The Lateral Border of Scapula for Alveolar Ridge Reconstruction: A Prospective Clinical Study

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Purpose: The purpose of this prospective clinical study was to evaluate the efficiency of alveolar ridge reconstruction with the lateral border of scapula (LBS) prior to implant placement and to assess onlay graft retention and bone resorption during a short term of function. ***Materials and Methods:*** A total of 25 partially or fully edentulous patients with severe alveolar bone atrophy received ridge reconstruction with grafts harvested from the LBS. Histologic analysis of bone grafts was performed. Six months after augmentation, patients underwent CBCT and received dental implants. After another 3 months, healing abutments and implant-supported dentures were placed. Patients were followed for an average of 24 months. ***Results:*** Thirteen patients received primary bone grafting from LBS. Twelve patients experienced unsuccessful ridge reconstruction with other grafts before and were secondarily augmented with LBS. The average dimensions of LBS grafts were 6.3 × 2.3 × 1.2 cm. Histologic analysis confirmed the cortical nature of the graft. No donor-site complications occurred, and arm movements were restored within 2 weeks. Following augmentation, two patients had sutures disrupted that healed uneventfully after revision. The average resorption of LBS grafts after 6 months was 12.2% ± 3.0%. At the time of implant placement, the dimension of the ridge was 12.3 ± 2.0 mm and 6.9 ± 1.6 mm in height and width, respectively. The survival rate of the 174 implants placed was 98.3%. ***Conclusion:*** LBS can be used as an alternative extraoral grafting site for extensive ridge reconstruction prior to implant placement. *Int J Oral Maxillofac Implants 2020;35:1218–1228. doi: 10.11607/jomi.8331*

Keywords: autologous bone grafts, lateral border of scapula, ridge reconstruction, severe bone atrophy

Alveolar resorption of edentulous ridges can increase the maxillomandibular distance, making rehabilitation difficult. For implant placement in a prosthetically correct position, sufficient alveolar width and height are needed. Autogenous grafts alone or in combination with biomaterial are used for rehabilitation of atrophic ridges.[1] It requires vertical and horizontal onlay bone grafting,[2,3] not only to restore the alveolar bone, but also to lower the interarch distance to improve functional and esthetic results. In such cases, simultaneous onlay grafting and sinus elevation is performed.[4] While intraoral bone can serve smaller augmentations,[5,6] severe atrophy requires extraoral donor sites.[7] Accordingly, reconstructive alveolar surgery indicates the demand for harvesting bone blocks.

The iliac crest is the most frequently used harvesting site, providing abundant cancellous and cortical bone.[8] However, the iliac crest shows a high resorption rate,[9] donor site morbidity, painful walking, and sometimes limping.[10–12] Skin sensory disturbance and abdominal hernia formation were also reported.[11] The calvarium is another extraoral harvesting area, providing large amounts of cortical bone, characterized by high mechanical resistance and lower resorption rates.[13] Possible complications associated with this grafting site are, however, limited thickness and fragility of the bone blocks, neurologic sequelae, and dura damage.[14,15] Further limitations can potentially result in the need for additional surgeries and scars that cause difficulties during daily hair combing and alopecia.[16] There is thus a demand for alternative areas for bone block harvesting.

The lateral border of scapula (LBS) was first introduced as a vascularized graft in 1978 by Saijo.[17] The first scapular flap reconstruction was performed by Gilbert and Teot in 1979[18] and applied in head and neck surgery in 1986.[19] Today, the scapula is frequently used for maxillofacial reconstructions. Scapular bone harvesting

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is characterized by versatility, reliability, low donor site morbidity, and good functional outcomes.[20] LBS provides large amounts of cortical and cancellous bone, although the reports on its use in implant dentistry are rare.[21] The present authors propose that for simultaneous onlay grafting and sinus elevation, as well as in cases of horizontal and vertical augmentation, LBS grafting can be used as an alternative to iliac crest bone, especially in patients whose jobs require moving around or standing still for prolonged periods of time.

The aim of this prospective study was to evaluate the performance of ridge reconstruction with the LBS grafts according to clinical, radiologic, and histologic methods. Consolidation of the graft, its resorption, and implant survival rates were also assessed during a short-term follow-up.

MATERIALS AND METHODS

Histomorphometric Analysis of LBS

Biopsy specimens from LBS were obtained during implant placement with a trephine bur with 3.0-mm outer diameter and 2.5-mm inner diameter (Kohler, Kohler Medizintechnik). The bone blocks from LBS that remained after trimming were fixed in 10% neutral formalin solution for 24 hours, decalcified in 25% sodium ethylenediaminetetraacetic acid salt, dehydrated, and embedded in paraffin. Serial sections of 5 µm thickness were cut with a microtome (Leica, Leica Microsystem) and stained with hematoxylin and eosin (Biovitrum). Samples were examined under a light microscope (Nikon 50i, Nikon). Bone histomorphometry was performed by the hardware-software complex VideoTesT Morphology (VideoTesT), and the trabecular bone volume per tissue volume was determined.

Clinical Part and Patients

This prospective clinical trial was approved by the ethics committee of the Pavlov University, Saint Petersburg, Russian Federation (#11/2015). Each patient was familiarized with the proposed surgery protocol and was given at least a full day to make the decision before signing the informed consent form. A total of 25 patients with vertical and/or horizontal alveolar ridge atrophy in the anterior and/or posterior region of the maxilla and/or mandible, Class V and VI,[22] were enrolled in this study. All patients were treated at the Department of Oral and Maxillofacial Surgery (Pavlov University, Saint Petersburg, Russian Federation). The inclusion criteria were ages 18 to 70 years, partial or total edentulism, and insufficient bone ridge width and/or height for conventional implant placement. The exclusion criteria were general contraindications for dental and/or surgical treatments, previous immunosuppressant, bisphosphonate or high-dose corticosteroid therapy, pregnant or lactating women, smoking more than 10 cigarettes per day, history of scapular and clavicular fractures, axillary lymph node dissection, and axillary joint diseases.

Surgical Procedure: Harvesting the LBS Graft

All patients underwent treatment by the same protocol (Fig 1). All procedures were performed by the same group of oral and maxillofacial surgeons (S.S., N.K.), and all dental prostheses were made by the same restorative practitioner (O.P.). A two-team approach under general anesthesia was used for reconstruction. The patient was in the contralateral position during the grafting stage with the hand of the harvesting site laid down and along the chest. The patient's head was turned sideways; therefore, augmentation in the oral cavity was started in a nontraditional position. After surgical area sterilization, a preoperative sketch was done (Fig 1a); scapula angle, spine, and lateral borders were palpated and marked between posterior axial and scapular lines. Arteria circumflexae scapula pulsation was detected in foramen trilaterum (Fig 1b), a 2-cm mark from the outermost pointing of the cut was drawn, and the incision area was determined. The skin and subcutaneous cut in the projection of LBS and electrocautery was made, and the superficial fascia incision was performed (Fig 1c). The latissimus dorsi muscle was visualized and retraced downward and anteriorly (Fig 1d). An important aspect is to avoid latissimus dorsi and teres major muscle separation to prevent any potential damage to the artery and the thoracodorsal nerve. Fascial space between the teres major and minor muscles was visualized and was gone through until LBS (Fig 1e); then, a periosteal incision was performed along with required area separation (Fig 1f). In accordance with the graft dimensions, two vertical reciprocating saw cuts were made, and distal points of the cuts were joined by a horizontal cut parallel to LBS. Harvested bone block (Fig 1g) was handed over to the second group of surgeons. Bone edges and sharps were smoothed (Fig 1h). After the final electrocautery, a vacuum tube was introduced, and layered closure was performed. Periosteum with teres minor muscles from one side of the postoperative wound were sutured with teres major and periosteum from the other side; then, latissimus dorsi muscles with superficial fascia were fixed with the upper part of teres major and minor muscles with superficial fascia by single resorbable sutures with 1.0-cm intervals (Monosyn 2/0, B-Braun). Subcutaneous areas were sutured by single resorbable sutures with 0.5- to 0.8-cm intervals (Monosyn 3/0, B-Braun), and skin by subcuticular or single nonresorbable sutures (Prolene 3/0, Ethicon; Fig 1i). Dressing applications were performed and the patient turned on the back.

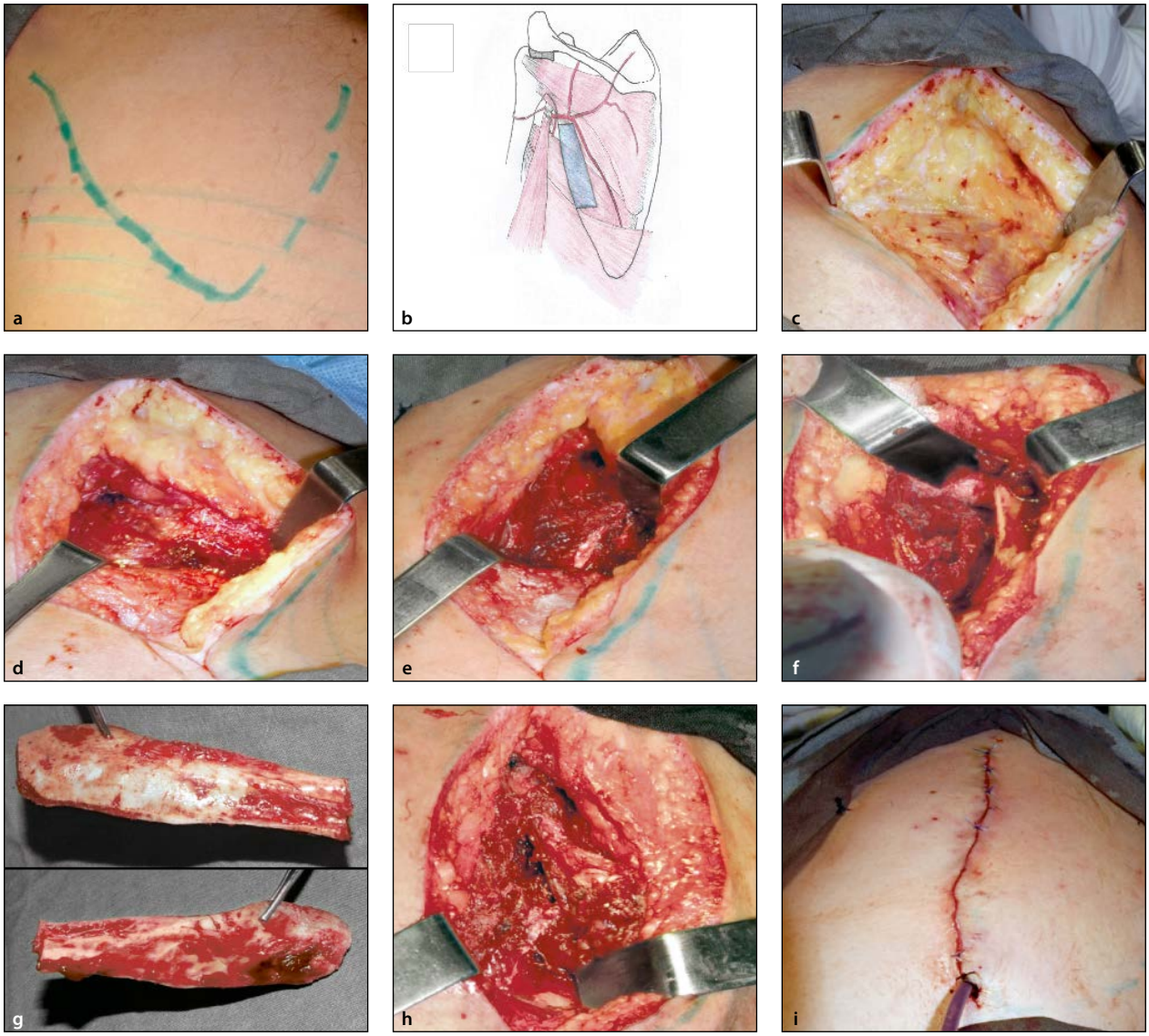

Fig 1 Surgical approach to LBS represented with one case. *(a)* Preoperative donor site view. *(b)* Operation sketch. *(c)* Skin and subcutaneous cut. *(d)* Retraced latissimus dorsi muscle. *(e)* Fascial space between teres major and minor muscles. *(f)* LBS periosteal incision. *(g)* Bone block (anterior and posterior surface). *(h)* Wound after graft harvesting. *(i)* Sutured wound.

Surgical Procedure: Augmentation with the LBS Graft

The second group of surgeons made a full-thickness midcrestal incision on the edentulous ridge. A bilateral mucoperiosteal flap was raised, and atrophic alveolar bone was visualized. In accordance with the localization and characteristics of the alveolar defect, blocks were placed as follows: *(1)* in horizontal atrophy, only buccally; *(2)* in vertical bone defect, buccally and vertically; *(3)* in combined horizontal and vertical, buccally and vertically, sometimes orally. In the posterior maxilla, in vertical defects, sinus floor elevation was performed; in horizontal and vertical defects, sinus elevation and onlay grafting were performed buccally and vertically. Harvested graft was divided into bone blocks with required size, structure, and form and into bone chips. Blocks were properly adapted to the atrophic ridge and tightly fixed with titanium miniplates, miniscrews, or microscrews (Conmet); then, newly formed bone width and height were measured. All remaining gaps between recipient sites and blocks were filled with bone chips. Periosteal releasing incisions were performed to prevent soft tissue tension and wound closure using both interrupted and vertical mattress sutures (Prolene 4/0, Ethicon).

Postoperative Follow-up Procedure

All patients were prescribed with preoperative and postoperative antibiotics (2 × Amoxiclav [amoxicillin + clavulanic acid], 1,000.0 mg, intravenously for 7 days;

3 × metronidazole, 500.0 mg intravenously for 3 days), probiotic (3 × Linex, 280.0 mg for 14 days) and antihistamine drug (1× Suprastin, 20.0 mg for 3 days), and analgesics (Ketorolac 30 mg), if necessary. From the second day postoperative, Metrogyl Dental Gel (metronidazole + chlorhexidine) was applied on the sutures line 4 times a day. When sinus elevation was done, patients were instructed to sneeze and to cough with an open mouth, not to blow their nose for 14 days postoperatively, to avoid flying on a plane for 1 month after reconstruction, and to use nasal decongestants (Polydexa, Sophartex) if feeling of fullness occurred. The vacuum tube was removed 3 days postoperatively. Suture removal was performed from the donor area 10 days after surgery and from recipient sites at 14 days. Physical examination of the donor area was performed every day for the first 5 days, then at 10 and 14 days postoperatively, and the following variables were analyzed: tenderness, arm movement range, and morbidity. Superficial pain was tested by dull and sharp instruments while the patients were blindfolded.

Implant Therapy

Six months after reconstruction, all patients had CBCT and received dental implants (Xive, Dentsply Sirona). A midcrestal incision was made under local anesthesia, and the mucoperiosteal flap was raised. All blocks were checked for the Barone success criteria of bone grafting,[23] and titanium miniplates, miniscrews, and microscrews were removed. Implants were inserted according to the standard protocol; the neck was on the level of the alveolar ridge, followed by wound closure. The sutures were removed 7 days postoperatively. Three months later, healing abutments were placed, and soft tissue augmentation was performed in cases of reduced or absent keratinized mucosa. Provisional implant-supported dentures were made to achieve proper soft tissue conditions; all patients then received definitive partial and fixed implant-supported prostheses.

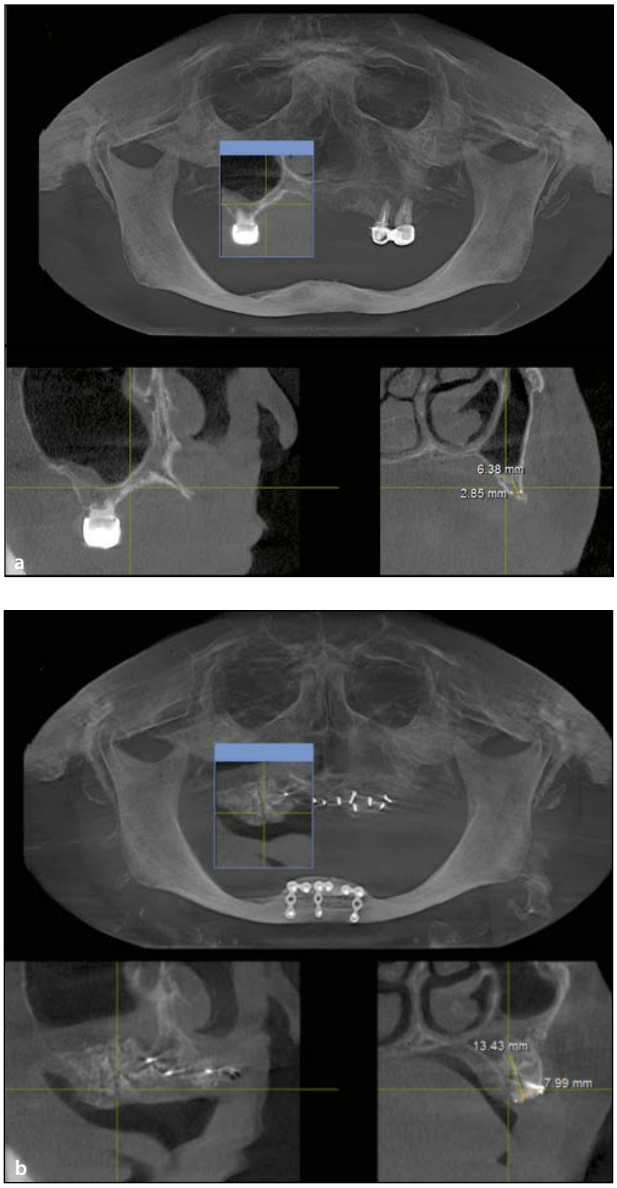

Fig 2 CBCT scans. *(a)* Baseline. *(b)* 6 months after reconstruction.

CBCT Analysis

According to the treatment protocol, 3D computed tomography was performed at the baseline (Fig 2a) and before implant placement (Fig 2b). The following parameters were calculated: baseline alveolar ridge height (BHb) and width (BWb) and alveolar bone height and width after augmentation (BHa, BWa). Newly formed bone was calculated for vertical dimension as (BHa-BHb) and for horizontal dimension as (BWa-BWb). All measurements were made by the same calibrated investigator (S.S.) and performed at the position of two, four, and six teeth in fully edentulous patients and in partially edentulous patients according to defect localization. Immediate postgrafting bone width and height (BHi, BWi) were measured intraoperatively with the same criteria to prevent patient x-ray overdose. Bone gain during reconstruction was calculated for alveolar height as (BHi-BHb) and for alveolar width as (BWi-BWb). Graft resorption 6 months after reconstruction was analyzed in counts for vertical dimension as (BHi-BHa), for horizontal dimension as (BWi-BWa), in percentage for bone height as (100 – BHa*100/BHi), and for bone width as (100 – BWa*100/BWi). The primary endpoint was to obtain sufficient ridge width and height for implant placement in the prosthetically correct position 6 months after reconstruction, without the need for secondary grafting.

Follow-up Procedure

Patients were followed clinically after prosthetic loading at 6, 12, 18, and 24 months, then annually. From the donor area, the following variables were examined: scar length, contour deficits, tenderness, and arm movements. From the recipient site, implant survival rates and related complications were evaluated by the following parameters: absence of persistent pain, absence of mobility, absence of dysesthesia, and absence of peri-implant infection. The following parameters were analyzed at six aspects around each implant to check for the signs of peri-implant infection: suppuration and bleeding on probing (evaluated within 60 seconds). Radiologic analysis was performed in cases of positive bleeding on probing to diagnose peri-implant mucositis and peri-implantitis.[24] Dental implants were considered a failure if the following features were detected: fractures, chronic pain, and peri-implant infection not responding to medical and surgical treatment. Therefore, the secondary endpoint was to evaluate implant success rates in LBS reconstructed alveolar bone at least 18 months after prosthetic loading.

Statistical Analysis

All statistical analysis was performed using a software program, Statistica 10.0 (TIBCO). Counts and percentages were used to describe categorically scaled variables. Mean, median, standard deviation, range, and first and third quartile were calculated for continuously scaled variables. The radiologic data were analyzed with the Wilcoxon signed rank test and the Mann-Whitney test. Statistical significance was considered for $P < .05$.

RESULTS

Clinical Results and Histologic Characterization of LBS Grafts

From September 2015 until September 2017, 25 partially or fully edentulous patients (mean age: 47.5 ± 10.2 years; 5 men, 20 women) underwent ridge reconstruction with free, nonvascularized LBS bone graft prior to the implant placement (Fig 3). A detailed description of the reconstructive operation is reported in Table 1, about grafting stage, and LBS bone block is displayed in Table 2. Histology revealed an average trabecula area of 67.5% ± 10.19% (data not shown), with vascularization and osteogenic cells representing mature bone (Fig 4).

Bone Grafting

All patients were treated for bone atrophy: 13 patients received primary bone grafting, and 12 experienced unsuccessful ridge reconstruction before. Nine patients had surgery on the maxilla, 6 on the mandible, and 10 on both arches. Seventeen patients had partial edentulism: 6 bounded dental defects; 11 patients with free defects (3 one side, 8 bilateral); and 8 fully edentulous (5 maxilla, 3 maxilla and mandible). The mean dental defect length was 12.9 ± 7.9 teeth. A total of 17 patients had simultaneous sinus elevation and onlay bone grafting (Figs 3d and 3e); in 8 cases, only horizontal grafts were used. Seventeen patients received simultaneous vertical and horizontal augmentation (Fig 3f). The median number of bone blocks was 4 (Q1: 2.3; Q3: 5.0). The median time of surgery was 220 minutes (Q1: 190; Q3: 280). The median LBS grafting time was 60 minutes (Q1: 55; Q3: 75). Ten patients had right side scapula harvesting, and 15 left side (Figs 1a and 3a). Grafts consisted of only lateral border of scapula in 15 cases (Fig 1g), lateral border and flat part of scapula in 7 patients (Fig 3b), and lateral border and scapula angle in 3 patients. Average graft dimensions were as follows: median length of 7 cm (Q1: 4.0; Q3: 7.5), median height of 2 cm (Q1: 2.0; Q3: 2.5), median width of 1 cm (Q1: 1.0; Q3: 1.5), median cortical layer thickness of 2.5 mm (Q1: 2.0; Q3: 3.0), and median cancellous layer thickness of 5.0 mm (Q1: 5.0; Q3: 9.0).

Complication Rate and Dropout

No donor site complications occurred intraoperatively (eg, arteria circumflexae scapula and branch hemorrhage, nerve thoracodorsalis damage, fractures, etc) and postoperatively (eg, infection, hematoma, etc). Five days postoperative, all patients had painless shoulder abduction for at least 110 degrees and were able to hold a 250-g bottle with a stretched-out arm for at least 10 seconds without experiencing discomfort. No skin sensory disturbances or complaints about pain during arm movements were detected, and the hand function was restored in 24 cases within 14 days, except for one patient for whom the hand function was restored in 21 days; however, this case was considered as a donor site complication. At the recipient cite, graft exposure happened in two cases due to suture disruption. In one of the two cases, superficial revision was performed, vertical bone block was debrided, and the wound closed. In the other case, there was superficial grinding and secondary wound healing. In all cases, no additional grafting was performed, and implants were successfully placed. Four patients dropped out from the study after the reconstructive operation due to moving away. According to phone appointments, all excluded patients received implant-supported dentures by local dentists. The other 21 patients received allocated treatment and completed the study with a follow-up period after prosthetic rehabilitation lasting at least 1.5 years.

Implant Placement and Prosthetic Rehabilitation

During the second stage, all grafts from LBS fulfilled the Barone success criteria 6 months after augmentation

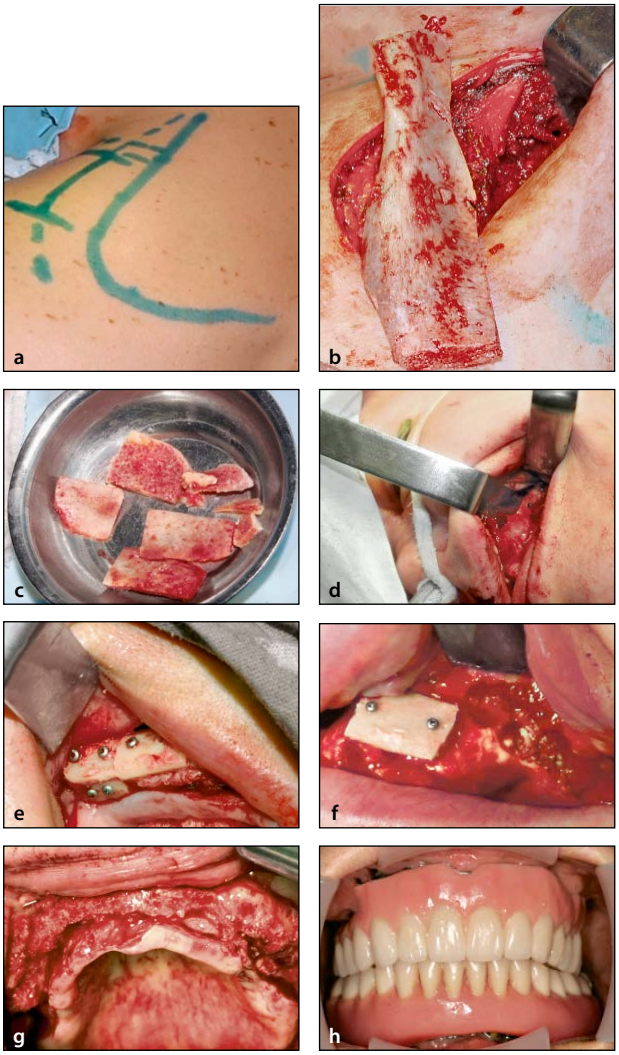

Fig 3 Clinical procedures represented with one case. *(a)* Preoperative donor site view. *(b)* LBS graft in the wound. *(c)* Bone blocks prepared to augmentation. *(d)* Contralateral head position with performed sinus elevation. *(e)* Block adaptation. *(f)* Onlay grafting. *(g)* Reconstructed ridge (6 months after surgery). *(h)* Prosthetics.

Table 1 Bone Grafting Characteristics

Parameters	n = 25
Type of osteoplasty	
Primary	13 (52%)
Secondary	12 (48%)
Arch	
Maxilla	9 (36%)
Mandible	6 (24%)
Both	10 (40%)
Type of edentulous space	
Bounded	6 (24%)
Free-end	11 (44%): one-side—3 (12%); bilateral—8 (32%)
Fully	8 (32%): maxilla—5 (20%); both arches—3 (12%)
Dental defect length (teeth)	
Mean ± SD	12.88 ± 7.93
Median (Q1; Q3)	12 (6; 17)
Min, Max	3, 28
Sinus elevation	
Yes	17 (68%)
No	8 (32%)
Vertical bone augmentation	
Yes	17 (68%)
No	8 (32%)
Bone block number	
Mean ± SD	3.73 ± 1.89
Median (Q1; Q3)	4 (2.25; 5)
Min, Max	1, 7
Surgery duration (min)	
Mean ± SD	234.80 ± 70.10
Median (Q1; Q3)	220 (190; 280)
Min, Max	125, 400
Recipient site complication	
No	23 (92%)
Yes	2 (8%)

SD = standard deviation; Q1 = first quartile; Q3 = third quartile.

(Fig 3g). An average LBS graft resorption rate was 12.22% ± 2.98%; the median was 12.28% (Q1: 9.91; Q3: 14.53). In reconstructed bone, 174 dental implants (120 on the maxilla; 54 on the mandible) were placed in the prosthetically correct position. The median number of implants per patient was 8 (Q1: 4; Q3: 10); detailed information about implant diameter and length is given in Table 3. Wound healing was considered as uneventful due to the absence of inflammation signs and soft tissue dehiscence. Three months later, 7 (33.33%) patients had soft tissue augmentation: in 3 (14.29%) cases, vestibuloplasty was performed, and 4 (19.05%) patients had subepithelial connective tissue grafts from palate harvested by the single incision technique. Three (1.72%) implants in two patients were lost without replacement due to poor stabilization; all other implants were prosthetically loaded (Fig 3h). Twenty-one patients received prostheses: 16 fixed and 5 partial implant-supported dentures.

Alveolar Bone at Baseline and After Reconstruction

Radiologic analyses included 3D computed tomography for 25 patients before bone grafting and CBCT scans for 21 patients 6 months after reconstruction, due to 4 patients dropping out. Descriptive statistics were performed for 21 patients and are shown in Table 4. Before surgery, average ridge characteristics on the maxilla were as follows: median height of 4.90 mm (Q1: 3.08; Q3: 7.27), median width of 2.55 mm (Q1: 1.80; Q3: 3.15).

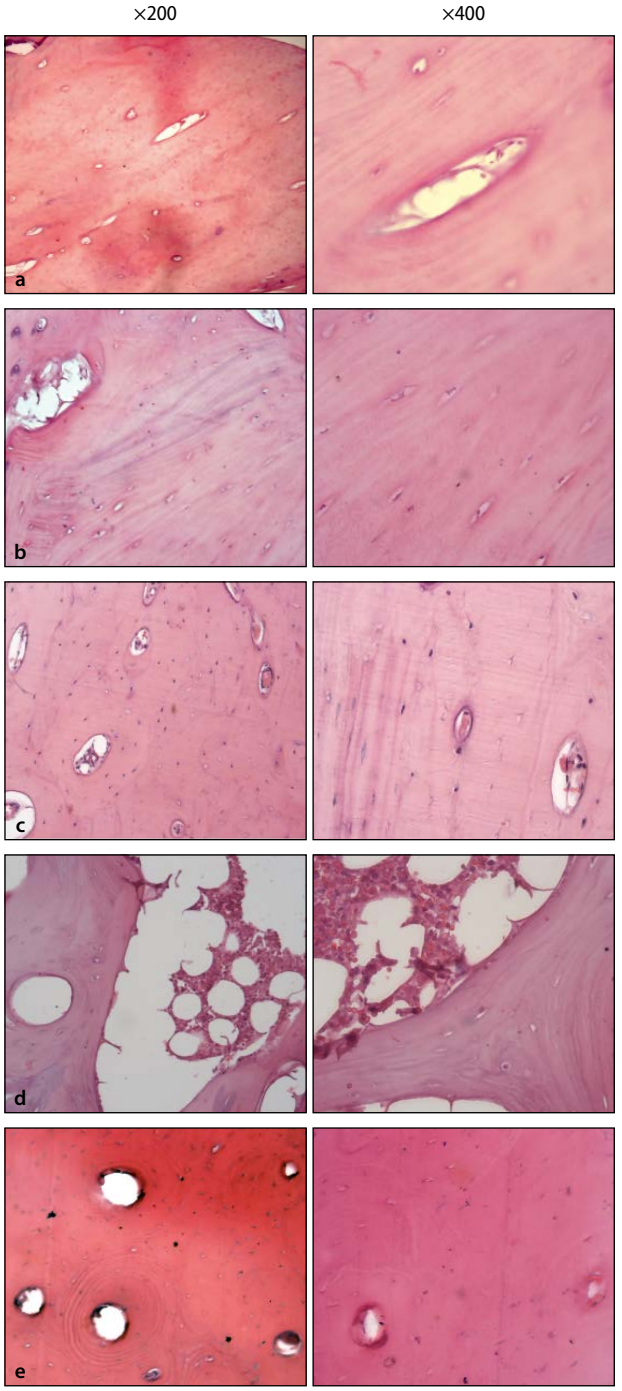

Fig 4 Histologic slides stained with hematoxylin and eosin at ×200 and ×400 original magnification representing control group and grafting sites. *(a)* Alveolar ridge. *(b)* Mandibular ramus. *(c)* Calvarium. *(d)* Iliac crest. *(e)* LBS.

Table 2 Grafting Stage Characteristics

Parameters	n = 25
Grafting site	
Right	10 (40%)
Left	15 (60%)
Graft dimensions	
Length (cm)	
Mean ± SD	6.26 ± 2.27
Median (Q1; Q3)	7 (4; 7.5)
Min, Max	3, 10
Height (cm)	
Mean ± SD	2.27 ± 0.67
Median (Q1; Q3)	2.0 (2.0; 2.5)
Min, Max	1.0, 4.0
Width (cm)	
Mean ± SD	1.15 ± 0.50
Median (Q1; Q3)	1.00 (1.00; 1.50)
Min, Max	0.50, 2.50
Cortical layer thickness (mm)	
Mean ± SD	2.46 ± 0.76
Median (Q1; Q3)	2.50 (2.00; 3.00)
Min, Max	1.00, 4.00
Cancellous layer thickness (mm)	
Mean ± SD	6.60 ± 3.71
Median (Q1; Q3)	5.00 (5.00; 9.00)
Min, Max	3.00, 17.00
Block structure	
Lateral border	15 (60%)
Lateral border and flat part of scapula	7 (28%)
Lateral border and scapula angle	3 (12%)
Grafting stage (min)	
Mean ± SD	66.40 ± 19.87
Median (Q1; Q3)	60 (55; 75)
Min, Max	40; 120
Donor site complication	
No	24 (96%)
Yes	1 (4%)

SD = standard deviation; Q1 = first quartile; Q3 = third quartile.

On the mandible, the alveolar parameters were as follows: median height of 7.23 mm (Q1: 4.77; Q3: 9.11), median width of 3.51 mm (Q1: 2.35; Q3: 4.15).

Immediately after reconstruction, the ridge characteristics on the maxilla were as follows: median height of 14.45 mm (Q1: 12.87; Q3: 15.49), median width of 7.42 mm (Q1: 6.39; Q3: 8.77). On the mandible, the alveolar parameters were as follows: median height of 14.17 mm (Q1: 11.33; Q3: 16.86), median width of 8.01 mm (Q1: 5.75; Q3: 10.93). For bone gain during reconstruction, on the maxilla in vertical dimension, the median was 9.08 mm (Q1: 8.07; Q3: 9.72), and width was 4.92 mm (Q1: 4.69; Q3: 5.45); on the mandible in horizontal dimension, the median was

Table 3 Distribution of Implants (n = 174) According to Implant Diameter and Length (mm)

	Implant diameter				
Implant length	3.4	3.8	4.5	Total	Percent
8.0	0	3	4	7	4.0%
9.5	6	24	29	59	33.9%
11.0	33	38	9	80	46.0%
13.0	4	23	0	28	16.1%
Total	44	88	42	174	100.0%
Percent	25.3%	50.6%	24.1%	100.0%	

Table 4 Alveolar Bone Changes in 21 Patients Who Completed the Study

	Height (mm)				
	Maxilla		Mandible		
	Mean ± SD	Median (Q1; Q3)	Mean ± SD	Median (Q1; Q3)	*P* value
Timing					
Baseline	4.92 ± 2.45	4.90 (3.08; 7.27)	6.88 ± 2.43	7.23 (4.77; 9.11)	.617
After reconstruction (immediate)[a]	13.79 ± 1.84	14.45 (12.87; 15.49)	14.07 ± 2.88	14.17 (11.33; 16.86)	.363
Bone gain during reconstruction	8.87 ± 0.93	9.08 (8.07; 9.72)	7.18 ± 0.94	6.93 (6.59; 7.88)	.802
After surgery (6 mo)	12.14 ± 1.66	12.57 (11.13; 13.77)	12.32 ± 2.52	12.00 (10.70; 13.20)	.992
Newly formed bone	7.07 ± 3.62	7.05 (4.34; 9.87)	6.38 ± 3.31	7.82 (3.86: 8.70)	.555
6 mo graft resorption (mm)	1.65 ± 0.46	1.56 (1.31; 2.09)	1.75 ± 0.57	1.74 (1.26; 2. 25)	.308
6 mo graft resorption (%)	12.02 ± 2.81	12.29 (9.91; 13.79)	12.39 ± 3.13	12.27 (9.89; 13.77)	.211
Width (mm)					
Baseline	2.75 ± 1.57	2.55 (1.80; 3.15)	3.56 ± 1.98	3.51 (2.35; 4.15)	.674
After reconstruction (immediate)[a]	7.71 ± 141	7.42 (6.39; 8.77)	8.31 ± 2.66	8.01 (5.75; 10.93)	.509
Bone gain during reconstruction	4.96 ± 0.81	4.92 (4.69; 5.45)	4.76 ± 1.73	4.60 (3.31; 6.43)	.211
After surgery (6 mo)	6.76 ± 1.20	6.56 (5.87; 7.49)	7.24 ± 2.40	7.41 (5.39; 8.60)	.704
Newly formed bone	4.89 ± 2.98	5.16 (2.77; 7.05)	3.55 ± 2.56	4.56 (2.51; 5.23)	.897
6 mo graft resorption (mm)	0.94 ± 0.34	0.91 (0.71; 1.10)	1.07 ± 0.50	0.93 (0.68; 1.47)	.704
6 mo graft resorption (%)	12.11 ± 3.18	11.89 (9.30; 15.25)	12.49 ± 2.74	12.66 (9.90; 14.53)	.711

SD = standard deviation; Q1 = first quartile; Q3 = third quartile; [a]clinical data.

6.93 mm (Q1: 6.59; Q3: 7.88), and the median width was 4.60 mm (Q1: 3.31; Q3: 6.43). Six months after bone augmentation, on the maxilla, median ridge height was 12.57 mm (Q1: 11.13; Q3: 13.77), and width was 6.56 mm (Q1: 5.87; Q3: 7.49); on the mandible, the median alveolar height was 12.00 mm (Q1: 10.70; Q3: 13.20), and the median width was 7.41 mm (Q1: 5.39; Q3: 8.60). A statistically significant difference was detected between the ridge parameters immediately and 6 months after reconstruction ($P < .01$). Vertical amounts of newly formed bone on the maxilla were a median 7.05 mm (Q1: 4.3; Q3: 9.9; $P = .19$); horizontal amounts were 5.16 mm (Q1: 2.8; Q3: 7.1; $P = .12$). On the mandible, the average amount of newly formed bone in vertical dimension was a median 7.82 mm (Q1: 3.9; Q3: 8.7; $P = .29$); in horizontal dimension, it was 4.56 mm (Q1: 2.5; Q3: 5.2; $P = .21$).

Alveolar Bone Resorption 6 Months After Reconstruction

As indicated in Table 4, graft resorptions 6 months after surgery on the maxilla were a median 1.56 mm in height (Q1: 1.31; Q3: 2.09) and 0.91 mm (Q1: 0.71; Q3: 1.10) in width. In vertical and horizontal dimensions, resorption was 12.29% (Q1: 9.91; Q3: 13.79) and 11.89% (Q1: 9.30; Q3: 15.25). Resorption of the mandible was 1.74 mm (Q1: 1.26; Q3: 2.25) and 0.93 mm (Q1: 0.68; Q3: 1.47) in height and width, respectively. In vertical and horizontal dimensions, resorption was 12.27% (Q1: 9.89; Q3: 13.77) and 12.66% (Q1: 9.90; Q3: 14.53). According to the Mann-Whitney test, no statistically significant changes were detected between the maxilla and mandible ridge parameters and resorption rate ($P > .01$). The obtained data demonstrated the primary endpoint, that there was sufficient alveolar width and

height for implant placement in a prosthetically correct position received 6 months after reconstruction with LBS bone block and no additional grafting is needed.

Follow-up Procedure

The follow-up period was between 18 and 48 months after prosthetic loading, with the median 24 months (Q1: 18; Q3: 36). Donor site arm movements were painless and equal to those of a nonoperated hand. No scapular winging, pathologic fractures, or axillary joint disorders were detected. Postoperative scars were linear and normotrophic, with a mean length of 6.83 ± 0.26 cm, and no contour alterations were observed. From the recipient site, patients had no complaints of persistent pain or dysesthesia. With respect to the implant dentistry, no suppuration or implant mobility was observed. Three implants in two patients had peri-implant mucositis and bleeding on probing, 36 and 48 months after prosthetic loading. Peri-implant mucositis was relieved after an oral hygiene program and stayed healthy within an observation period of 2 years. No implant failure was detected, and all prostheses were in good functional conditions with no need of new restoration manufacturing by the end of the observation period. With the loss of three implants before prosthetic loading, the overall implant success rate in the LBS reconstructed ridge was 98.3%. From there, the secondary endpoint was reached: that high implant success and implant-supported restoration survival rates were demonstrated, and that the implants placed in LBS reconstructed bone can stably function at least 18 months after loading.

DISCUSSION

This study has demonstrated that corticocancellous grafts harvested from LBS are sufficient for large ridge augmentation with low intraoperative and postoperative complication rates due to the absence of prominent arteries, veins, and nerves in the operating field. LBS grafting allows fast hand function recovery and lower donor site morbidity caused by the muscle retracting surgery. The bone quality and the amount of LBS used to reconstruct the ridges were sufficient for implant placement 6 months after augmentation. Similar to calvarium bone with its cortical nature,[25,26] LBS grafts demonstrated around one-tenth the resorption rate 6 months after reconstruction. The dental implants were well-integrated into LBS reconstructed bone and resisted loading. Based on the preliminary results of a 1.5-year follow-up period, no major implant or prosthetic complications were observed. The approach described above is technically easier compared to the head and neck reconstructions; however, experience in vascularized scapular grafting is recommended.

Ridge reconstruction with extraoral grafting sites included two surgical fields; therefore, a two-team approach is crucial in order to keep operating times low and thereby minimize potential side effects of general anesthesia. During LBS grafting, the patient is in the contralateral position with his or her head turned sideways. This position is common for reconstructive surgery with vascularized graft harvesting (thoracodorsal, rib, scapular), as it does not interfere with working on the recipient site. For example, sinus elevation and ridge preparation can be performed during LBS harvesting; therefore, LBS grafting does not extend the total operation time. The average grafting time for the anterior iliac crest is 35 minutes[27] and for LBS is 60 minutes. Nevertheless, LBS harvesting is somewhat more time-consuming compared with the iliac crest; the surgical protocols presented here can be refined to speed up the procedure in the future.

For harvesting large vascularized scapular grafts, the elbow incision from LBS projection to the axillary region is performed to visualize the subscapular and circumflexa scapular vessels.[28,29] In nonvascularized free LBS grafts, a linear cut 2 cm below the lower border of the axillary joint was made, resulting in postoperative scar formation within the area covered by clothes. Contour alteration is another important esthetic aspect. In the iliac crest harvesting site, the absence of prominent superficial muscles may cause bone deformities,[30] especially in slim patients; in the calvarium, it can be manifested during everyday hair care.[16] LBS grafting, however, is located under the thoracodorsal muscle (lower part) and teres major and teres minor muscles (middle and upper third), which covers the grafting area and prevents step appearance.

Harvesting of the scapular free flap resulted in low rates of donor site morbidity, without interfering with the shoulder function and the patient's daily activity.[20,31] However, surgical approach plays a crucial role in preventing intraoperative and postoperative complications, including postoperative morbidity. During microvascular scapular grafting infraspinatus, teres minor and partially teres major muscle cuts were performed, which caused long periods of recovery of the hand function.[32] In contrast, the present proposed avascular LBS harvesting technique included only muscle retracting, with the integrity of muscles, nerves, and vessels maintained. As a result, patients experienced less postoperative pain and a faster hand function recovery within approximately 2 weeks at lower postoperative morbidity. No serious complications and side effects after LBS harvesting were observed in this study, demonstrating that this grafting technique can be used in routine practice.

The results of the present study confirm that alveolar ridges reconstructed with autogenous bone grafts

are predictable and safe, allowing the placement of implants in the prosthetically correct position.[33,34] Six months after augmentation with LBS bone blocks, the ridge dimensions were on average 12.2 mm and 6.9 mm in height and width, respectively. This grafted area allowed placement of dental implants in the optimal position to achieve the desired esthetic and functional results. In terms of implant failure and survival rates, calvarium grafts demonstrated 2.4% implant failure rate[35] and iliac crest had 4.4% and 7.3% failures.[36,37] In other studies, calvarial bone had 1.5% implant failure and iliac crest grafted ridge had no failures.[25] Comparably, LBS grafted ridges showed implant failure rates of 1.7%. The dropout of four patients had a minor impact on the major conclusions of this study.

The decision to choose an extraoral harvesting area is difficult and has to be made according to defect localization and severity of ridge atrophy. Today, the iliac crest graft is the gold standard for large ridge reconstructions, despite its relatively high resorption. Thus, overall size of the bone block harvested from the iliac crest has to be larger compared with the LBS graft. Both blocks are corticocancellous, but iliac crest has cancellous bone predominance, due to a thin superficial cortical layer,[27] whereas LBS has cortical majority. Another advantage of LBS harvesting is the two-team approach, albeit experienced surgeons are needed for its implementation. LBS demonstrated lower donor site morbidity and quick hand function recovery, while the iliac crest grafting is frequently associated with painful walking in the postoperative period and sometimes limping. Moreover, no skin sensory disturbance occurred from scapular grafting in contrast to the iliac crest. On the other hand, the scar is less wide in the iliac crest compared with LBS grafting sites, due to less frequent movements. Taken together, ridge reconstruction with LBS graft has numerous advantages compared with the iliac crest and, therefore, can be used as a method of choice for patients with severe alveolar atrophy prior to implant placement.

This study has limitations. First, LBS as a grafting site for ridge reconstruction was introduced by the authors, and the original treatment protocol presented here can be modified in the future. Second, due to limited clinical experience for LBS harvesting, all patients enrolled in this study had to choose between LBS and other extraoral harvesting sites, and no controlled study with other established donor areas was performed. Third, CBCT after implant loading for 6 months was performed in only 21 out of 25 cases. However, CBCT will be performed 3 years after prosthetic rehabilitation to analyze ridge changes and to evaluate the periimplant resorption rates and other criteria of implant success. Fourth, during the minimal follow-up period of 18 months, implant pocket depths were evaluated in all cases, but not recorded at six aspects. Finally, the overall follow-up period was relatively short; thus, the conclusions related to implant-supported prosthetic rehabilitation in the LBS reconstructed ridge must be considered preliminary.

CONCLUSIONS

LBS is a viable source for harvesting free bone grafts used for the reconstruction of severe bone atrophy prior to implant placement. The graft volume is sufficient, and the donor site morbidity is low. The resorption rate of the augmented area is comparably low. Dental implants were osseointegrated in the augmented bone, and the complication rate after a follow-up period of at least 18 months is small. Therefore, the use of LBS as an alternative extraoral donor site for alveolar reconstruction can be recommended.

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REFERENCES

1. Benic GI, Hämmerle CH. Horizontal bone augmentation by means of guided bone regeneration. Periodontology 2000 2014;66:13–40.
2. Aghaloo TL, Misch C, Lin GH, Iacono VJ, Wang HL. Bone augmentation of the edentulous maxilla for implant placement: A systematic review. Int J Oral Maxillofac Implants 2016;31(suppl):s19–s30.
3. Chiapasco M, Zaniboni M. Methods to treat the edentulous posterior maxilla: Implants with sinus grafting. J Oral Maxillofac Surg 2009;67:867–871.
4. Chiapasco M, Zaniboni M, Rimondini L. Dental implants placed in grafted maxillary sinuses: A retrospective analysis of clinical outcome according to the initial clinical situation and a proposal of defect classification. Clin Oral Implants Res 2008;19:416–428.
5. Cordaro L, Torsello F, Miuccio MT, di Torresanto VM, Eliopoulos D. Mandibular bone harvesting for alveolar reconstruction and implant placement: Subjective and objective cross-sectional evaluation of donor and recipient site up to 4 years. Clin Oral Implants Res 2011;22:1320–1326.
6. Misch CM, Misch CE. The repair of localized severe ridge defects for implant placement using mandibular bone grafts. Implant Dent 1995;4:261–267.
7. Hernández-Alfaro F, Sancho-Puchades M, Guijarro-Martínez R. Total reconstruction of the atrophic maxilla with intraoral bone grafts and biomaterials: A prospective clinical study with cone beam computed tomography validation. Int J Oral Maxillofac Implants 2013;28:241–251.
8. Sjöström M, Sennerby L, Nilson H, Lundgren S. Reconstruction of the atrophic edentulous maxilla with free iliac crest grafts and implants: A 3-year report of a prospective clinical study. Clin Implant Dent Relat Res 2007;9:46–59.
9. Sjöström M, Sennerby L, Lundgren S. Bone graft healing in reconstruction of maxillary atrophy. Clin Implant Dent Relat Res 2013;15:367–379.
10. Barone A, Ricci M, Mangano F, Covani U. Morbidity associated with iliac crest harvesting in the treatment of maxillary and mandibular atrophies: A 10-year analysis. J Oral Maxillofac Surg 2011;69:2298–2304.

11. Dimitriou R, Mataliotakis GI, Angoules AG, Kanakaris NK, Giannoudis PV. Complications following autologous bone graft harvesting from the iliac crest and using the RIA: A systematic review. Injury 2011;42(suppl 2):s3–s15.
12. Swan MC, Goodacre TE. Morbidity at the iliac crest donor site following bone grafting of the cleft alveolus. Br J Oral Maxillofac Surg 2006;44:129–133.
13. Schortinghuis J, Putters TF, Raghoebar GM. Safe harvesting of outer table parietal bone grafts using an oscillating saw and a bone scraper: A refinement of technique for harvesting cortical and "cancellous"-like calvarial bone. J Oral Maxillofac Surg 2012;70:963–965.
14. Scheerlinck LM, Muradin MS, van der Bilt A, Meijer GJ, Koole R, Van Cann EM. Donor site complications in bone grafting: Comparison of iliac crest, calvarial, and mandibular ramus bone. Int J Oral Maxillofac Implants 2013;28:222–227.
15. Tessier P, Kawamoto H, Posnick J, Raulo Y, Tulasne JF, Wolfe SA. Taking calvarial grafts, either split in situ or splitting of the parietal bone flap ex vivo—Tools and techniques: V. A 9650-case experience in craniofacial and maxillofacial surgery. Plast Reconstr Surg 2005;116(suppl):54s–71s; discussion 92s–94s.
16. Touzet S, Ferri J, Wojcik T, Raoul G. Complications of calvarial bone harvesting for maxillofacial reconstructions. J Craniofac Surg 2011;22:178–181.
17. Saijo M. The vascular territories of the dorsal trunk: A reappraisal for potential flap donor sites. Br J Plast Surg 1978;31:200–204.
18. Gilbert A, Teot L. The free scapular flap. Plast Reconstr Surg 1982;69:601–604.
19. Swartz WM, Banis JC, Newton ED, Ramasastry SS, Jones NF, Acland R. The osteocutaneous scapular flap for mandibular and maxillary reconstruction. Plast Reconstr Surg 1986;77:530–545.
20. Choi N, Cho JK, Jang JY, Cho JK, Cho YS, Baek CH. Scapular tip free flap for head and neck reconstruction. Clin Exp Otorhinolaryngol 2015;8:422–429.
21. Sadilina S, Kalakutskiy N. Lateral border of scap A new bone-grafting site for alveolar ridge reconstruction prior to implant placement. Clin Oral Implants Res 2019;30:12.
22. Cawood JI, Howell RA. A classification of the edentulous jaws. Int J Oral Maxillofac Surg 1988;17:232–236.
23. Barone A, Covani U. Maxillary alveolar ridge reconstruction with nonvascularized autogenous block bone: Clinical results. J Oral Maxillofac Surg 2007;65:2039–2046.
24. Sanz M, Chapple IL, Working Group 4 of the VIII European Workshop on Periodontology. Clinical research on peri-implant diseases: Consensus report of Working Group 4. J Clin Periodontol 2012;39(suppl 12):202–206.
25. Mertens C, Decker C, Seeberger R, Hoffmann J, Sander A, Freier K. Early bone resorption after vertical bone augmentation—A comparison of calvarial and iliac grafts. Clin Oral Implants Res 2013;24:820–825.
26. Lenzen C, Meiss A, Bull HG. Augmentation of the extremely atrophied maxilla and mandible by autologous calvarial bone transplantation [in German]. Mund Kiefer Gesichtschir 1999;(3 suppl 1):s40–s42.
27. Conway JD. Autograft and nonunions: Morbidity with intramedullary bone graft versus iliac crest bone graft. Orthop Clin North Am 2010;41:75–84; table of contents.
28. Teot L, Charissou JL, Pous JG, Arnal F. Pedicled scapular apophysis transplantation. Growing grafts studied in dogs. Acta Orthop Scand 1986;57:163–167.
29. Sundine MJ, Sharobaro VI, Ljubic I, Acland RD, Tobin GR. Inferior angle of the scapula as a vascularized bone graft: An anatomic study. J Reconstr Microsurg 2000;16:207–211.
30. Kuik K, Putters TF, Schortinghuis J, van Minnen B, Vissink A, Raghoebar GM. Donor site morbidity of anterior iliac crest and calvarium bone grafts: A comparative case-control study. J Craniomaxillofac Surg 2016;44:364–368.
31. Ferrari S, Ferri A, Bianchi B, Varazzani A, Perlangeli G, Sesenna E. Donor site morbidity after scapular tip free flaps in head-and-neck reconstruction. Microsurgery 2015;35:447–450.
32. Hartman EH, Spauwen PH, Jansen JA. Donor-site complications in vascularized bone flap surgery. J Invest Surg 2002;15:185–197.
33. Nkenke E, Neukam FW. Autogenous bone harvesting and grafting in advanced jaw resorption: Morbidity, resorption and implant survival. Eur J Oral Implantol 2014;7(suppl 2):s203–s217.
34. Schwartz-Arad D, Ofec R, Eliyahu G, Ruban A, Sterer N. Long term follow-up of dental implants placed in autologous onlay bone graft. Clin Implant Dent Relat Res 2016;18:449–461.
35. Iizuka T, Smolka W, Hallermann W, Mericske-Stern R. Extensive augmentation of the alveolar ridge using autogenous calvarial split bone grafts for dental rehabilitation. Clin Oral Implants Res 2004;15:607–615.
36. Neyt LF, De Clercq CA, Abeloos JV, Mommaerts MY. Reconstruction of the severely resorbed maxilla with a combination of sinus augmentation, onlay bone grafting, and implants. J Oral Maxillofac Surg 1997;55:1397–1401.
37. Raghoebar GM, Schoen P, Meijer HJ, Stellingsma K, Vissink A. Early loading of endosseous implants in the augmented maxilla: A 1-year prospective study. Clin Oral Implants Res 2003;14:697–702.