

# Mandibular Bone Block Harvesting from the Retromolar Region: A 10-Year Prospective Clinical Study

Fouad Khoury, PhD, DMD<sup>1</sup>/Thomas Hanser, DMD<sup>2</sup>

**Purpose:** The aim of this prospective study was to evaluate the outcome of bone block harvesting from the external oblique ridge with the MicroSaw, assess the volume of the harvested block, and identify possible morbidity and complications related to the procedure. **Materials and Methods:** Bone blocks were harvested from the external oblique line of the mandible according to the MicroSaw protocol. The bone blocks were split into two thinner blocks with a diamond disk according to the split bone block (SBB) technique for biologic grafting procedures. **Results:** In all, 3,874 bone blocks were harvested from the external oblique line of the mandible in 3,328 patients. Four hundred nineteen patients (12.59%) underwent bilateral bone block harvesting, and 127 patients (3.82%) had more than one block harvested from the same area during the study period. In 431 cases (11.12%), only one block was required, so the second was repositioned to reconstruct its donor site. The average harvesting time was  $6.5 \pm 2.5$  minutes, and a mean volume of  $1.9 \pm 0.9$  cm<sup>3</sup> was obtained (maximum 4.4 cm<sup>3</sup>). In 168 (4.33%) cases, the alveolar nerve was exposed, leading to sensory problems lasting up to 6 months. In 20 cases (0.5%), minor nerve injury resulted in hypesthesia or paresthesia that lasted for up to 1 year in most patients. No major nerve lesions with permanent anesthesia were observed. Sixty-one (1.58%) donor sites showed primary healing complications, most in smokers (80.4%). Reentry of 16 reimplanted harvested areas was performed between 6 and 40 months later, showing a well-regenerated and healed external oblique ridge. **Conclusion:** This study demonstrated that relatively large volumes of bone block graft can be retrieved in the mandible with a low complication rate. Reimplantation of half of the bone block offers the possibility for complete regeneration of the donor site. *INT J ORAL MAXILLOFAC IMPLANTS* 2015;30: 688–697. doi: 10.11607/jomi.4117

**Key words:** autogenous bone block, diamond disk, external oblique line, mandibular bone graft, mandibular bone harvesting, MicroSaw, split bone block

The reconstruction of alveolar defects after tooth loss is one of the biggest challenges in implant dentistry. To augment existing bone defects, grafts of various origins have been used, eg, alloplastic grafts, xenografts, allografts, and autografts. The mode of graft integration with respect to regeneration depends primarily on its origin and composition. Xenografts and allografts, as well as alloplastic material of natural or synthetic origin, with their osteoconductive properties, serve as scaffolds for new bone growth

originating from the native bone. However, autogenous bone grafts are osteoinductive, osteogenic, and osteoconductive, with significant regenerative capacity in comparison to all other grafts. This is why autogenous bone, especially for larger lateral or vertical defects, remains the gold standard for augmentation.<sup>1</sup>

Extraoral donor sites for autogenous bone include the skull, the fibula, the ribs, and the iliac crest, all of which inevitably lead to additional patient morbidity.<sup>2,3</sup> Intraoral sources have the advantages of proximity of the donor and recipient sites, convenient surgical access, low morbidity, and elimination of a hospital stay.<sup>1,3–5</sup> The maxilla offers only small amounts of mainly cancellous autografts. However, corticocancellous bone block grafts, suitable for two- or three-dimensional reconstructions of alveolar ridge defects, can be harvested only from the mandibular symphysis (chin area), the retromolar and paramolar areas (external oblique ridge), or edentulous areas.<sup>1,6–9</sup>

The removal of large bone block grafts with drills or engraving or oscillating saws may be particularly dangerous in the anterior mandibular ramus. The MicroSaw

<sup>1</sup>Professor, Department of Oral and Maxillofacial Surgery, University of Münster, Germany; Chairman, Private Clinic Schloss Schellenstein, International Dental Implant Center, Olsberg, Germany.

<sup>2</sup>Senior Surgeon, Private Clinic Schloss Schellenstein, International Dental Implant Center, Olsberg, Germany.

**Correspondence to:** Prof Dr Fouad Khoury, Am Schellenstein 1, 59939 Olsberg, Germany. Fax: +49-2962-9719-22. Email: prof.khoury@t-online.de

©2015 by Quintessence Publishing Co Inc.

**Fig 1** Visualization of the external oblique line on a panoramic radiograph.



(Dentsply Implants), a diamond-tipped disk described in 1984 for the preparation of a bone lid as part of the root resection of mandibular molars, is well suited for safe and quick removal of bone blocks from different areas of the mandible.<sup>1</sup> Bone block grafts harvested with the MicroSaw can be used as onlay, inlay, or lateral bone block grafts, as well as filler in sinus floor elevation and guided bone regeneration procedures.<sup>1,6</sup>

This prospective clinical study details the 10-year clinical experience in a private clinic with harvesting of mandibular bone blocks from the external oblique ridge in the retromolar area. Diagnostic methods, instruments, and harvesting technique are presented, and indications, advantages, and complications are discussed. The aim of this prospective study was to evaluate the outcome of bone block harvesting from the external oblique ridge with the MicroSaw. This study was performed following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology, <http://www.strobe-statement.org>) guidelines.<sup>10</sup>

## MATERIALS AND METHODS

Between 2000 and 2010, patients who underwent bone block harvesting from the retromolar area in the mandible for the reconstruction of large bony defects or severe bone atrophy of the maxilla or/and the mandible prior or simultaneous with implant placement were included in this study. Patients with general contraindications to implant surgery, poor oral hygiene (full mouth plaque and bleeding score  $\geq 20\%$ ), active periodontal lesions, and lack of motivation were excluded from the study.

### Preoperative Clinical and Radiographic Examinations

Visual examination and digital palpation allowed for a preliminary estimation of the morphologic contours and dimensions of the donor site, such as the thickness

and extent of the external oblique ridge (linea obliqua externa). This clinical examination provided information on the shape of the available bone at the donor site. Panoramic radiographs were used to gather additional information on the donor site and its relationship to important neighboring anatomical structures (Fig 1). In the years 2009 and 2010, cone beam computed tomographic (CBCT) scans (Galileos, Siemens) were also performed to obtain a three-dimensional view of the anatomical structures and to allow better evaluations of bone thickness and exact mandibular nerve position (Figs 2 and 3).

### Surgical Procedure

Preoperative antibiotic administration was performed, either intravenously (penicillin G, 1 million IU)<sup>11</sup> immediately before local anesthetic was injected (before vasoconstriction occurred) or by mouth (penicillin V, 1 million IU) at least 1 hour prior to surgery. Antibiotics were to be continued for 7 days postoperatively (1 million IU three times per day). In case of a penicillin allergy, clindamycin 300/600 mg<sup>1</sup> was administered (1.2 g/day). Amoxicillin<sup>12</sup> (2 g per day) was prescribed in patients who were also undergoing a sinus floor elevation.

Harvesting of intraoral bone for block grafting was generally performed under local anesthesia in conjunction with intravenous sedation. General anesthesia was indicated for large reconstructions involving multiple donor sites and for surgery exceeding 3 hours.

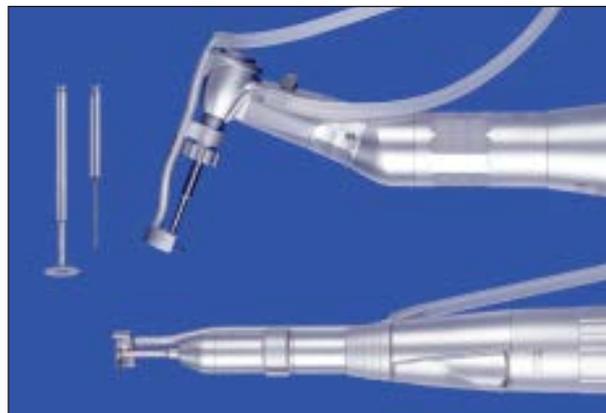
An inferior alveolar nerve block was avoided in almost all patients; instead, only local vestibular and lingual infiltration with 4% articaine and 1:100,000 epinephrine (Ultracain DS forte, Sanofi Aventis) was performed. This was important so that minimal sensation was retained to warn the surgeon when approaching the mandibular nerve. The only exception to this rule was a situation in which bone block harvesting was combined with the removal of an impacted third molar; in this situation, an inferior alveolar nerve block was performed.



**Fig 2** CBCT scan of the retromolar area showing the shape of the external oblique line and the thick cortical bone plate. The distance between the bone surface and the mandibular nerve in this area is usually more than 3 mm.



**Fig 3** CBCT view at the junction of the vertical/horizontal part of the mandible (ramus mesial border). In this area, the nerve is more superficial because the bone is thinner.



**Fig 4 (left)** Exposure of the retromolar area with the external oblique line.

**Fig 5 (right)** MicroSaw Kit (Dentsply Implants).

A trapeze-like incision (starting distal to the second molar with a 2-cm vestibular incision over the ramus bone, continuing parallel and lateral to the second molar, and then going back in the vestibular direction on the distal border of the first molar) was followed by the elevation of a mucoperiosteal flap (similar to that used for the removal of impacted third molars). This exposed the bone at the level of the external oblique ridge to a length of 3 to 4 cm and a depth of 2 cm (Fig 4).

The volume of bone to be harvested depended on the size and extent of the external oblique ridge and the quantity of bone needed for grafting. The harvesting osteotomy was performed with the MicroSaw

following a clear protocol. The MicroSaw consists of an 8-mm-diameter, 0.25-mm-wide diamond disk mounted on a contra-angle or MicroSaw handpiece with a soft tissue protector (Fig 5). In the harvesting protocol, three osteotomies are performed with the diamond disk: two proximovertical osteotomies are made with the MicroSaw handpiece, and one is made apicohorizontally with the contra-angle handpiece (Figs 6 to 8). The apicohorizontal osteotomy was made slightly overlapping both vertical osteotomies basally. Once the osteotomy lines were positioned apical to the alveolar nerve level, the MicroSaw's maximum cutting capacity of 3.2 mm was avoided in the distal section

**Fig 6 (left)** A distal vertical osteotomy is made with the MicroSaw handpiece on the mesial border of the ramus.



**Fig 7 (center)** A mesial vertical incision is performed on the mesial border of the external oblique line.



**Fig 8 (right)** Apical connection of both vertical incisions is carried out using the MicroSaw contra-angle handpiece. The disk protector reduces the risk of damage to the soft tissues.



**Fig 9 (left)** Crestal connection of both vertical incisions is performed with a drill bur.



**Fig 10 (right)** Connection of the perforations with a fine 4-mm chisel and dislocation of the block.



**Fig 11 (left)** The block is split longitudinally.



**Fig 12 (right)** The resulting two thin blocks.



of the donor site, starting directly behind the second molar. In this area, the maximal depth of the incision with the diamond disk was 2 mm (the diamond layer is 1 mm wide). The final osteotomy, on the occlusal crestal site parallel to the external oblique ridge, was achieved with a thin 1-mm drill bur. Small perforations of 3 to 4 mm in depth, parallel to the buccal bone wall, were made with the drill bur at the level of the crestal platform of the external oblique ridge approximately 4 to 5 mm from the external border of the external oblique line and between the two vertical incisions (Fig 9). These perforations were connected with a fine chisel, producing tension in the cortical bone and

creating a kind of “explosive effect” in the area of the crestal perforations, leading to easy lateral dislocation of the bone block (Fig 10). The donor site was typically sealed with collagen fleece.

The harvested bone blocks were split into two thin bone blocks with the diamond disk according to the split bone block (SBB) technique of the biologic concept of grafting procedures (Figs 11 and 12). This grafting technique, which uses pure autogenous bone in the form of a thin bone block in combination with autogenous bone chips without any biomaterial or membranes, has shown clinical volume stability as well as a success rate above 95%.<sup>1</sup>

**Fig 13** (below) Vertical three-dimensional reconstruction is performed with one-half of the split block, in combination with autogenous particulate bone. No other augmentation material or membranes were used.



**Fig 14** (above) The second half of the bone block is replanted at its origin and secured with a MicroScrew to reconstruct the external oblique line.

**Fig 15** (left) Postoperative radiograph showing the reconstructed area in the maxilla and the replanted bone, secured with a screw to reconstruct the donor site.

If only one block was required, the second block was replaced to reconstruct its donor site (Figs 13 to 15). When needed, they were additionally stabilized with a small screw (Microscrew, Stoma Instruments). The remaining half-blocks were placed back over the collagen fleece, without any screw stabilization, within the contour of the external oblique line.

Finally, the donor wound was closed with 5-0 monofilament sutures, and grafting procedures were performed.

### Postoperative Management

In addition to antibiotics, analgesics (ibuprofen 400) and chlorhexidine 0.02% mouth rinse were prescribed for patients after surgery. Patients were advised to consume a soft diet during the first 6 postoperative weeks to avoid a potential postoperative mandible fracture. Sutures were removed 10 days postoperative.

### Outcome Measures

This study evaluated the outcome of bone block harvesting from the retromolar area with the MicroSaw. The outcome measures were as follows:

- **Osteotomy time.** This was measured from the moment the osteotomy incision began with the MicroSaw until the bone block was completely removed.
- **Volume of block graft.** This was measured by Archimedes' law while maintaining aseptic conditions. The harvested graft was placed inside a graduated tube filled with a 0.9% saline solution physiologic serum. Graft volume was determined by subtracting the volume of saline solution serum remaining after the graft was removed from the total volume (graft plus saline solution physiologic serum).<sup>1,12,13</sup>
- **Intraoperative complications.** These included fracture of the diamond disk, difficulties in luxation of the bone block (more than 10 minutes after the last osteotomy), heavy bleeding (ie, required separate measures to control it), nerve exposure, and nerve injury (determined clinically).
- **Postoperative pain.** The amount of pain was classified into three categories: heavy pain, with the patient taking more than eight painkillers (ibuprofen 400); moderate pain, when the patient

- took four to eight painkillers; or little pain, when the patient needed fewer than four painkillers.
- **Healing of the surgical site.** This was determined clinically by primary healing of the soft tissue over the harvested area; any tissue necrosis, suppuration, or bone exposure was noted. The soft tissue was supposed to show normal color without any inflammation by 2 weeks after the surgery (removal of the sutures) as well as at later recall appointments.
  - **Presence or absence of complications caused by injury to adjacent teeth or the mandibular nerve with the diamond disk.** This was determined clinically by the absence of any pain or pathologic symptoms on the neighboring teeth. In addition, pulp sensitivity in neighboring teeth was recorded by testing with carbon dioxide snow (cold vitality test). Patients were asked whether they sensed any paresthesia, hypesthesia, anesthesia, or any other subjective difference versus the contralateral site. Sensation in the lower lip and chin areas on the right and left was compared using a probe with an extra-fine sharp point (EX8, Stoma Instruments) while patients' eyes were closed.
  - **Regeneration of the harvested area.** The presence or absence of the external oblique ridge was determined clinically by palpation of the donor site with the second finger and radiologically on the control panoramic radiograph by detection of the presence or absence of the lamina dura in the retromolar area.
  - In patients who underwent CBCT scans, the level of the external oblique ridge was compared before and up to 36 months after the bone harvesting procedure with or without reimplantation of the half bone block if another CBCT scan was made for other presurgical diagnostic reasons. The CBCT scan was used to evaluate the level of bone regeneration after the healing of the donor site.

Outcomes were assessed by the surgeon and therefore were not blinded or independent.

## RESULTS

During this 10-year study, 3,328 patients (2,007 [60.3%] women and 1,321 [39.7%] men) underwent bone block harvesting. The youngest patient was 17 years old, and the oldest was 84 years old, and the average age was 57.8 years. There were 912 (27.4%) smokers and 2,416 (72.6%) nonsmokers or previous smokers (had stopped smoking at least 4 weeks before the surgery); most of the smokers (81.7%) consumed more than 10 cigarettes per day. Most patients (2,859, 85.9%) were

treated under intravenous sedation, and 469 (14.1%) patients underwent surgery under general anesthesia because they required multiple grafting procedures. One hundred nine patients (3.28%) received an inferior alveolar nerve block. A total of 3,874 bone blocks were harvested from the external oblique line at the retromolar area of the mandible. Some patients (419, 12.59%) underwent bilateral bone block harvesting. In 127 patients (3.82%), more than one block was harvested from the same area during the 10-year study period.

A total of 431 (11.12%) half-blocks were repositioned, and about 228 (52.9%) of them required additional stabilization with a small screw. The remaining 203 (47.1%) half-blocks were placed back over the collagen fleece, without any screw stabilization within the contour of the external oblique line.

The average time required to harvest a bone block from the mandibular retromolar area (time between starting the osteotomy and total luxation of the block) was  $6.5 \pm 2.5$  minutes. In eight (0.2%) cases, the osteotomy time was more than 15 minutes because the donor site bone was of dense cortical quality.

Of the 3,874 bone grafts harvested from the external oblique ridge, a mean volume of  $1.9 \pm 0.9$  cm<sup>3</sup> was measured (maximum 4.4 cm<sup>3</sup>) with a thickness up to 6.5 mm. In this area, bone quality was normally cortical, with little cancellous bone. The cortical bone in the area of the distal osteotomy had a thickness of 1.5 to 3.5 mm (average thickness,  $2.2 \pm 0.5$  mm). The cortical bone in the area of the mesial osteotomy was thicker, with a range of 2.5 to 5.5 mm (average,  $3.3 \pm 0.8$  mm). All blocks were successfully split; no fractures were seen.

In 2,285 donor sites, osteotomy lines were positioned apical to the alveolar nerve. In 168 (7.35%) of those cases, the mandibular alveolar nerve was exposed, generally in the distal area of the donor site, leading to transient sensory problems that lasted for a maximum of 6 months. In 20 cases, minor nerve injury occurred (0.5%): 8 patients (0.2%) demonstrated hypesthesia, and 12 patients (0.31%) suffered paresthesia that lasted for up to 1 year. In 4 patients (0.1%) the paresthesia was present for more than 1 year. No major nerve lesion of the mandibular nerve with permanent anesthesia was observed in any case.

Heavy bleeding at the donor site that required additional procedures to control it, such as electrocoagulation or compression with bone chips, occurred in 56 patients (1.44%). Postoperatively, minimal pain was observed in 1,624 patients (48.8%). Another 1,589 patients (47.74%) reported moderate pain, and only 115 patients (3.45%) reported severe pain.

A total of 61 (1.58%) donor sites showed complications related to primary healing. Most of these (46, 1.19%) were minor complications, eg, wound



**Fig 16** (above) Two implants are inserted into the well-vascularized and healed graft.



**Fig 17** (right) Exposure of the replanted bone block half (to harvest a second block) 7 months postoperative. Total regeneration of the external oblique line is confirmed clinically.

dehiscence related to superficial infection of the donor site, and 37 of these patients (80.4%) were smokers. All wounds healed by secondary intention after local rinsing for up to 1 week. Major infection occurred in 15 patients (0.39%), all of whom were smokers. Treatment included intensive local rinsing and drainage for up to 3 weeks. No infection occurred in the 431 donor areas in which half of the bone block was reimplanted. No complications caused by injury to the adjacent teeth with the diamond disk were observed.

The mandibular donor sites with the osteotomy borders were well visualized on postoperative panoramic radiographs (Fig 15). These surgical scars disappeared radiographically within 6 to 12 months, but the lamina dura of the external oblique line had not regenerated. Exceptions were patients in whom reimplantation of half of the bone block was performed; in these cases, a lamina dura was already radiographically visible after 3 months.

In 16 patients, reentry of the harvested area was performed between 6 and 40 months after reimplantation of half the block to harvest another block for another augmentation procedure. In all the cases, a well regenerated and healed external oblique ridge was observed.

In 52 patients an additional CBCT was made for other presurgical diagnostic reasons within 18 to 36 months (average, 29 months). In 33 patients, the donor site had been treated with collagen fleece, and in 19 patients half of the bone block had been reimplanted to regenerate the donor site. In addition, 7 patients underwent bilateral harvesting from the retromolar area, but one site had been reimplanted and the other site had not.

Comparison of preoperative and postoperative CBCT scans (in 341 patients) showed that, after at least 18 months, a certain amount of bone regeneration had taken place, but the external oblique line had not been re-formed, compared to the original external oblique ridge, which was more pronounced with the typical step and the thick cortical bone. In the 19 cases in which half of the bone block had been reimplanted, excellent regeneration of the donor site with re-formation of external oblique ridge was observed. This was confirmed in the 7 patients who underwent bilateral harvesting with and without reimplantation of the half bone block.

## DISCUSSION

To obtain large mandibular bone block grafts, the external oblique ridge is favorable. The proximity of the donor and grafted sites reduces the time needed for surgery and anesthesia, leading to ideal conditions for implant surgery using autogenous bone grafts.<sup>1-3,7-9</sup>

Special attention should be given to the presence of contraindications, either local or systemic, to intraoral bone harvesting. All patients must be well informed of both the advantages and disadvantages of autologous bone grafts.<sup>1,14</sup>

Anatomical variations in donor sites result in grafts with morphologic differences. Clinical evaluation and comparison of donor sites are essential.<sup>3,4</sup> Visual examination and digital palpation<sup>1</sup> allow for preliminary assessments of the morphologic contours and dimensions of the donor site, such as the thickness

and extent of the external oblique ridge. This provides information on the shape of the available bone at the donor site. Radiography should be used to provide additional information on the donor site and its relationship to vital neighboring anatomical structures. The locations of the mandibular canals and the mental foramina can be traced on a panoramic radiograph, while the density of the external oblique ridge is evident. An estimate of bone quality can sometimes be obtained.<sup>1</sup> In this paper, during the period 2000 to 2008, the panoramic radiograph was the only radiologic diagnostic method used before harvesting bone from the external oblique ridge. One study found that the distance from the mandibular alveolar nerve to the buccal wall in the retromolar area is approximately 3.8 to 5.7 mm (mean, 4.7 mm).<sup>15</sup> Thus, the maximum cutting depth of the MicroSaw of 3.2 mm seems to be anatomically appropriate for safe harvesting of blocks from the retromolar and paramolar areas. In the area of the ascending branch (ramus mandibulae), however, the nerve runs much closer to the surface.<sup>15,16</sup> Nerve exposure may occur if the external oblique line is weak and the osteotomies made during bone block preparation are below the level of the nerve course, and also if the distal vertical osteotomy is positioned in the area of the ascending ramus, as the alveolar nerve in this area remains close to the buccal cortex before it extends lingually into the body of the mandible.<sup>16</sup> In this study, to avoid alveolar nerve injury, an inferior alveolar nerve block was avoided; in most cases, only local vestibular and lingual infiltration was performed. This retained minimal sensation to warn the surgeon when approaching the mandibular nerve. The authors recommend that the MicroSaw not be used to its full cutting depth in the distal retromolar area behind the second molar when osteotomies are created below the nerve. A secure 2-mm margin of the osteotomy in this area is recommended (the diamond layer of the disk is 1 mm wide). A low complication rate was experienced in the present study; thus, the described clinical and radiologic protocol seems to be sufficient for safe bone block harvesting.

Since 2009, CBCT scans<sup>17</sup> have been used in this study. According to the authors' experience, this additional diagnostic test is not essential for safe bone harvesting using the MicroSaw, but it provides further information, such as the thickness of the cortical wall and the position of the mandibular nerve.<sup>18</sup> Therefore, it gives helpful information prior to surgery. This information is important, especially if the osteotomies are located below the mandibular nerve. In this study, 2,285 donor site osteotomy lines were positioned basal to the alveolar nerve. The cortical bone in the area of the distal osteotomy had a thickness of 1.5 to 3.5 mm (average thickness, 2.2 mm). The cortical bone

in the area of the mesial osteotomy was much thicker, ranging from 2.5 to 5.5 mm (average, 3.3 mm). In 168 (7.35%) of those cases, mandibular alveolar nerve exposure occurred, generally in the distal area of the donor site, leading to transient sensory problems that lasted, in almost all cases, for a maximum of 12 months. Although no major lesion of the mandibular nerve with permanent anesthesia was observed in any case and only 4 patients (0.1%) felt paresthesia for more than 1 year, the distal osteotomy seems to be more critical and requires special attention to cutting depth.

The results of the present study demonstrate that relatively large volumes of bone can be successfully harvested from the mandible with a low complication rate using a specific technique with the specified instrumentation and protocol. Despite the fact that a large part of the external oblique ridge was removed, no esthetic or functional deficiencies resulted. No complications caused by injury to the adjacent teeth with the diamond disk were observed. In a study of 50 patients, a mean ramus graft of 0.9 cm<sup>3</sup> was obtained using fissure burs.<sup>4</sup> Another study used a piezoelectric surgical device and obtained a mean graft volume of 1.15 cm<sup>3</sup>, with a maximum of 2.4 cm<sup>3</sup>.<sup>13</sup> The difference between that study and the current study (mean volume of 1.9 cm<sup>3</sup>; maximum volume 4.4 cm<sup>3</sup>; graft thickness up to 6.5 mm) might be explained by the different harvesting technique and different instrumentation. In fact, the MicroSaw's thin diamond disks contributed to significantly less bone loss than other techniques.<sup>6,12</sup>

Currently, several types of instruments are used to obtain intraoral grafts; most are piezoelectric instruments<sup>19</sup> or trephine burs<sup>20</sup> of different forms and diameters. However, a trephine bur can remove only small bone pieces in core form and provides only particulate bone, rather than a bone block. The use of such instruments along the ramus is risky because of poor access and uncontrolled depth of the horizontal and vertical sections. The MicroSaw allows the surgeon to obtain a large graft in a short time; an average osteotomy time of 6.5 minutes to harvest a bone block from the mandibular retromolar area was achieved, with few complications. This is documented by the current results with bone block preparation.<sup>1,6</sup>

The postoperative situation after bone harvesting from the retromolar area is similar to that observed after the osteotomy of impacted third molars: edema, hematoma, and pain, for example.<sup>21-23</sup> Postoperatively, minimal pain was observed in 1,624 patients (48.8%), another 1,589 patients (47.74%) had moderate pain, and only 115 patients (3.45%) reported severe pain. However, primary healing complications in this study (1.58%) were rarer than infections following third molar extraction (6% to 8%).<sup>1</sup> This could be related to the presence of a lamina dura, pericoronally and around

the third molar roots, which can have a negative influence on blood supply, bleeding capacity, and the healing process. Concerning disturbances in wound healing, smoking<sup>24</sup> seems to have a negative impact after block removal; 80.4% of patients with this type of complication were smokers. Obviously, repositioning of half the block into the donor site seems to reduce the likelihood of disturbed wound healing, since no infection occurred in any of the reimplanted 431 donor sites.

Osseous regeneration of the mandibular donor site is similar to that observed for the osteotomy of impacted third molars.<sup>21,25</sup> When large bone blocks are harvested, patients should be advised during the first 6 postoperative weeks to eat only soft foods to avoid a potential mandibular fracture. The risk of fracture is greatest approximately 2 to 3 weeks after bone harvesting, because swelling is usually gone by then and the patient can eat again without hindrance.<sup>1</sup>

Autogenous bone, with its capacity to regenerate and form new bone through osteoinductive, osteogenic, and osteoconductive properties, is still the gold standard for the treatment of large lateral and vertical bone defects.<sup>4,5</sup> However, mandibular bone blocks, which consist primarily of cortical bone and a low percentage of cancellous bone, are more resistant to revascularization and consequently may have poor regeneration potential.<sup>1</sup> For this reason, the harvested thick bone blocks were split into two thin bone blocks with the diamond disk according to the split bone block technique of the biologic concept of grafting procedures.<sup>1</sup> Splitting the thick blocks into two thin blocks not only increases the number of bone blocks, offering the possibility to graft more surfaces in different forms, but also improves revascularization and regeneration (Fig 16).<sup>1</sup> The thin blocks were stabilized at the recipient site with microscrews, and any gaps were filled with autogenous bone chips harvested from the donor site with a bone scraper. No biomaterials or membranes were used. This technique with pure autogenous bone, which has been used for 20 years, has shown a high success rate.<sup>1</sup> A prospective study of this modified technique of grafting procedure, with more than 10 years of data, is in preparation for publication.

Surgical scars of the osteotomy borders in the area of the mandibular donor site, which were apparent on the postoperative panoramic radiographs, disappeared radiographically within 6 to 12 months, depending on the regenerative potential of the donor site.<sup>1,25</sup> Donor sites, treated with collagen fleece, usually healed without re-formation of the lamina dura of the external oblique line. In this study, regeneration of the donor site was nearly complete, if one of the blocks left after grafting was replaced at its donor site (Fig 17). This was shown clinically within 6 to 40 months when

reentry of the harvested area was performed and radiologically within 18 to 36 months when a CBCT scan was made. Because the diamond disk in the MicroSaw is thin, it makes a precise osteotomy, and in 47.1% of cases, half bone blocks were placed back into the donor site within the contour of the external oblique line over the collagen fleece, without the need for a stabilizing screw. The remaining 52.9% of repositioned bone blocks were stabilized with a small screw. In all cases, a well regenerated and healed external oblique ridge was found. The complete regeneration of the donor site allows for future re-harvesting of a well-dimensioned bone block if needed for another bone augmentation procedure.

## CONCLUSION

The data and experience described in this 10-year analysis indicate that the described diagnostic protocol and surgical procedure allowed efficient and safe harvesting of bone blocks from the external oblique ridge. The use of cone beam computed tomographic scans is not essential, but it is recommended, as these scans provide additional information about the thickness of bone structures and the position of the mandibular nerve. Because anatomical variations are common, this information is important, especially if bone blocks are harvested from below the mandibular nerve. Repositioning of the split bone block after the grafting procedure at the donor site seems to be an adequate means to almost completely rebuild the mandibular donor site and to reduce wound healing.

## ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

## REFERENCES

1. Khoury F, Antoun A, Missika P. *Bone Augmentation in Oral Implantology*. Berlin, London: Quintessenz, 2007.
2. Zouhary K. Bone graft harvesting from distant sites: Concepts and techniques. *Oral Maxillofac Surg Clin North Am* 2010;22:301–316.
3. Nkenke E, Neukam FW. Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival. *Eur J Oral Implantol* 2014 Summer;7(suppl 2):S203–217.
4. Misch CM. Comparison of intraoral donor sites for onlay grafting to implant placement. *Int J Oral Maxillofac Implants* 1997;12:767–776.
5. Cordaro L1, 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. Khoury F. Augmentation of the sinus floor with mandibular bone block and simultaneous implantation: A 6-year clinical investigation. *Int J Oral Maxillofac Implants* 1999;14:557–564.

7. Pikos MA. Atrophic posterior maxilla and mandible: Alveolar ridge reconstruction with mandibular block autografts. *Alpha Omegan* 2005;98:34–45.
8. Pikos MA. Mandibular block autografts for alveolar ridge augmentation. *Atlas Oral Maxillofac Surg Clin North Am* 2005;13:91–107.
9. Misch CM. Use of the mandibular ramus as a donor site for onlay bone grafting. *J Oral Implantol* 2000;26:42–49.
10. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61:344–349.
11. Resnik R, Misch C. Prophylactic antibiotic regimens in oral implantology: Rationale and protocol. *Implant Dent* 2008;17:142–150.
12. Khoury F, Happe A. Diagnostic and methods of intra oral bone harvesting [in German]. *Z Zahnärztl Implantol* 1999;15:167–176.
13. Happe A. The use of piezoelectric surgical device to harvest bone grafts from the mandibular ramus: Report of 40 cases. *Int J Periodontics Restorative Dent* 2007;27:241–249.
14. Pikos MA. Atrophic posterior mandibular reconstruction utilizing mandibular block autografts: risk management. *Int J Oral Maxillofac Implants* 2003;18:765–766.
15. Kane AA, Lo LJ, Chen YR, Hsu KH, Noordhoff MS. The course of the inferior alveolar nerve in the normal human mandibular ramus and in patients presenting for cosmetic reduction of the mandibular angles. *Plast Reconstr Surg* 2000;106:1162–1174.
16. Leong DJ, Li J, Moreno I, Wang HL. Distance between external cortical bone and mandibular canal for harvesting ramus graft: A human cadaver study. *J Periodontol* 2010;81:239–243.
17. Al-Ani O, Nambiar P, Ha KO, Ngeow WC. Safe zone for bone harvesting from the interforaminal region of the mandible. *Clin Oral Implants Res* 2013;24(suppl A100):115–121.
18. Kainmueller D, Lamecker H, Seim H, Zinser M, Zachow S. Automatic extraction of mandibular nerve and bone from cone-beam CT data. *Med Image Comput Assist Interv* 2009;12(Pt 2):76–83.
19. Sohn DS, Ahn MR, Lee WH, Yeo DS, Lim SY. Piezoelectric osteotomy for intraoral harvesting of bone blocks. *Int J Periodontics Restorative Dent* 2007;27:127–131.
20. Hernández-Alfaro F, Pages C, Garcia E, Corchero G, Arranz C. Palatal core graft for alveolar reconstruction: A new donor site. *Int J Oral Maxillofac Implants* 2005;20:777–783.
21. Inocêncio Faria A, Gallas-Torreira M, López-Ratón M, Crespo-Vázquez E, Rodríguez-Núñez I, López-Castro G. Radiological infrabony defects after impacted mandibular third molar extractions in young adults. *J Oral Maxillofac Surg* 2013;71:2020–2028.
22. Guerrouani A, Zeinoun T, Vervaeet C, Legrand W. A four-year monocentric study of the complications of third molars extractions under general anesthesia: About 2112 patients. *Int J Dent* 2013;2013:763837.
23. Misch CM. The harvest of ramus bone in conjunction with third molar removal for onlay grafting before placement of dental implants. *J Oral Maxillofac Surg* 1999;57:1376–1379.
24. Li J, Wang H. Common implant-related advanced bone grafting complications: Classification, etiology, and management. *Implant Dent* 2008;17:389–401.
25. Diez GF, Fontão FN, Bassi AP, Gama JC, Claudino M. Tomographic follow-up of bone regeneration after bone block harvesting from the mandibular ramus. *Int J Oral Maxillofac Surg* 2014;43:335–340.