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Outcomes and Treatments of Mal Fractures Caused by the Split-Crest Technique in the Mandible

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ABSTRACT

In this study, we investigated cases of mal fracture occurring during the split-crest procedure. In all subjects (six patients), the free cortical bone segment caused by the mal fracture was carefully maintained in the lateral position without fixation using a titanium plate or screw. On pre- and postoperative multiplanar reconstruction CT, the average total alveolar increase was 5.0 mm in the lower portion 1 mm from the top of the alveolar ridge, and the average total alveolar increase in the lower portion 11 mm from the top of the alveolar ridge was 2.2 mm. A total of 11 dental implants were placed immediately at the same time as the split-crest procedure, while three dental implants were placed after a waiting period of 4-11 months from bone augmentation. During an average follow-up of 27.8 months, there were no complications or cases of failed implants. Consequently, among the patients who experienced mal fracture during the split-crest technique, a sufficient volume of alveolar bone was obtained without the need for rigid fixation of the free bone segment, and the dental implants placed within the area of the mal fracture showed a good prognosis.

INTRODUCTION

Alveolar bone resorption reduces the bone volume available for the placement of dental implants, and a diminished bone quantity increases the incidence of implant failure. As to the horizontal dimension of bone quantity around the dental implant, at least 1 mm of bone is required on both the buccal and palatal sides. In cases involving a severely narrow alveolar ridge, the use of bone augmentation techniques, including the split-crest procedure, can improve the diminished bone quantity. The split-crest technique was first described by Simion et al. as a procedure for bone augmentation in combination with immediate implant placement (1). The aim of this procedure is to create a new site for implant placement via longitudinal osteotomy in the alveolar bone. The vestibule cortical bone is repositioned laterally using a greenstick fracture, although various authors have experienced mal fracture of the vestibule segment in the mandible in some cases treated with the split-crest technique. The risk of a mal fracture is higher in the mandible than in the maxilla because the bone in the mandible is harder and more brittle (2, 3). The fractured segment subsequently becomes a full free cortical block, with the disadvantage of microvascular perfusion, which results in bone necrosis. However, to the best of our knowledge, there have been no reports regarding the outcomes of this complication. Consequently, we investigated mandible cases involving a mal fracture caused by the split-crest technique and examined pre- and postoperative alveolar bone dimensions determined on multiplanar reconstruction CT as well as the implant prognosis.

PATIENTS AND METHODS

A total of six patients (five females and one male) treated with mandibular augmentation surgery using the split-crest technique between April 2004 and March 2013 at the Department of Oral and Maxillofacial Surgery at Kobe University Hospital were included in this study. All patients provided their informed consent to participate, and this study was exempted by the Medical Ethics Committee of Kobe University due to the

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retrospective design. In addition, the study protocol conformed with the Declaration of Helsinki. The age of the patients ranged from 25 to 71 years, with a mean age of 58.7 years. The reasons for missing teeth included three cases of trauma, two cases of periodontitis and one case of a cyst. The study population included no smokers and only one patient with hyperlipemia. There were no patients affected by diabetes or undergoing radiation therapy. The preoperative alveolar bone quantity and morphology were observed using multiplanar reconstruction CT in all cases.

The surgical procedures are described below. The procedures were performed under local anesthesia in three cases and general anesthesia in three cases. An incision was made intraorally along the mandibular alveolar crest, followed when necessary by two vertical incisions defining the surgical area. After raising the mucoperiosteum on the vestibule side, a horizontal groove along the alveolar crest and two vertical grooves at the mesial and distal sites on the vestibule side were formed using a micro bone saw (Aesculap Power Systems®/Aesculap, USA) or ultrasonic bone cutting device (Surgery Falcon®/Osada, Japan). Additional osteotomy was performed using a bone chisel, and a repositioning trial of the vestibule cortical bone was conducted in order to place the bone laterally via a greenstick fracture. In cases of a mal fracture of the osteotomized segment, the free cortical bone was carefully maintained in the lateral position without the use of fixation with a titanium plate or screw. When there was a need to place the dental implant immediately to shorten the treatment duration, a TiUnite® implant (Nobel Biocare, Sweden) was employed. In order to obtain rigid fixation of the implant, the tip of the implant was deeply inserted below the fracture line (**Fig. 1**). When the implant could not be rigidly fixed in this procedure, the immediate placement was not performed. The gap between the free vestibule cortical bone and lingual original bone was filled with grafted bone chips or bone substitute materials (**Fig. 2**). The grafted bone was taken from the iliac crest (at the anterosuperior edge of the iliac wing) in one case, the mandibular ramus in one case and the chin in one case, while artificial bone substitute materials were grafted in five cases (**Table I**). The vestibule periosteum was cut, when necessary, in order to extend the vestibule mucoperiosteal flap, and the mucoperiosteum was tightly closed with interrupted sutures (Vicryl 3/0). At least three months later, additional TiUnite® implants were inserted in the regions where immediate implant placement had not been performed. In all cases, implant placement was carried out according to the two-stage method, and the secondary operation was performed at least three months after the first operation.

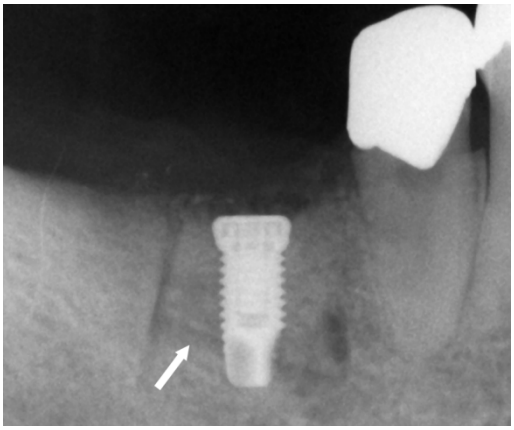

Fig. 1. The periapical radiography. To get rigid fixation of the implants, the tip of the implants is deeply inserted below the fracture line (arrow).

Fig. 2. The view of surgical site. A gap between the free vestibule cortical bone and lingual original bone is filled with grafted bone chips or bone substitute materials.

Table I. Grafted autologous bone and artificial bone substitute materials.

Case No.	Autologous bone grafts	Artificial bone substitute materials
1	Iliac crest	NEOBONE®
2	Mandibular ramus	None
3	Chin	NEOBONE®
4	None	NEOBONE®
5	None	NEOBONE®
6	None	NEOBONE®

Alveolar horizontal thickness was evaluated using the preoperative and three months postoperative multiplanar reconstruction CT. Within the area of implant insertion, two horizontal lines were drawn from the lingual side to the vestibule (buccal or labial) side. Line A was drawn on the lower portion 1 mm from the top of the alveolar ridge, and line B was drawn on the lower portion 10 mm from line A. The width of the bone ridge was measured along both lines A and B (**Fig. 3**).

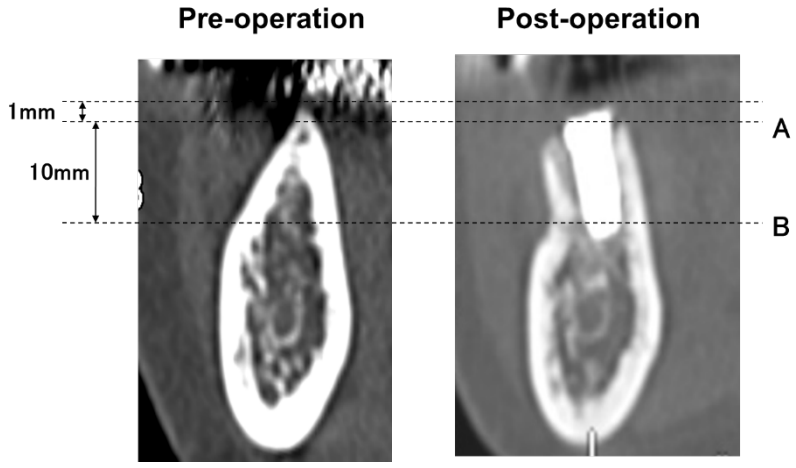

Fig. 3. The pre- and postoperative multiplanar reconstruction CT. Two horizontal lines (line A: the lower part of 1 mm from the top of alveolar ridge, line B: the lower part of 10 mm from the line A) are drawn, and the bone ridge widths are measured on both lines.

RESULTS

The surgical site of the split-crest technique is shown in **Fig. 4.** This technique was adapted to molar or premolar regions in all cases, and two cases also included the incisor region. There were no complications except mal fractures, during or after the operation. Pre- and post-operative bone ridge widths are shown in **Table II.** Along line A on multiplanar reconstruction CT, the mean preoperative bone ridge width of 11 regions in six cases was 3.4 mm, with a range of 1.6 to 6.4 mm, while the mean postoperative width of 10 regions in five cases was 8.3 mm, with a range of 6.4 to 11.9 mm. Along line B, the mean preoperative width of 11 regions in six cases was 9.8 mm, with a range of 6.6 to 13.0 mm, while the mean postoperative width of 10 regions in five cases was 12.0 mm, with a range of 9.5 to 17.4 mm. Consequently, the average total alveolar increase was 5.0 mm on line A and 2.2 mm on line B.

In total, 14 dental implants were placed (**Table III**). The median length of the fixtures was 9.9 mm, with a range of 8.5 to 13.0 mm, and the median width was 3.6 mm, with a range of 3.3 to 3.75 mm. A total of 11 dental implants were placed immediately in six cases at the time of the split-crest procedure, while three dental implants in three cases were placed after a waiting period of 4-11 months after alveolar augmentation. Among the 14 dental implants, there were no cases of failed implants after an average follow-up of 27.8 months (range: 8 to 59 months).

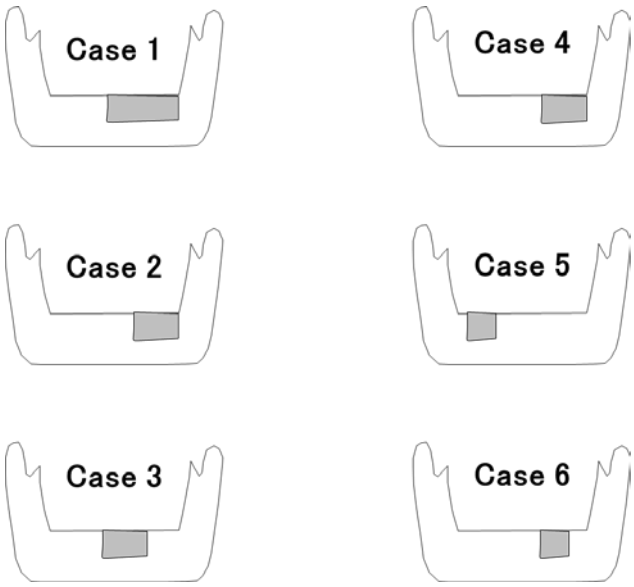

Fig. 4. Distribution of the operation site with the split-crest technique

Table II. Pre- and post-operative bone ridge widths

Case No.	Measure point (Two-digit system)	Line A			Line B		
		Pre -operation	3 months post -operation	Bone increase	Pre -operation	3 months post -operation	Bone increase
1	31	4.0	8.0	4.0	13.0	13.5	0.5
	34	3.8	6.5	2.7	11.0	11.0	0.0
	36	4.0	9.0	5.0	9.0	9.5	0.5
	37	2.7	7.0	4.3	8.5	10.0	1.5
2	35	2.3	10.0	7.7	8.3	12.0	3.7
	37	2.2	8.2	6.0	12.2	17.4	5.2
3	32	4.0	7.2	3.2	6.6	10.0	3.4
	34	6.4	11.9	5.5	7.9	10.0	2.1
4	37	1.6	6.4	4.8	11.5	14.3	2.8
5	46	2.8	9.2	6.4	10.5	12.5	1.9
6	34	3.8	-	-	9.3	-	-
Ave.		3.4	8.3	5.0	9.8	12.0	2.2

Table III. Size and number of implants

Case No.	Size of implant (length/diameter)	Number of total implants	Number of immediate -placed implants
1	3.75/8.5	3	3
	3.3 x 11.5	1	1
2	3.75 x 10.0	2	1
	3.75 x 8.5	1	1
3	3.3 x 13.0	2	2
	3.75 x 8.5	1	None
4	3.75 x 10.0	2	1
5	3.75 x 8.5	1	1
6	3.3 x 10.0	1	1

DISCUSSION

In cases of alveolar bone resorption, onlay bone grafts, guided bone regeneration (GBR), the titanium-mesh technique, distraction osteogenesis and the split-crest technique are used for alveolar bone augmentation (1, 4 -7). A weak point in the split-crest technique is the impossibility of vertical alveolar bone development. However, some of the advantages of this technique include the fact that simultaneous implant insertion can be adapted and autologous bone grafting is not indispensable. Therefore, many clinicians employ this method for dental implant surgery.

In the split-crest technique, it is necessary to reposition the vestibule bone segment laterally using a greenstick fracture. It is difficult to induce a greenstick fracture, especially in the mandible, which is hard and brittle. In order to increase bone elasticity and improve mobilization, a longitudinal basal notch is sometimes created on the surface of the vestibular bone (8, 9). The creation of this notch requires full stripping of a mucoperiosteal flap on the vestibular side; therefore, one demerit of this technique is that full stripping can inhibit microvascular perfusion between the mucoperiosteal flap and the vestibular bone segment. On the other hand, Piccinini presented a case report in which a split bone on the vestibular side was completely removed then replaced and stabilized with bone screws (2). In the present study, the vestibular segment was kept in the lateral position and healed without the need for rigid stabilization with a titanium plate or screw. The free vestibular bone segment was indirectly but tightly closed with interrupted mucoperiosteal sutures to the original lingual bone; thus, the free vestibular segment should be protected from surrounding stressors, such as bite strength. Consequently, a free bone segment associated with a mal fracture does not require rigid fixation. In contrast, dental implants with an abutment, which are used in one-stage surgery, conducts surrounding stressors to the jaw bone. Increased stress and deflection prevent healing of the free bone. Accordingly, dental implants without the abutment which are used in two-stage surgery are required in cases of simultaneous dental implant insertion.

Anitua et al. measured the bony ridge before and after the split-crest procedure at two points: one in the basal portion of the crest and one in the middle zone located 8 mm from the first measurement (3). The authors showed a mean expansion of the 37 inserted implants in 20 cases of 3.35 mm. Although the measured points differed between that and the present study, the mean expansion in the current study (the average of the two measured points on line A and B) was 3.56 mm, which approximates that observed in the other study. Accordingly, the occurrence of mal fractures following the split-crest technique does not reduce the gain in bone quantity.

Among the 14 dental implants evaluated in this study, four were 3.3 mm in diameter and 10 were 3.75 mm in diameter. Anitua et al. demonstrated that 64.9% of used implants in cases involving the split-crest technique are less than 3.3 mm in diameter (3). The use of a narrow implant has an advantage in terms of ease of insertion into narrow bone, although narrow implants are undesirable for application in the molar or premolar region due to a mismatch with the site of crown formation. In the present study, there were no cases of failed implants or complications. Therefore, middle-sized implants (3.75 mm) can be employed in cases of a mal fracture associated with the split-crest technique.

Although controversy exists regarding the simultaneous use of implant placement and free bone grafting, some authors have reported the application of simultaneous dental implant placement and block grafting (10 -12). Riu et al. demonstrated the high potential of cortical bone in allowing for simultaneous implantation (13). In the present study, the mal fracture segment was turned into a full free cortical block, and simultaneous implant placement was acceptable when the tip of the implant was inserted deeply below the fracture line in order to obtain rigid fixation.

Autologous bone is considered to be the best material for reconstructing bone defects, whereas grafted bone decreases in quantity by 30-50% within the first year after surgery (13). The mechanisms underlying bone graft resorption are not fully understood, although it is thought that graft resorption is associated with local vascularization or trauma during the early healing period and the bone remodeling process thereafter. Several authors have demonstrated that membranous bone grafts maintain their volume to a greater extent than endochondral bone grafts, as the origin of membranous bone involves a higher level of cortical bone quality (14), while cancellous bone grafts revascularize much more quickly than cortical bone grafts (15). Accordingly, the use of a combination of a cortical bone block and iliac cancellous bone promotes early vascularization and maximum graft maintenance. In contrast, hydroxyapatite ceramics (NEOBONE®/MMT, Japan) (16), an artificial bone substitute, was grafted alone in three of six cases in this study. This type of hydroxyapatite ceramics has a three-dimensional structure, with spherical pores of uniform size interconnected by window-like holes that allow for new bone formation. Unfortunately, the number of subjects in this study was too small to draw any conclusions regarding the usefulness of bone substitutes in cases of mal fractures. Importantly, however, there were no complications or cases of failed implants in this study.

CONCLUSION

Even if mal fracture occurred in the split-crest technique, sufficient volume of the alveolar bone could be obtained without any rigid fixation of a free bone segment, and the dental implants placed within the mal fracture area showed good prognosis.

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