Dental Sciences Journal of International
Uluslararası Diş Hekimliği Bilimleri Dergisi

Research Araştırma

Expansion the Narrow Posterior Mandibular Alveolar Ridge Using Two-Stage Ridge Splitting Technique

İki Aşamalı Alveolar Kemik Split Tekniği Kullanarak Dar Mandibulanın Posterior Alveolar Kemiğin Genişletilmesi

ABSTRACT

Alveolar ridge splitting technique with immediate implant placement is usually performed to overcome the deficiency of the alveolar bone width and significantly shortens the treatment time. In the mandible there is a higher risk of malfractures and a lack of initial stability for the implants, so the two-stage technique is recommended. The present study reports the clinical results of the two-stage ridge technique in the posterior region of the mandible.

A total of 12 patients with an edentulous narrow alveolar bone ridge in the posterior mandibular region were included in the present study, Two-stage ridge splitting technique was applied to increase the width of alveolar bone. After 4 months of surgery, 15 dental implants were inserted in the expanded ridges. The alveolar bone width, complications of the surgery, and survival rate of dental implants were evaluated.

The mean bone gain in the width of the alveolar bone was: after surgery 2.8 mm (SD: 0.53) (range, 2.1 – 3.6 mm), and after 4 months of surgery 2.22 mm (SD: 0.23) (range, 1.9 – 2.6 mm). One case of wound dehiscence was recorded. The survival rate of implants was 93.3 % after 6 months of functional loading. 84.61% of the expanded areas were successful in providing an adequate width.

This technique can be considered a safe procedure with satisfactory results if appropriate cases selected.

Key words: Narrow alveolar ridge, Ridge splitting technique, Posterior mandible, Dental implant.

ÖZ

Alveolar kemik split tekniği, hemen implant yerleştirilmesi ile birlikte, genellikle alveolar kemik genişliğinin eksikliğini gidermek ve tedavi süresini önemli ölçüde kısaltmak için yapılır. Mandibulada daha yüksek kırık riski ve primer implant stabilitesi eksikliği vardır. Bunun için iki aşamalı teknik tavsiye edilir. Bu çalışma, mandibulanın posterior bölgesindeki iki aşamalı alveolar kemik split tekniğinin klinik sonuçlarını raporlamaktadır.

Posterior mandibular bölgede, dar dişsiz alveoler kemiğe sahip toplam 12 hasta çalışmaya dahil edildi ve alveolar kemiğin genişliğini arttırmak için iki aşamalı alveolar kemik split tekniği uygulandı. Ameliyattan 4 ay sonra genişletilmiş alveolar kemiklere 15 dental implant yerleştirildi. Alveolar kemik genişliği, cerrahi komplikasyonlar ve dental implantların

Abdulkareem ALMARRAWI
ORCID: 0000-0002-9163-6973

Bülent Ecevit Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Cerrahisi Anabilim Dalı, Zonguldak, Türkiye

Geliş tarihi / *Received*: 24.06.2020
Kabul tarihi / *Accepted*: 10.08.2020
DOI:

İletişim Adresi/*Corresponding Adress:*
Abdulkareem ALMARRAWI
Bülent Ecevit Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Cerrahisi Anabilim Dalı, Zonguldak, Türkiye
E-posta/*e-mail*: a-marrawi@hotmail.com

sağkalım oranları değerlendirildi.
Alveolar kemiğin genişliğindeki ortalama kemik kazancı şuydu: ameliyattan sonra 2.8 mm (SD: 0.53) (aralık, 2.1 - 3.6 mm) ve ameliyattan 4 ay sonra 2.22 mm (SD: 0.23) (aralık, 1.9 - 2.6 mm). Ayrıca bir komplikasyon (yara dehisens) kaydedildi. 6 aylık fonksiyonel yüklemeden sonra implantların sağkalım oranı% 93.3 olarak tespit edilmiştir. Genişleyen alanların % 84.61'i yeterli genişlik sağlamada başarılı olmuştur.
Bu teknik, uygun vakalar seçildiğinde tatmin edici sonuçlarla güvenli bir teknik olarak kabul edilebilir.
Anahtar sözcükler: Alveolar kemik split tekniği, Dar alveoler kemik, Posterior mandibula, Dental implant.

INTRODUCTION

The resorption and remodeling of the alveolar ridge after tooth removal is a natural healing phenomenon (1, 2). Following tooth loss, the adjacent bone resorbs to a greater extent horizontally than vertically in the anterior and posterior regions of the mouth (3-5). This resorption process results in a narrower and shorter ridge (6).

Sufficient bone volume is a prerequisite for the long-term success of an implant (7), and in cases of very narrow ridges, a surgery for augmentation is still a necessary intervention (8).

Ridge split technique is a way to solve the problem of the width in narrow ridges with adequate height. In 1985 Osborn et al described the 'extension plasty', a two-stage method for splitting and extending the alveolar crest and filling the expanded space with hydroxyapatite or autogenous bone, while insertion of the implant was performed 8–12 weeks later (9). Nentwig & Kniha reported the bone splitting technique in 1986, as a one-staged method that allowed the extension of the alveolar crest and insertion of the implant at the same time (10).

The lateral ridge expansion technique is aimed at the creation of a new implant bed by longitudinal osteotomy of the alveolar bone (11). Splitting of atrophic alveolar ridges essentially converts a one-wall defect to a four-wall defect. The benefit of additional defect walls was demonstrated by Cortellini et al. 1993 who found that bone defect filling improved proportionally to the number of residual defect walls (12).

The lateral ridge expansion technique with simultaneous immediate implant placement is usually performed because it shortens the total treatment time (13-15). This technique is more suitable to the maxilla than the mandible owing to the thinner cortical plates and softer medullary bone (15). In the mandible, the risk of mafracture of the osteomized buccal segment is greater because of the lower flexibility and thicker cortical plates. So the two-stage ridge splitting technique (16), or staged ridge splitting technique (11) are used in the mandible.

The purpose of this study was to report the clinical results of the two-stage splitting ridge technique used to expand the edentulous narrow posterior mandibular alveolar ridges.

MATERIALS AND METHODS

A total of 12 patients (3 males, 9 females, with a mean age of 40.4 years) with an edentulous narrow alveolar bone ridge in the posterior mandibular region were included in the present study, Two-stage ridge splitting technique was applied to all patients to increase the width of alveolar bone before dental implants insertion.

Inclusion Criteria

1) narrow edentulous alveolar ridge in the posterior mandibular region, 2) a minimum ridge width of 3.0 mm is preferred with a minimum bone height of 10 mm, 3) absence of any facial bone concavities, 4) absence of any systemic diseases including those affect bone healing, 5) no previous radio or chemotherapy, 6) absence of any disease in soft tissue over the surgical site and 7) the patient should not be smoky or alcoholic with good oral hygiene.

Patients gave informed consent, and approval of the Scientific Research Committee of Damascus University was obtained (registration number 1467).

Surgical Technique

Before the surgical operation, the preoperative patient assessment which included the medical history, physical examination, and radiographic examination using the CBCT was done.

The surgery was performed under local anesthesia (2% lidocaine with epinephrine) using subperiosteal infiltration from buccal and submucosal infiltration

from lingual in all cases to avoid the inferior alveolar nerve injury during alveolar bone splitting.

The partial-thickness flap with minimal mucoperiosteal stripping was used. Tow full-thickness incisions were done in the soft tissue: the first a midcrestal gingival incision (figure 1 and 2), and the second was releasing incision at the mesial side (figure 3).

Figure 1: An edentulous narrow alveolar ridge before surgery.

Figure 2: The midcrestal

Figure 3: The mesial releasing incision.

Then the alveolar bone was exposed just on the crest of the alveolar bone and on the mesial, so mucoperiosteal dissection was not performed toward the alveolar crest on the buccal side. At the distal, just a tunnel was made by the periosteal elevator under the periosteum without releasing incision (figure 4).

Figure 4: At the distal, a tunnel was made by the periosteal elevator under the periosteum without releasing incision.

So the surgery was done without a full mucoperiosteal flap to preserve the blood supply to the buccal plate.

A midcrestal osteotomy with a diamond disc was performed and terminated approximately 1.5 mm from adjacent teeth, and two vertical cuts with a fissure bur were then performed on the proximal and distal ends of the midcrestal osteotomy (figure 5).

Figure 5: Vertical bone cut on mesial.

The three-dimensional radiography performed before the surgery was used to study the shape and inclination of the alveolar bone, thus directing the bone chisels during the splitting. The splitting was performed using chisels with a depth between 6-8 mm (figure 6), and at least 2 mm of bone was maintained over the inferior mandibular canal. Carefully and gradually the splitting was done to avoid any malfracture. After inserting the chisel to the decided depth it was left for a while to give time for buccal plate extension, and then gradually the buccal plate extended buccally before making the greenstick fracture (figure 7). In two cases a corticotomy at the base of the buccal bone plate was done through a tunnel was made from the mesial releasing incision due to very thick cortical plates.

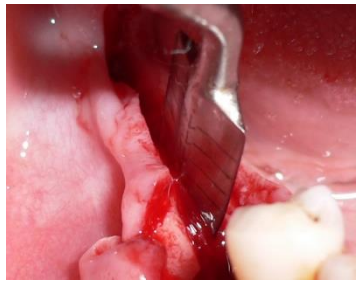


Figure 6: Inserting the chisel to the decided depth.

Figure 7: Completing the buccal plate splitting.

After bone splitting the bony gap was filled by a ground autogenous bone graft taken from the retromolar region (figure 8), and then wound closure was performed using 3-0 silk sutures (figure 9).

Figure 8: Filling the bone gap by the autogenous bone graft.

Figure 9: Suturing.

Instructions of postoperative care were given. Postoperative medications include: antibiotic (amoxicillin + clavulanic acid), anti-inflammatory (ibuprofen) and mouth rinses (0.12% chlorhexidine). After 7-10 days, the sutures were removed (figure 10).

Figure 10: After removing the sutures.

Bone graft harvest

The bone graft which used in all cases was autogenous bone graft harvested from the retromolar region from the same side of bone splitting. The all retromolar regions were studied by the CBCT to ensure adequate bone height and width, and absence of impacted teeth.

Under local anesthesia the surgical incision was made and the retromolar region exposed, then the bone grafts were taken by trephine bur (the outside diameter 6 mm and the inside diameter 5 mm) (Figure 11), at least 1 mm of cortical bone in lingual and buccal sides and 2 mm over the inferior mandibular canal were kept. The bone grafts were then ground by a bone mill and applied in the splitting gap, and then the suture was done by 0.3 silk.

Figure 11: Bone graft harvest from the retromolar region.

Measurement of alveolar bone width

The width of the alveolar bone was measured using cone-beam computerized tomography (CBCT) three times: 1) before surgery, 2) after surgery, 3) after 4 months of surgery. A reference level was adopted (the level passing through the mental foramina) to obtain the same studied sections every time. The interval between the sections was determined by 1 mm, and the thickness of 0 mm (very small) was chosen. At every time the width of the alveolar bone was measured horizontally below the crest of the alveolar bone by 1 mm on three cross-sections (table 1), and then the mean was calculated.

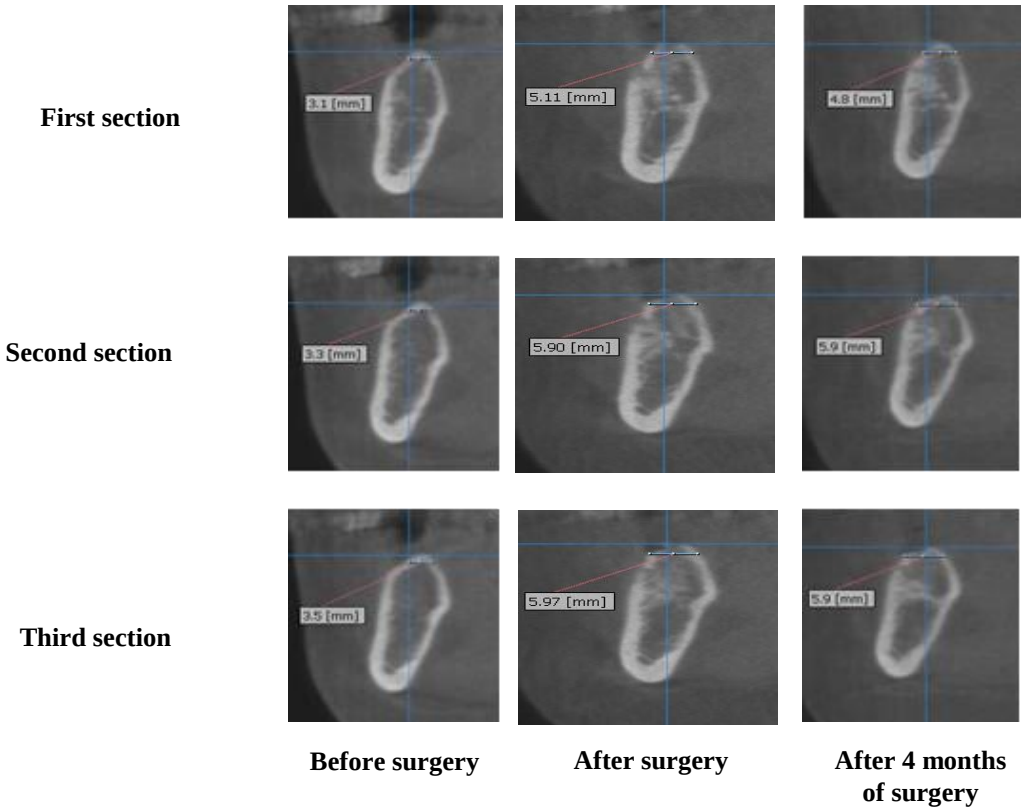
The three cross-sections were chosen as follows:

1- The first cross-section: 1 mm away from the medial vertical bone cut.

2- The second cross-section: in the middle of the work area.

3- The third cross-section: 1 mm away from the distal vertical bone cut.

Table 1: The alveolar bone width measurement on the CBCT cross-sections.



Dental implants

After a healing period of four months, 15 implants were installed in expanded narrow ridges. The diameters of all implants were 3.8 mm, while the lengths were between 8 and 12 mm. In two cases, the alveolar bone width was not enough (the width was 4.7 mm). So after implant insertion, minor augmentation of the implant's exposed part has been made by particles of synthetic bone graft. After an implant healing period of 4 months, implants were exposed and gingival formers placed for 15 days. Eventually, the implant-supported definitive crowns or bridges were inserted. Each patient was followed-up for at least 6 months.

The survival rates of dental implants

The survival rates of dental implants were studied in two periods: 1) the first was after an implant healing period of 4 months (before functional loading); 2) the second was after 6 months of functional loading. Survival rate criteria were: 1) absence of mobility (clinical stability), 2) absence of persistent pain or dysesthesia, 3) absence of peri-implant infection with suppuration, 4) absence of continuous radiolucency around the implant (using panoramic x-rays)

RESULTS

Alveolar bone width

The mean width of the alveolar bone: before surgery 3.33 mm (range, 2.7 – 4.4 mm), after surgery 6.13 mm (range, 4.9 – 6.8 mm) and after 4 months of surgery 5.55 mm (range, 4.7 – 6.6 mm) (tables 2, 3). So the mean bone gain in the width of the alveolar bone was: after surgery 2.8 mm (SD: 0.53) (range, 2.1 – 3.6 mm) and after 4 months of surgery 2.22 mm (SD: 0.23) (range, 1.9 – 2.6 mm) (Table 4). The mean of recurrence amount was 0.58 mm and the recurrence rate 18.73 %.

The results of the statistical study showed that the increase in the width of the alveolar bone was statistically significant in the two periods: after surgery, and after 4 months of surgery. Also, the average of the alveolar bone width after 4 months was lower than that of after surgery with statistically significant differences (Table 5).

Table 2: The alveolar bone width before, after, and after 4 months of surgery.

Patient number	Alveolar bone width (in mm)		
	Before surgery	After surgery	4 months after surgery
1	3.1	6.7	5.4
2	3.4	6.1	6
3	3.3	5.7	5.5
4	2.8	4.9	4.7
5	2.7	5	4.7
6	2.9	6.4	5
7	3	6.2	5.2
8	4.2	6.8	6.6
9	3.8	6.3	6.1
10	3.2	6.6	5.2
11	4.4	6.6	6.4
12	3.2	6.3	5.8

. **Table 3:** Arithmetic mean, standard deviation, and standard error of the amount of alveolar bone width (in mm).

Studied variable	Study period	Number of patients	Arithmetic mean	Standard deviation	Standard error	Minimum	Maximum
The width of alveolar bone (by mm)	Before surgery	12	3.33	0.54	0.16	2.7	4.4
	After surgery	12	6.13	0.63	0.18	4.9	6.8
	After 4 months	12	5.55	0.63	0.18	4.7	6.6

Table 4: Arithmetic mean, standard deviation, and standard error of the amount of change in the width of the alveolar bone (in mm).

Studied variable	Study period	Number of patients	Arithmetic mean	Standard deviation	Standard error	Minimum	Maximum
The change in the width of alveolar bone (by mm)	After surgery	12	2.80	0.53	0.15	2.1	3.6
	After 4 months	12	2.22	0.23	0.07	1.9	2.6

Table 5: Results of the T-Student test for correlated samples to study the significance of differences in the average amount of alveolar bone width (in mm) between the three studied periods (before surgery, after surgery, after four months).

Studied variable	Comparison of the alveolar bone width between the two periods:	The difference between the two means	The calculated value of t	Degrees of freedom	P-Value	Significant differences?
The width of alveolar bone (by mm)	Before surgery- after surgery	2.80	18.154	11	0.000	Yes
	Before surgery- after 4 months	2.22	32.970	11	0.000	Yes
	After surgery- after 4 months	-0.58	-3.821	11	0.003	Yes

Complications of surgery

1- Complications during surgery: No complications were reported during the surgical procedure.

2- Complications after surgery: There was one case of wound dehiscence during the initial recovery period (figure 12). This complication was managed as follows: the surgical sutures were removed, and the patient was recommended to continue the use of oral rinses with antibiotics for an additional week. The healing of the wound was obtained (Fig 13), and this complication did not affect the course of the following stages.

Figure 12: The case of wound dehiscence.

Figure 13: Wound healing

The survival rate of dental implants

1- After an implant healing period of 4 months (before functional loading): one implant was removed at the time of abutment connection because of a lack of integration with radiolucency around the implant on panoramic x-rays. The failed implant was substituted after two months with a new implant which was found osseointegrated 4 months later. Thus, the survival rate of implants was 93.3 %.

2- After 6 months of functional loading: all implants were physically stable, with the absence of any signs and symptoms, and the absence of any pathology on the radiograph. Thus, the survival rate of implants was 100 %.

DISCUSSION

In the ridge splitting technique the buccal cortex is repositioned laterally (11), so converts a one-wall defect to a four-wall defect leading to rapid vascularization, improved bone healing, and the expanded defect heals similarly to an extraction socket (12). The ridge splitting technique with simultaneous immediate implant placement is usually performed because it shortens the total treatment time (14, 17-19).

The application of this technique accompanied by unfavorable complications. The main complication was a complete fracture of the cortical plate, which leads to problems with perfusion (20, 21). So the other problem reported with ridge splitting is the excessive resorption of the buccal plate associated with labial exposure of the implants (17). Elnayef et al. 2015 in their systematic review found that the Buccal wall fracture represented the most frequent postoperative complication, followed by postoperative ridge resorption (22). Jensen et al. 2009 found that the most full flap alveolar split cases had facial bone loss and gingival recession, so they suggested that full mucoperiosteal flaps should not be reflected when an alveolar split is done (20). Scipioni et al. 1994 (23) and Chiapasco et al. 2006 (24) suggested using the partial thickness flap approach instead of the traditional full-thickness flap approach to preserve periosteal blood supply and therefore minimize the amount of alveolar bone loss. The periosteum has another function in treating the mal-fractures that might occur during the splitting procedure in which it prevents any cracked segment from dislodging and maintains the blood supply.

Besides, Ella et al. 2014 found that the narrow initial crest width increased the risk of fracture, the ridge bone must have a minimum width, and there must be a minimum amount of cancellous bone between the cortical plates to prevent fracture during surgery (25). Also, Bassetti et al. 2016 found that the limitations of this technique arise from the presence of highly compact residual bone and the lack of a cancellous bone layer between the oral and buccal cortical plates (26). So the ridge splitting technique is more suitable to the maxilla than the mandible owing to the thinner cortical plates and softer medullary bone (15). Flanagan 2008 found that edentulous mandibular ridges have thicker cortices and decreased volumes of vascular trabecular bone than their maxillary counterparts (27). Enislidis et al. 2006 (11) and Elian et al. 2008 (28) recommended a staged technique in the mandible to avoid postoperative complications from malfracture of the buccal segment.

On the other side, molars are the most commonly missing teeth. Mandibular free-end edentulism is greater than its maxillary counterpart in all age groups (29). Usually, the reconstruction

of bone width in the posterior region of the mandible is increased using block grafting or guided bone regeneration, late bone resorption associated with block grafting and guided bone regeneration has been documented (30, 31).

For all of these reasons, in this study, the tow-stage technique with a partial-thickness flap was used to increase the width of the alveolar bone in the posterior region of the mandible. At the same time, Elian et al. 2008 noted that a two-stage approach for ridge splitting procedures allows for a reevaluation of the surgical site before implant placement and better control over implant position, angulation, and ultimately a more esthetic restoration (28). While the one-stage ridge splitting technique with simultaneous implant placement has resulted in several complications such as a lack of initial stability for the implants, fracture of the buccal segmented bone, and compromised implant placement in the bucco-lingual and apico-coronal direction (32).

In this study, the alveolar bone width, the complications of the surgery, and the survival rate of the dental implants were reported

Alveolar bone width

In this study, the mean bone gain in the width of the alveolar bone was: after surgery 2.8 mm (SD: 0.53), and after 4 months of surgery 2.22 mm (SD: 0.23). The mean recurrence amount was 0.58 mm (18.73%).

In the previous reviews, Elnayef et al in their review which included 17 articles found that the mean bone gain was 3.19 mm (SD: 1.19) (range, 2 - 4.03 mm) (22). While Waechter et al in their review which included twenty-seven articles found that the mean bone gain in studies that used conventional surgical instruments was 3.61 mm, and 3.69 mm in those that used ultrasound. But in this review, studies included ridges with a thickness of between 1 mm and 7 mm for the alveolar ridge division and the gain in thickness was not always fully described and different methodologies were employed to measure it (33).

Using the two-stage splitting technique in the posterior region of the mandible the mean bone gain in the study of Holtzclaw et al. 2010 was 4.03 mm (±0.67) (16). But in this study, the full thickness flaps were used and additional particulated bone was placed buccally to fill and diffusely cover the vertical corticotomies and apical hinge cut and the split ridge and particulated graft material were then covered with resorbable collagen membranes.

Using staged ridge splitting technique (At first stage: Corticotomies, at second stage: splitting after one month to 40 days) the mean bone gain was in the study of Li et al. 2017: 2.37 mm (SD: 1.44) (rang, 0.20-5.75 mm) (34), Abu Tair 2014: 3.22 mm (SD: 0.97) (rang, 2-5 mm) (35), and Agabiti & Botticelli. 2017: 2.6 mm (SD: 0.6) (36).

Using one-stage bone splitting (bone splitting with immediate implant placement)) the mean bone gain was in the study of Anitua et al. 2013: 3.35 mm (SD: 0.34)(17), Rahpeyma et al. 2013: 2 mm (SD: 0.3) (18), Chiapasco et al. 2006: 4 mm (range, 2-5 mm) (24), Kumar et al. 2019: 2.59 ± 0.15 (19), and Santagata et al. 2015: 3,.5 (range, 1.45–4.9) (14). But most cases of these studies were done in the maxilla, and the initial mean bone width in most of these studies was more than that of this study. Also, for example in the study of Kumar et al. 2019 (19) the measurement of bone width after surgery was done just immediately after splitting, and Chiapasco et al. 2006 (24) used "extension crests devices" and in the mandible, a slow activation was used (1mm/day, for 4–5 days)

So the mean bone gain in this study agrees with studies of Li et al. 2017 (34), and Agabiti & Botticelli 2017 (36), Rahpeyma et al. 2013 (18), and Kumar et al. 2019 (19), while it was less than the others, and this may be due to many reasons. In this study, a ground autogenous bone graft was used to accelerate healing but it doesn't keep the space like block graft, also the full mucoperiosteal flaps were not used so during wound closure a kind of relapse in the buccal plate may be occurred due to pressure. Most studies used the one-stage technique with immediate implant placement so implants preserve the space and prevent the relapse during the closure. The measurement of alveolar bone width was not done at the widest region of alveolar bone after splitting but at three fixed regions then the mean was calculated. The initial mean bone width in most of these studies was more than that of this study and Anitua et al. 2013 found that the bone gain in wider ridges was more that of thinners ones (17). Finally, this study was done in the posterior region of the mandible which has the thicker cortices (lesser flexibility) in the two jaws while most of the other studies were done in the maxilla (27).

In two cases of this study the alveolar bone width

before splitting were 2.7 and 2.8 and after 4 months of surgery were 4.7 in both cases, so there was no enough bone width for implants and to overcome this problem minor augmentation of the implant's exposed part has been made by particles of synthetic bone graft. So 84.61% of the expanded areas were successful in providing an adequate width, and this agrees with the findings of Abu Tair et al. 2014 86% (35).

Complications

Buccal wall fracture represented the most frequent complication of ridge splitting, followed by postoperative ridge resorption (22). Sohn et al. 2010 recorded malfracture of the buccal cortical plate in 5 of 23 patients (32), and Olate et al. 2015 in 4 of 11 patients (37). Ella et al. 2014 showed that the vast majority of fractures occurred in crests narrower than 3 mm (25). In this study, there were no instances of malfractures, and this may be returned to the careful extension of the buccal plate during splitting. Clinically it was noted that the difficulty of splitting in the mandible is returned to involve the basal bone of mandible in the splitting process, so if there is a height alveolar bone the splitting can be easier.

Wound dehiscence happened in one case of this study, and it is thought that the reason is the presence of tension on both sides of the wound after suturing. None of the patients complained of paresthesia due to keeping the splitting away from the inferior mandibular canal by 2 mm at least.

The survival rate of dental implants

The survival rate of dental implants in this study was 93.3 %; one implant was failed at the healing phase before loading. While after 6 months of loading the survival rate of the remaining implants was 100%.

This result agrees with the finding of other studies, Elnayef et al. 2015 found in their systematic review that the implant survival rate of 17 studies was 97.0% (range, 94.4% to 100%) with the full thickness flap approach and 95.7% (range, 86.6% to 100%) with the partial thickness flap approach. (22). Also, Waechter et al. 2017 found that the overall implant survival rate of 4115 implants installed after the ridge splitting technique was 97% (33).

CONCLUSION

Within the limitations of the current study, the following conclusions were drawn: the use of the two-stage ridge splitting technique to expand the narrow alveolar ridge in the posterior region of the mandible can be considered a safe procedure with satisfactory results if appropriate cases are selected. A minimum alveolar bone width of 3 to 4 mm is recommended to achieve predictable outcomes. The use of particulate bone graft to fill the bone gap without immediate implant placement may lead to a kind of relapse in the expanded bone plate.

REFERENCES

1- Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed longitudinal study covering 25 years. J Prosthet Dent 1972;27: 120-32.

2- Aimetti M, Romano F, Griga FB, Godio L. Clinical and histologic healing of human 12. Extraction sockets filled with calcium sulfate. Int J Oral Maxillofac Impl 2009; 24: 902-9.

3- Johnson K. A study of the dimensional changes occurring in the maxilla following tooth extraction. Aust Dent J 1969; 14(4): 241-4.

4- Lekovic V, Camargo PM, Klokkevold PR, et al. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. J Periodontol 1998; 69(9): 1044-9.

5- Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: A clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent 2003; 23(4): 313-23.

6- Pinho, M. N., Roriz, V. L., Novaes, A. B. Jr., Taba, M. Jr., Grisi, M. F., de Souza, S. L. & Palioto, D. B. Titanium membranes in prevention of alveolar collapse after tooth extraction. Implant Dentistry 2006; 15, 53-61.

7- Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: Anatomic and surgical considerations. Int J Oral Maxillofac Implants 2004; 19(Suppl.): 43-61.

8- Klein, Marc O, Schiegnitz, Eik, Al-Nawas, et al. Systematic review on success of narrow-diameter dental implants. Int J Oral & Maxillofac Implants 2014; 29 :43–54.

9- Osborn JF. Die alveolar-expansionsplastik. Quintessenz 1985: 39: 9–14.

10- Nentwig GH, Kniha H. Die rekonstruktion lokaler alveolar-fortsatzrezessionen im forntzahnbereich mit kalziumphosphat- keramic. Z Zahna¨rztl Implantol 1986: 2: 80–85.

11- Enislidis G, Wittwer G, Ewers R: Preliminary report on a staged ridge splitting technique for implant placement in the mandible: A technical note. Int J Oral Maxillofac Implants 2006; 21: 445.

12- Cortellini P, Pini Prato G, Tonetti MS. Periodontal regeneration of human infrabony defects. II. Re-entry procedures and bone measures. J Periodontol 1993; 64: 261-268.

13- Sethi A, Kaus T: Maxillary ridge expansion with simultaneous implant placement: 5-Year results of an ongoing clinical study. Int J Oral Maxillofac Implants 2000; 15: 491.

14- Santagata M, Guariniello L, Tartaro G. Modified Edentulous Ridge Expansion Technique and Immediate Implant Placement: A 3-Year Follow-Up. Journal of Oral Implantology 2015; 2: 184-187.

15- Misch CM: Implant site development using ridge splitting techniques. Oral Maxillofac Surg Clin North Am 2004; 16: 65.

16- Holtzclaw DJ, Toscano NJ, Rosen PS. Reconstruction of posterior mandibular alveolar ridge deficiencies with the piezoelectric hinge-assisted ridge split technique: a retrospective observational report. J Periodontol 2010; 81(11): 1580-1586.

17- Anitua E, Begon˜a L, Orive G. Clinical evaluation of split-crest technique with ultrasonic bone surgery for narrow ridge expansion: status of soft and hard tissues and implant success. Clin Implant Dent Relat Res 2013; 15: 176–187

18- Rahpeyma A, Khajehahmadi S, Hosseini VR. Lateral ridge split and immediate implant placement in moderately resorbed alveolar ridges: How much is the added width? Dent Res J (Isfahan) 2013; 10: 602–608.

19- Kumar I, Singh H, Arora S.S, Singh A, Kumar N. Implant placement in conjunction with ridge split and expansion technique. Oral Surgery 2019; 12: 214-223.

20- Jensen OT, Cullum DR, Baer D. Marginal bone stability using 3 different flap approaches for alveolar split expansion for dental implants: A 1-year clinical study. J Oral Maxillofac Surg 2009; 67: 1921–1930.

21- Koo S, Dibart S, Weber HP. Ridge-splitting technique with simultaneous implant placement. Compend Contin Educ Dent 2008; 29: 106–10.

22- Elnayef B, Monje A, Lin GH, Gargallo- Albiol J, Chan HL, Wang HL, et al. Alveolar ridge split on horizontal bone augmentation: a systematic review. Int J Oral Maxillofac Implants 2015; 30: 596–606.

23- Scipioni A, Bruschi GB, Calesini G. The edentulous ridge expansion technique: a five-year study. Int J Periodont Restor Dent 1994; 14: 451-9.

24- Chiapasco M, Ferrini F, Casentini P, Accardi S, Zaniboni M. Dental implants placed in expanded narrow edentulous ridges with the Extension Crests device. A 1–3-year multicenter follow-up study. Clin Oral Impl Res 2006; 17: 265–272.

25- Ella B, Laurentjoye M, Sedarat C, Coutant JC, Masson E, Rouas A. Mandibular ridge expansion using a horizontal bone-splitting technique and synthetic bone substitute: An alternative to bone block grafting? Int J Oral Maxillofac Implants 2014; 29: 135–140.

26- Bassetti M, Bassetti R, Bosshardt D. The alveolar ridge splitting/expansion technique: a systematic review. Clin. Oral Impl. Res 2016; 27: 310–324.

27- Flanagan D. A comparison of facial and lingual cortical thicknesses in edentulous maxillary and mandibular sites measured on computerized tomograms. Journal of Oral Implantology 2008; 34(5): 256-258.

28- Elian N, Jalbout Z, Ehrlich B, et al: A two-stage full-arch ridge expansion technique: Review of the literature and clinical guidelines. Implant Dent 2008; 17: 16.

29- Misch C. Rationale for dental implants. In: Misch C. Contemporary implant dentistry. Third Edition, Canada, Mosby, Inc. 2008; (ch1): pp 3-25.

30- Chiapasco M, et al. Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. Clin Oral Impl Res 2006; 17(2): 136–159.

31- Rasmusson L, et al. Effects of barrier membranes on bone resorption and implant stability in onlay bone grafts. An experimental study. Clin Oral Impl Res 1999; 4: 267–277.

32- Sohn DS, Lee HJ, Heo JU, et al. Immediate and delayed lateral ridge expansion technique in the atrophic posterior mandibular ridge. J Oral

Maxillofac Surg 2010; 68(9): 2283-2290.

33- Waechter J, Leite FR, Nascimento GG, Carmo Filho LC, Faot F. The split crest technique and dental implants: a systematic review and meta-analysis. Int. J. Oral Maxillofac. Surg 2017; 46: 116–128

34- Li X, Xu P, Xu X, Liu S. The application of a delayed expansion technique for horizontal alveolar ridge augmentation in dental implantation. Int J Oral Maxillofac Surg 2017; 46(11): 1451-1457.

35- Abu Tair J. Modification of mandibular ridge splitting technique for horizontal augmentation of atrophic ridges. Annals of Maxillofacial Surgery 2014; 4(1): 19-23.

36- Agabiti I & Botticelli D. Two-stage ridge split at narrow alveolar mandibular bone ridges. J Oral Maxillofac Surg 20017; 75: 2115.e1-2115.e12.

37- OLATE, S.; MARêN, M.; OPORTO, G.; FARIAS, D. & CANTIN, M. Alveolar ridge splitting for implant installation in atrophic sites. Analysis of a case series. Int. J. Odontostomat 2015; 9(2): 249-254.