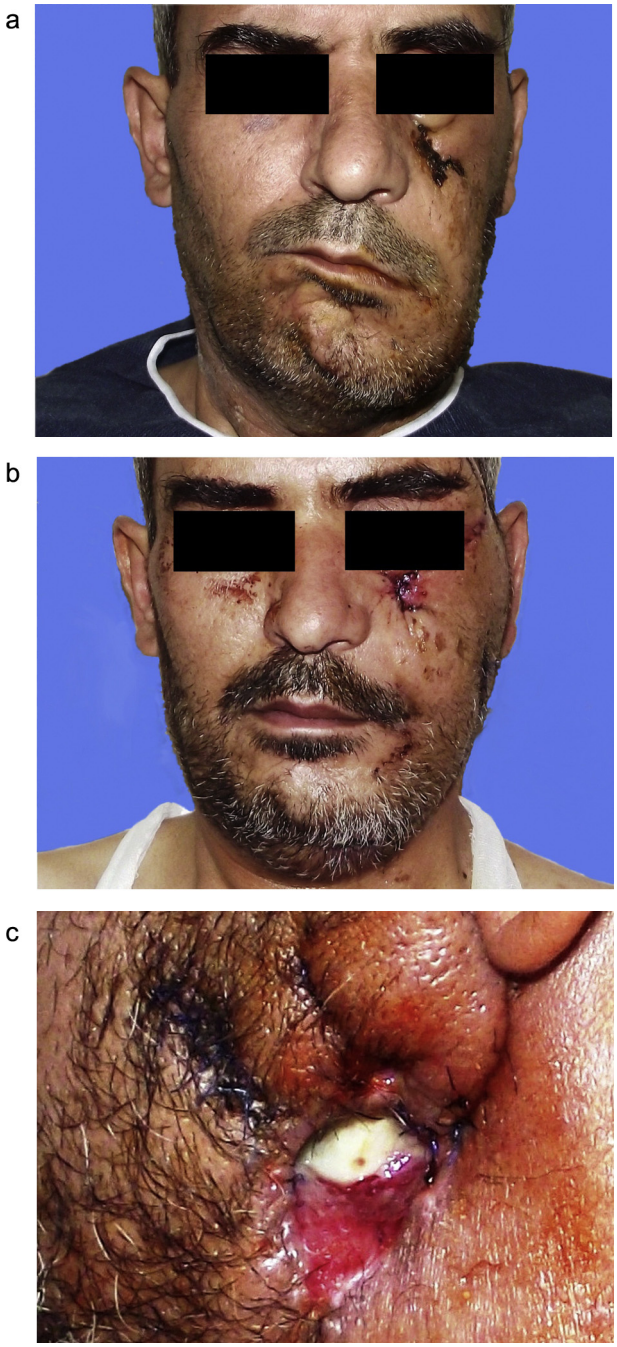

Fig. 2. Bone defect involving ramus, angulus and partially corpus of mandible was reconstructed by non-vascular scapula graft. In the same session, static facial suspension was performed by using temporal fascia for facial paralysis (a). Face appearance after suspension (b). Good blood supply and nutrition at head–neck region resulted in wrapping of graft by surrounding tissue in short term (c).

choice of bone graft of either non-vascular grafts or grafts with free vascular anastomosis for cases with segmental bone defect [4,15].

In the cases where soft tissue defect grafting is required, free composite grafts with vascular anastomosis should be firstly preferred. However, non-vascular grafts is another surgical alternative, as they can be easily structured; one can work on these grafts for long time in vitro; and lower morbidity when compared to free flaps. The stability of bone grafts against ischemia and resistance to resorption for long years, even in the case of having no circulation, can make non-vascular grafting attractive. Convenient in structuring these grafts by cutting, ability to obtain pieces with various volume, and size and to use in multiple fragments as needed, play major role in this attractiveness. The disadvantages of these grafts are difficulties in supply or rapid resorption. However, resorption rate is not as high as estimated in bones with strong cortex [16]. We found that graft resorption did not occurred after six months on 3-dimensional CT scan in the case, in which non-vascular graft of 7 cm in size removed from iliac crest was used in mandibular reconstruction after ameloblastoma surgery. On the Tc-99 m MDP scintigraphy, increased activity was seen at graft-mandible union site along with decreased activity within graft at early period. Again, in the same case, revascularization was seen over whole graft in the evaluation on day 30 after surgery. We assessed all patients reconstructed due to trauma by using bone grafts by scintigraphy after we demonstrated that a non-vascular segmental graft of 7 cm in size was supplied at the end of first month in this first case. We used non-vascular bone grafts in isolated bone defects, since patients in the present study were at younger ages and had no systemic diseases; and we detected that these grafts were supplied over time by scintigraphy. Some important advantages of non-vascular grafting include minimal donor site morbidity and bleeding. We did not make blood transfusion and did not experienced complication related to donor site.

Xiang et al. emphasized importance of vascular bundle implantation in order to improve angiogenesis in autogenous, non-vascular bone grafting [17]. In this method, maxillary artery was transposed from cavity of bone marrow as a bundle. In that study, they showed that graft was supplied at week 6. In fact, sufficient blood supply at head-neck region can provide supply to graft as well as protection against infection. In the case of defect at a large segment in mandible, fibula grafts are more useful in the reconstruction as they are appropriate in terms of length, despite being thinner [18]. We used fibula graft in a case with a segmental defect of 14 cm in length. We cut fibula at 2 points in order to form bends as in mandible. In fact, we had been used 3 non-vascular graft of 5 cm in size by this cut. This allowed better blood supply than a single, long graft. Moreover, we created several bores on the graft by drilling. We increased contact surface between bone and surrounding tissue and even bone marrow. Even though non-vascular fibula grafts with multi-bores drilling is not as much effective as vascular bundle implantation, we would like to recommend this method.

Free iliac bone graft provides reasonable bulk of bone of high quality, large amounts of bone marrow and resemblance with the curved lateral surface of the mandible [19]. Iliac crest can be first choice in isolated, short segment bone defects of mandible without soft tissue defect, which are resulted from trauma or tumor resection. Fibula may be the first choice in long segment defects, as iliac crest may be insufficient [16].

In accordance with mandibular anatomy, corpus and symphysis are tubuler, whereas angulus, ramus and condylar regions are flat. Given this, scapula grafts are more compatible to the defects at mandibular ramus and angulus than iliac bone, as they are flat. However, fibula or iliac crest may be used in other defects. We also used scapula graft in a case with a defect at ramus and angulus.

Partial bone graft from iliac crest may provide esthetic solutions in the marginal mandibular defects or monolayer defects of external cortex. Marginal defects cause problems during dental process and prosthesis applications, while defective external cortex mainly causes esthetic problems. We performed reconstruction by using split-thickness iliac graft and screws but not plate in a child with giant cell granuloma at mandibular parasymphysis, since preoperative esthetic appearance was found to be unsightly. External and alveolar appearance was quite satisfactory.

Fig. 3. A wide segmental bone defect at mandible was seen in association with partial soft tissue defect (a). Three-dimensional CT was used to determine size of defect and to plan reconstruction (b). Reconstruction was performed by using non-vascular fibula bone graft (c) and a satisfactory result was achieved in this case (d).

In the mandibular reconstructions, one should take esthetic appearance into consideration as well as mastication functions. In the present study, mastication muscles were intact in all patients as isolated bone defects were reconstructed. Available mastication muscles were sutured as they adhere to graft implanted. This point is important particularly in the reconstructions of condylar, ramus and angular regions. However, graft nature, as being either non-vascular or micro-vascular free flap, is not associated to an advantage or disadvantage in terms of preserving mastication function alone.

We observed no difference in terms of recovery time, postoperative complications and surgical outcomes between patients underwent reconstruction due to tumor or gunshot injury. This may be resulted from the benign nature of the tumors reconstructed. Similar results achieved in reconstructions performed due to tumors or gunshot injuries can be explained by lack of tumor invasion to surrounding soft tissues or having no previous radiotherapy.

5. Conclusion

Non-vascular bone grafts can be successfully used in isolated bone defects of mandibular region in case of appropriate graft selection for fitting anatomical region. On our scintigraphy studies, it was found that single piece iliac crest grafts up to 7 cm was supplied at the end of first month. Fibula grafts can resist resorption due to robust cortex. These grafts can be applied in several pieces as needed. More esthetic and functional outcomes are achieved by more elegant grafts such as rib and perpendicular plate grafts at mid-facial and periorbital regions.

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Conflicts of interest

We have no conflicts of interest to declare.

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