Results of Computer-Guided Bone Block Harvesting from the Mandible: A Case Series

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Autogenous bone harvesting is a well-documented surgical procedure. Autogenous mandibular bone harvesting carries a risk of anatomical structural damage because the surgeon has no three-dimensional (3D) control of the osteotomy planes. The aim of this case series was to describe the results of mandibular bone block harvesting applying computer-guided surgery. A sample of 13 partially dentate patients presenting bone deficiencies in the horizontal and/or vertical plane were selected for autogenous mandibular bone block graft. The bone block dimension was planned through a computer-aided design (CAD) process, defining ideal bone osteotomy planes to avoid damage to anatomical structures (nerves, teeth roots, etc) and to generate a surgical guide that imposed the 3D working direction to the bone-cutting instrument. The bone block dimension was always related to the defect dimension to be compensated. A total of 13 mandibular bone blocks were harvested to treat 16 alveolar defects (9 vertical and 7 horizontal). The mean planned mesiodistal dimension of the bone block was 24.8 ± 7.3 mm, the mean height was 8 ± 1 mm, and the mean thickness was 4 ± 2 mm. None of the treated patients experienced neurologic alteration of their alveolar nerve function. The preliminary data from this case series suggested that computer-guided bone harvesting could be a concrete opportunity for clinicians to obtain an appropriate volume of autogenous bone in a safe manner.
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Due to its biologic properties, autogenous bone is considered the gold standard for reconstruction procedures in implant dentistry. Nevertheless, an autogenous graft involves a donor site, and the surgeon's choice may be intraoral. In fact, patients with extraoral donor sites have experienced substantial deterioration in the physical component of health-related quality of life compared with patients treated with intraoral donor sites.[1] The choice between intraoral or extraoral is mainly dictated by the extent of the defect, and consequently the quantity of bone needed for the reconstruction.

Autogenous bone block from the mandible has been indicated by the 4th ITI Consensus Conference as one of the most predictable ways to manage horizontal and vertical bone defects.[2,3] Many authors have described and proposed instruments and methods to harvest mandibular bone block, such as burs, Piezosurgery, diamond discs, and saws.[4–11] Limitations of the bone block harvesting procedure have been also reported.[12–14] These limitations are related to the risk of anatomical structural damage, postoperative patient morbidity, and insufficient volume at the donor site to treat the defect.[7,12–14] These aspects have surely reduced clinical application of this approach.

Although patients don't seem to reject the procedure, a recent publication demonstrated that 61% of patients accepted autologous bone augmentation if needed.[15]

The risk of anatomical structural damage represents the major complication and the primary limitation of this procedure. Surgeons have few reference points in the surgical field to relate to the anatomical information obtained through analysis of the volumetric image, such as the position of the mandibular canal and teeth roots. Some authors have suggested avoiding a complete cut of the cortical plate in the apical portion of the ramus/external oblique ridge area where the alveolar canal is located to overcome the risk of nerve damage.[7] At present, no instruments or methods described or used for cutting bone can avoid risk of anatomical structural damage due because the freehand tridimensional working direction is uncontrollable in relation to these anatomical structures.

Computer-guided implantation has been shown to be more precise compared with traditional freehand drilling procedures due to the working direction imposed by the surgical guide.[16–20] In a recent study, Arisan et al demonstrated that the possibility of improperly positioning a dental implant was statistically significantly higher with the freehand method compared with mucosa- and bone-supported guides.[21]

The aim of this study was to describe the results of the mandibular computer-guided bone harvesting procedure.

Materials and methods

A total of 13 partially edentulous patients presenting insufficient bone quantity for implant placement were selected for autogenous bone augmentation procedures. All patients were fully informed about the surgical procedures and treatment alternatives. The inclusion criteria were presence of a severe bone atrophy of the alveolar ridge in the horizontal and/or vertical plane and adequate bone quantity in the donor area of the mandible (external oblique ridge/ramus or chin). Exclusion criteria consisted of bone defects following tumor resection, tobacco abuse (more than 10 cigarettes per day), severe renal and/or liver disease, a history of radiotherapy in the head and neck region, chemotherapy for treatment of malignant tumors at the time of the surgical procedures, uncontrolled diabetes, active periodontal disease involving the residual dentition, mucosal disease in the areas to be treated, poor oral hygiene, and noncompliance with autogenous bone augmentation surgery.

Preoperative analysis included a complete medical history, a clinical and radiologic examination of the stomatognathic system, and a thorough analysis of the implant recipient site and the bone donor site. Cross-sectional images (reformatted computed tomographic [CT] scans or cone beam CT images) were obtained preoperatively for assessment of the crest dimension and for planning the bone block harvesting.

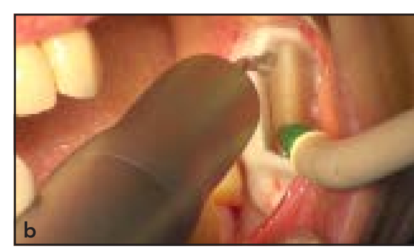
The protocol followed during the planning was that described in the International Patent N PCT/IB2014/061624.[22] The Digital Imaging and Communication in Medicine (DICOM) datasets were processed with diagnostic and analysis software (3Diagnosys 4.0, 3DIEMME) and the mesiodistal linear defect dimension was measured. This measure was reported in the area of the mandible most suitable for bone block harvesting. Using planning software, the anatomical structures, such as the alveolar canal, mental foramina, mental nerve, and teeth roots present in the area of the donor site, were visualized. Through each cross-sectional image, ideal bone-cutting planes were defined, keeping a secure margin from the above anatomical structures (Fig 1). The bone block was defined in all dimensions: length, thickness, and height. The form given to the block was rectangular with a cranial, an apical, and two vertical sides, one mesial and one distal. The thickness of the cutting instrument was considered in planning the block dimension. Once the cutting planes were established, their projection outside the bone body/surface defined the internal faces of the surgical guide (Fig 1). Each face guided the cutting tool direction once this the tool was simply leaning against the surface of the surgical guide. Using computer-aided design (CAD) software (PlastyCAD, 3DIEMME) the final guide design was shaped, including holes for screwing the guide to the bone or anchoring it to the occlusal plate of neighboring teeth. All surgical guides were produced in medical polyamide using a computer-assisted manufacturing (CAM) process (3Dfast).

Surgical protocol

Antibiotics were prescribed to all patients (amoxicillin [Zimox, Pfizer], 1 g orally every 12 hours) for 6 days beginning the day before the surgery. Prior to the surgery, patients were medicated intravenously with a sedative (Dormicum, Roche). In all patients, the surgical procedure was performed under infiltration of local anesthesia (Ultracain DS forte, Sanofi-Aventis). The procedure started in each patient with bone harvesting from the mandible. When the external oblique line was chosen as the donor site, the incision line was characterized by an intrasulcular incision in the molar area, if the teeth were present, or on the top of the alveolar crest in case of an edentulous ridge. A distal incision ran over the external oblique ridge, while a releasing incision was performed mesially. A full-thickness flap was elevated, exposing the external oblique ridge and the lateral aspect of the ramus as well as the lateral aspect of the mandibular body (Fig 2). The surgical guide was screwed to the bone with a 1.3-mm-diameter screw and, when planned, through a tooth anchorage (Fig 3a). Using a piezoelectric instrument (Piezomed, W&H) the osteotomy cuts were made facing the flat side of the piezoelectric insert to the internal face of the surgical guide (Fig 3b). The cutting direction was unequivocally defined by the surgical guide, while the working depth was defined by the volumetric image analysis (Fig 3c). The cranial and mesial osteotomies were done with the B7 insert, the apical and distal with the B2R and/or B2L (Piezomed, W&H). The block was then removed by a straight, thin elevator without the necessity of hammering (Fig 4). The flap was sutured with single and/or mattress sutures. Where chin bone was harvested, the incision line was intrasulcular in the frontal teeth area involving the bases of the papillae and two distal releasing incisions.

Fig 1 *Computer-guided bone harvesting planning. The cutting plane* (green and white) *projection outside the bone body/surface defined the internal faces of the surgical guide* (yellow).

Fig 2 *The external oblique ridge after elevation of a full-thickness flap.*



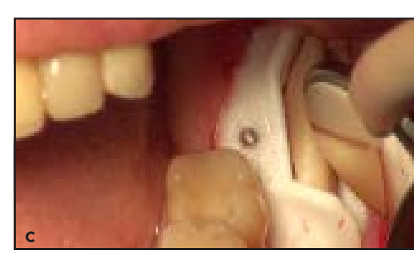


Fig 3 (a) *The surgical guide screwed in in situ.* (b) *Using a piezoelectric instrument, the osteotomy cuts were made facing the flat side of the piezoelectric insert to the internal face of the surgical guide. The cutting direction was unequivocally defined by the surgical guide.* (c) *A clinical aspect of the osteotomies done in accordance with the surgical guide.*

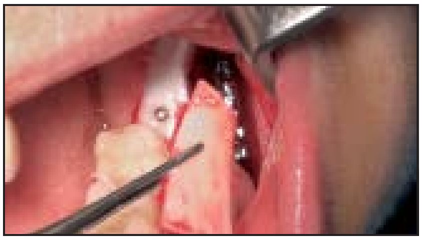


Fig 4 *Harvested bone block from the external oblique ridge.*

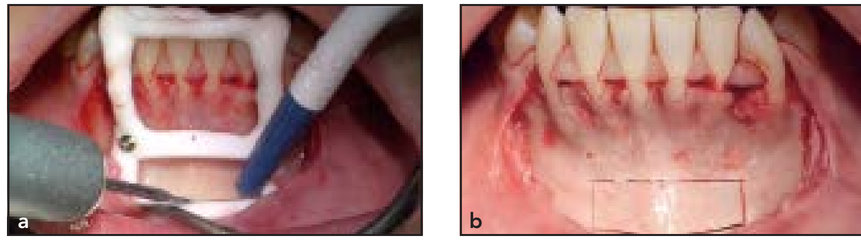


Fig 5 (a) *Clinical view of a bone block harvesting procedure from the chin area. The surgical guide is screwed to the bone and tooth supported. The flat face of the surgical tool was placed against the internal face of the surgical guide.* (b) *Clinical aspect of the osteotomy cuts done in accordance with the surgical guide.*

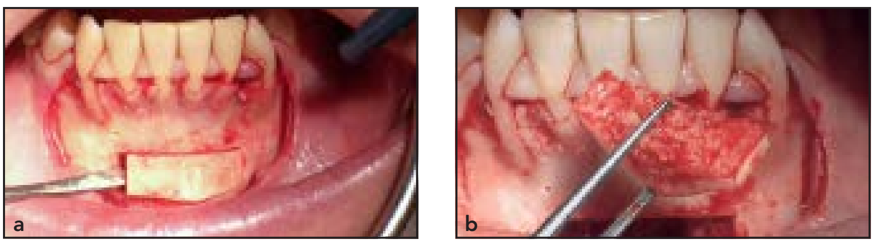


Fig 6 (a) *The bone block was luxated with a thin elevator.* (b) *The harvested bone block from the chin.*

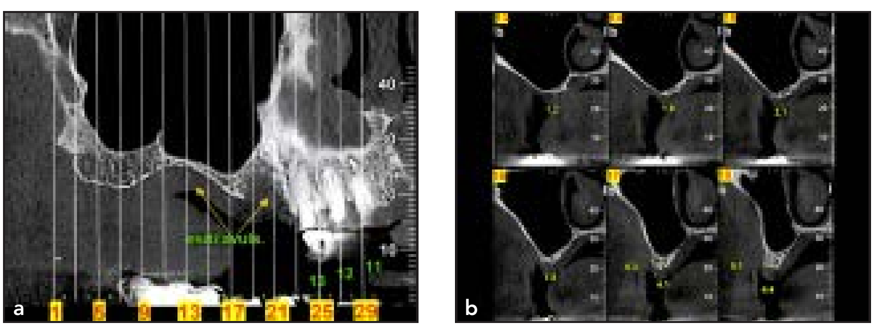


Fig 7 (a) *Presurgical situation of a 6-mm vertical defect in the upper right maxilla.* (b) *Cross-sectional images of the residual bone crest. A vertical autogenous bone augmentation and sinus lifting was planned.*

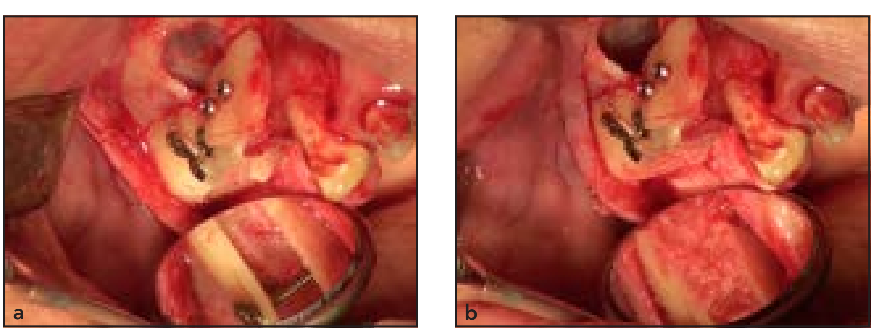


Fig 8 (a) *Autogenous bone laminae were screwed to build the vestibular and palatal walls of the alveolar crest.* (b) *The space between the two bone laminae was filled with autogenous bone particles.*

The flap was elevated and the guide secured to the bone as previously described. All osteotomies were done using the B7 insert (Piezomed, W&H) (Figs 5 and 6). Once the block was removed, the donor site was filled with collagen sponge. The flap was stabilized with tooth anchorage sutures. In all cases the bone blocks were then grafted following Khoury and Khoury's bone augmentation approach[9,23,24] (Figs 7 to 10).

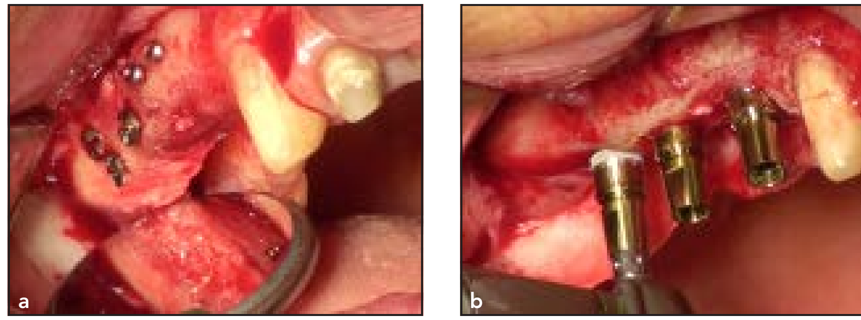


Fig 9 (a) *Clinical situation after 4 months healing. Optimal bone reconstruction of the alveolar crest was achieved.* (b) *Three implants were inserted (XiVE Cell Plus, Dentsply).*

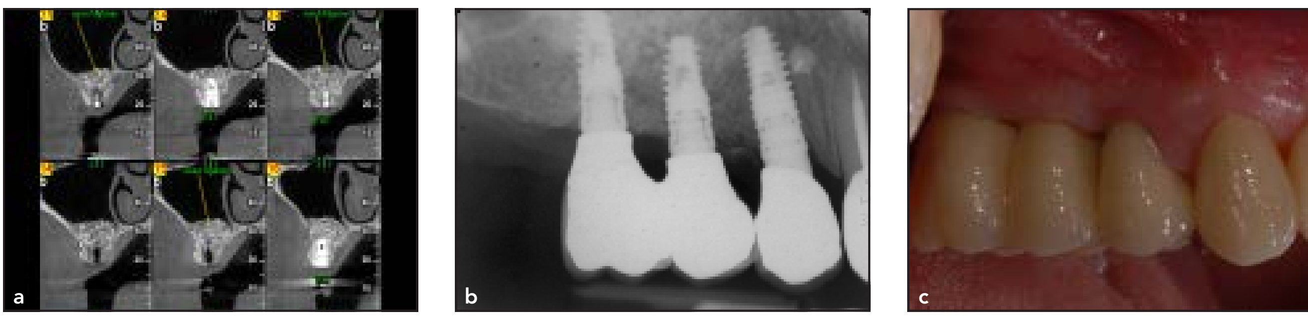


Fig 10 (a) *Radiographs of the treated area 4 months after the implantation surgery.* (b) *Intraoral radiograph of the implants after 12 months of loading.* (c) *Clinical view of the final restoration.*

Results

Demographic data and defect position and dimension are reported in Table 1. A total of 13 patients were treated with computer-guided bone harvesting to manage 16 alveolar deficiencies. The mean mesiodistal defect dimension measured on the preoperative volumetric images was 25 ± 6.1 mm (median: 27 mm). Except for one case, all the treated defects were multiple-tooth gaps (two to five missing teeth), and 64% involved gaps of three or more missing teeth. In three cases (patients 3, 11, and 13), the single harvested bone block was grafted in two different quadrants. In patient 3, the projected bone block was 37.5 mm in length and was grafted in two vertical bone augmentations: an 8-mm-height and 25-mm-length mandibular defect and a 6.5-mm-height and 20-mm-length defect in the maxilla. In patient 11, the 33.2-mm block was grafted horizontally in a maxillary nine-teeth defect from the right first premolar to the left second premolar.

In five cases, bone was harvested from the right, and in six cases, from the left external oblique ridge (see Table 2). In two cases, the bone was harvested from the chin. In 3 out of 12 the surgical guide was screwed to the bone and tooth supported. The mean mesiodistal bone block dimension was 24.8 ± 7.3 mm. The mean height was 8 ± 1 mm. The mean thickness was 4 ± 2 mm. The mean bone block volume from the ramus area was 0.80 ± 0.51 cm^3. The planned bone blocks from the chin area had a mean volume of 0.9 cm^3.

Following Khoury and Khoury's bone block management approach,[9,23,24] the bone block was bisected into two thinner cortical lamina and then grafted in combination with autogenous particles bone scraped from the same lamina (Fig 8). When needed, a sinus lift procedure was done in conjunction with the autogenous bone grafting procedure. The space under the sinus membrane was grafted with deproteinized bovine bone particles (Bio-Oss, Geistlich) mixed with blood. At the reentry after 4 months of healing, an optimal bone reconstruction of the alveolar crest had

Table 1 Patient Demographic Data and Alveolar Defect Characteristics

Patient	Age (y)	Sex (F = female; M = male)	Defect location (missing teeth) (FDI)	Mesiodistal defect dimension (mm)	Type of defect (V = vertical; H = horizontal)
1	50	F	25, 26	20	V
2	30	F	35, 36	21	H
3	45	F	35–37 25–27	25 20	V V
4	45	F	45–47	22	V
5	57	F	24–27	30	H
6	49	F	45–47	29	V
7	29	F	14	9	V
8	55	M	24–27	34	V
9	67	M	35–37	27	V
10	66	F	35, 36	20	V
11	63	M	11–14 21–25	28 32	H H
12	60	F	45–47	27	V
13	20	F	11–14 21–24	28 28	H H
Mean	**49**			**25**	
SD	**15**			**6.1**	

Table 2 Bone Block Data

	Donor site location			Guide anchorage		Planned bone block dimension				
Patient	Right ramus	Left ramus	Chin	Bone	Tooth + bone	Mesiodistal dimension (mm)	Mean height (mm)	Mean thickness (mm)	Volume (cm³)	Teeth present at the donor site (Y = yes; N = no)
1	X			X		27.0	8.0	4.00	0.78	Y
2		X			X	17.3	8.2	2.60	0.36	Y
3		X		X		37.5	10.0	5.70	2.13	N
4	X			X		22.7	7.5	3.57	0.60	N
5		X		X		19.9	8.0	3.97	0.63	Y
6	X			X		30.0	7.1	4.83	1.02	N
7			X		X	20.6	6.4	7.90	1.04	Y
8	X			X		26.8	8.5	3.80	0.86	Y
9		X		X		25.9	7.5	2.87	0.55	Y
10		X		X		12.0	7.1	3.40	0.28	Y
11		X		X		33.2	8.2	3.17	0.86	N
12	X			X		29.2	7.0	3.60	0.67	N
13			X		X	30.9	7.9	10.50	0.77	Y
Total	5	6	2	10	3					
Mean						24.8	8.0	4.00	0.80	
SD						7.3	1.0	2.00	0.50	

been achieved (Fig 9a). Three implants were inserted (XiVE Cell Plus, Dentsply) (Fig 9b). Figure 10a shows radiologic healing of the treated area 4 months after the implant surgery (8 months after the bone grafting procedure). After 12 months of loading, an intraoral radiograph (Fig 10b) showed absolute stability of the peri-implant bone with no resorption. In case of mandibular defect, the followed protocol was equivalent; implant surgery was done 4 months after the bone augmentation procedure (Figs 11–13).

In nine cases bone was grafted vertically, and in seven cases horizontally. Healing was uneventful in all cases and patients did not experience any alteration in function of the neurologic structures (inferior alveolar nerve and/or mental nerve) or of the tooth vitality in the short or long term.

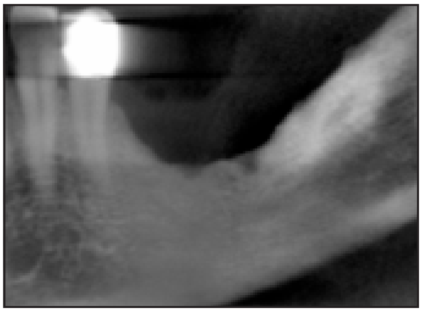


Fig 11 *Radiograph of a 7-mm vertical defect in the posterior left mandible.*

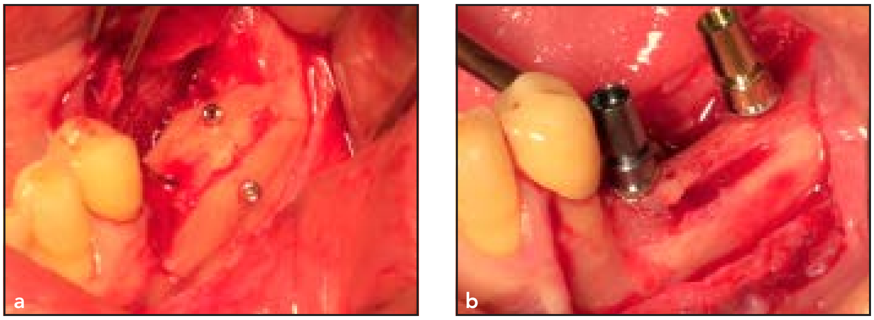


Fig 12 (a) *Clinical image of an autogenous vertical bone graft.* (b) *Clinical situation of the reconstructed alveolar crest 4 months post augmentation surgery, when two implants were inserted.*

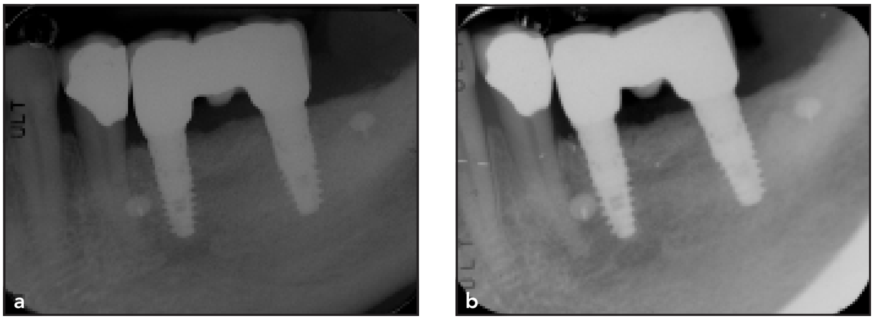


Fig 13 (a) *Radiograph of the treated area 12 months postloading.* (b) *Radiograph of the same site after 3 years of follow-up. The bone level seems to be well maintained.*

Discussion

The aim of this case series was to describe the results of a procedure for mandibular bone block harvesting using computer-guided surgery. Autogenous bone has superior biologic performance compared with bone substitute, as demonstrated in a recent study by De Santis et al.[25] Nevertheless, autogenous bone harvesting has limitations. Independent of the method/instrument used, all the bone cuts are done without sure reference points that could help the surgeon determine the positions of anatomical structures. So all osteotomies require a great safety margin, reducing the potential dimension of the harvestable bone block. In harvesting bone from the ramus area, Clavero and Lundgren suggested that the apical bone cut should not be done completely through the cortex to avoid the risk of inferior alveolar nerve damage.[7] In the superior/sagittal osteotomy, they used just the tip of the saw to avoid interference with underlying anatomical structures.[7] Other authors have suggested completely avoiding the apical osteotomy in the ramus area, instead promoting a fracture of the cortical plane.[13] Many authors stressed the fact that osteotomy instruments should not be used in the depth of the bone structure due to the clinical impossibility of controlling the osteotomy tridimensional direction. The osteotomy lines should involve just the thickness of the bone cortical plate or less, and the luxation of the block should be determined by a fracture line generated by a lever or by the combination of a bone chisel and a hammer, which may result in intraoperative patient discomfort. Because the fracture line runs uncontrolled following minor resistantance,[7,8] the block has to be carefully lifted to ensure that the inferior alveolar nerve is not trapped within the graft.[7] Computer planning of the osteotomy lines allows the instruments to be brought deeper into the bone, reducing the inner bone surface that has to be fractured or avoiding fracture completely if the osteotomy lines are planned to meet.

To maintain the front teeth vitality when harvesting bone in the chin area, Pommer et al suggest a safety zone of 8 mm in the vertical plane from the tooth apexes and avoiding any osteotomy deeper than 4 mm.[26] Other studies have reported that these safety margins could be reduced to 4 and 5 mm from the tooth apexes, while the depth limit is determined by the lingual cortical plate.[7,13] Nevertheless, all the measures appear to be generalized and not related to specific anatomical characteristics of the single patient to be treated. Bone harvesting with a surgical guide generated from a stereolithographic model[27] surely gives the surgeon an opportunity to bring into the surgical field information regarding the superficial position of the osteotomy lines (contour of the harvestable bone block on the bone surface). No information will help the surgeon determine the direction the cutting tool must follow to make a safe osteotomy. However, a computer-guided bone harvesting procedure allows for the osteotomy to be customized to the real and specific position of anatomical structures, minimizing and/or avoiding risk of damage. In fact, the superficial position of the osteotomy and the working directions into the bone volume are imposed to the cutting tools by the surgical guide. Moreover, the accuracy of the planned procedures means the surgeon can increase the harvestable bone block dimension, customizing the safety margin for each patient based on the anatomical structures.

In a recent study, Verdugo et al[28] calculated the harvestable bone volume from the chin and from the ramus using CAD software. The harvestable symphysis bone volume was 2.3 ± 0.7 cm^3 (range: 0.8 to 4.4 cm^3) and for the ramus, 0.82 ± 0.21 cm^3 (range: 0.42 to 1.31 cm^3).[28] The area where the bone volume was measured was defined and fixed independently from the real anatomical dimension (the ramus area, for example, was defined as the measurements extended from the midaspect of the first mandibular molar toward the ascending ramus midway between the third molar area and the mandibular foramen; apically, they extended 5 mm before reaching the inferior alveolar canal). The authors did not explain if or how they transferred the preoperative analysis and measures obtained on the CAD software into the surgical field. In the present protocol, no anatomical predefined limits were fixed. The harvestable bone volume was always related to the defect dimension, and in many cases this volume was not in accordance with the maximum harvestable volume from the donor site and in others the planned bone block exceeded Verdugo et al's proposed limits.[28] The mean bone block volume from the ramus area was 0.80 ± 0.51 cm^3, with range of 0.28 to 2.13 cm^3 (median 0.70 cm^3). The planned bone blocks from the chin area had a mean volume of 0.9 cm^3. These mean values are in accordance with ranges presented by Verdugo et al.[28]

Conclusions

The presented method combines the advantages of a computer-guided procedure in controlling the osteotomy lines with the ability to maximize and relate the harvestable bone block volume to the bone volume needed for defect reconstruction.

Acknowledgments

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

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