Alternative Bone Expansion Technique for Implant Placement in Atrophic Edentulous Maxilla and Mandible

Neophytos Demetriades, DDS, MD
Jong il Park, DDS
Constantinos Laskarides, DMD, PharmD

This clinical review is an evaluation of the effectiveness of the split ridge bone augmentation technique performed in the atrophic maxilla and mandible with buccolingual bony defects. The osseointegration success of implant placement in the area of split ridge bone augmentation is assessed and compared to implant success rates indicated in the literature. This evaluation includes 15 patients who were treated with alveolar split ridge bone augmentation at Tufts University School of Dental Medicine. During initial consultation, all patients were diagnosed with a buccolingual bone dimension of 3–5 mm on the edentulous alveolar crest. This bony buccolingual dimension was inadequate for placement of implants of desirable width and correct angulation as dictated by the prosthetic requirements. Crestal split augmentation technique involved a surgical osteotomy that was followed by alveolar crest split and augmentation after buccolingual bony plate expansion, prior to implantation. Implants were placed either immediately or 3 weeks after the initial augmentation. No fixation was used to stabilize the buccal bony cortex after the completion of the augmentation. All patients were placed on periodic follow-ups for a 24-month period postoperatively. Implant success was determined with the use of Buser’s Criteria. In total, 33 implants were placed in 15 patients. The overall success rate of osseointegration of the endosseous implants placed in the area of split ridge bone augmentation was found to be 97%. One patient presented with facial bone resorption and implant mobility 4 months after the surgery. The implant was removed and the area was reconstructed with autogenous bone graft and later implanted with an endosseous implant. Our results indicate that the split crest bone augmentation technique is a valid reconstructive procedure that can be used to augment the buccolingual alveolar defect prior to implant placement providing good bone foundation for placement of implants with desirable width in favorable angulation. In comparison to traditional bone grafts techniques, crestal split ridge bone augmentation enables placement of dental implants immediately or 3 weeks after augmentation and eradicates the possible morbidity of the donor sites.

Key Words: split ridge, buccolingual defect, augmentation
INTRODUCTION

While implant dentistry has become a desirable option for replacement of missing teeth, the available bone foundation determines the possibility of implantation. To facilitate osseointegration and avoid bone resorption, narrow, edentulous alveolar bony ridges less than 5-mm wide require bone augmentation prior to implant placement. By augmenting the defective area, the implant surgeon provides the necessary foundation for implant placement by establishing a bony wall thickness of at least 1 mm around screw-type implants. Traditional methods of ridge expansion include onlay and inlay bone grafts, sandwich osteotomies, guided bone regeneration, and alveolar distraction osteogenesis. Although these methods are effective, they require long periods for bone consolidation prior to implant placement and create a possible second morbidity at a donor site.

Crestal ridge bone augmentation is an alternative bone expansion technique that can be used to augment the atrophic maxilla and mandible prior to implant placement. This method was first introduced by Dr Hilt Tatum in the 1970s and was commonly referred to as ridge splitting, bone spreading, or ridge expansion technique. This method aims at the generation of bone around the implant sites by bone osteotomies that enable buccal cortex repositioning after greenstick fracture of the buccal bony wall. Since its introduction, many studies have attempted to prove that the alveolar ridge split technique is a good alternative to traditional alveolar augmentation procedures.

This clinical trial of 15 patients evaluates the effectiveness of the alveolar split ridge bone augmentation technique performed in atrophic maxilla and mandible with buccolingual bony defects. The osseointegration success rate of implants placed in the area augmented with split ridge bone technique was compared to the osseointegration rate of implants placed in areas augmented with other techniques as indicated by the existing literature. Furthermore, the time period from bone augmentation to delivery of the final prosthesis was also compared.

MATERIALS AND METHODS

Fifteen patients, 5 women and 10 men, who underwent implant placement following split ridge bone augmentation at Tufts University School of Dental Medicine, were included in this clinical trial. All qualified subjects presented with a buccolingual width dimension of 3–5 mm and a minimum bone height dimension of 10 mm prior to surgery. A split ridge bone augmentation technique was used to reposition the buccal cortex after performing a greenstick fracture of the buccal bony wall. Implants were placed simultaneously or 3 weeks following the initial surgery.

Thirty-four implants were placed in 15 patients: 22 implants were placed in the maxilla and 12 implants were placed in the mandible. All surgical procedures were performed by the same surgeon within a 1-year period. The choice of single-stage or two-stage split ridge bone augmentation was determined primarily by the bone density of the defective area, the size of buccolingual bony dimension, and the ability to achieve primary stability after implant placement (torque of greater than 35 N). All mandibular defective areas and maxillary defective areas with a buccolingual width of 3 mm were treated with two-stage split ridge bone augmentation technique. Implants with primary stability less than 35 N were removed and replaced in the area of augmentation in a second stage surgery 3 weeks later. Twelve patients were treated with single-stage split ridge bone augmentation and received 25 implants. The remaining 3 patients were treated with two-stage split ridge bone augmentation and received 9 implants.
**Surgical technique**

A no. 15 blade was used to perform a crestal incision (over the crest) followed by reflection of a full-thickness mucoperiosteal flap. The buccal wall was skeletonized and the bony surface was exposed. A 0.25-mm hall drill was used to complete a crestal corticotomy. The buccolingual bony walls were expanded using sequential sized osteotomes, and the buccal cortex was favorably positioned providing good foundation for implant placement while fulfilling the prosthetic angulation requirements. The implants were placed immediately in the osteotomy site while maintaining a primary stability greater than 35 N. The remaining bone gap was optionally grafted with particulate bone (Figure 1). This procedure was followed with primary closure of the mucoperiosteal flap. Undermining of the periosteum to facilitate primary closure with tension-free reapproximation of the flap was completed prior to suture placement.

In cases where the alveolar crest was less than 3 mm or the bony cortexes were very dense, a two-stage split ridge augmentation technique was performed to avoid unfavorable fracture of the buccal plate. A no. 15 blade was used to complete a crestal incision followed by elevation of a full-thickness mucoperiosteal flap. The buccal bony cortex of the defective area was skeletonized and the bony surface was exposed. A 0.25-mm hall drill was used to create a bony window by joining 2 vertical, a horizontal, and a crestal corticotomy. After completion of the corticotomies, no expansion of the cortical plates was achieved. The mucoperiosteal flap was reapproximated and the area of corticotomies was left to heal (development of soft callous) for a period of 3–4 weeks. After this healing period, a second stage surgery was performed by initializing a crestal incision (over the crest) followed by a reflection of a full-thickness mucoperiosteal flap that exposed the bony alveolar crest with no extension to the buccal bony wall. A controlled expansion of the pre-osteotomized buccal cortex to the predetermined implant width and height was achieved using sequential osteotomes. Implants were inserted in the bony osteotomy sites at the level of the crestal bone, and the remaining bony gap was grafted with the use of particulate bone graft (Biosis). Primary closure of the flap was established after performing supraperiosteal dissection of the soft tissue on the buccal surface of the surgical site. The periosteum was left intact on the buccal plate to provide blood supply to the bony segment (Figures 2 and 3). With this technique, we avoided unfavorable fractures of the buccal plate during expansion since we pre-osteotomized the expanded area (formation of soft callous). Furthermore, the completion of 2 extra vertical and 1 horizontal osteotomy enabled controlled expansion of the buccal bony cortex without the risk of unfavorable fracture.

All implants were submerged under the soft tissue and exposed 4–5 months after placement. This period was considered necessary for implant osseointegration. All final prostheses were delivered by the same prosthodontist 5 months after the initial surgery. No patients were subjected to primary loading.

**Clinical evaluation**

Six months following surgery, postoperative cone-beam computed tomography (CT) scans were obtained, and evidence of bone loss on the buccal and lingual aspect of the implant was evaluated (Figure 3). In addition to the CT scans, the patients were evaluated for implant osseointegration based on Buser’s Criteria. Implant success was determined according to an assessment of implant mobility, pain, infection, and radiolucency around the implant. The definition of implant success was defined according to the following 4 criteria:

1. absence of clinically detectable implant mobility,
FIGURE 1. One-stage split ridge procedure; maxillary split ridge augmentation with immediate implant placement. (a,b) Atrophic maxillary crest. (c,d) Crestal corticotomy and determination of implant position. (e) Implant placement. (f) Placement of temporary prosthesis. (g) Placement of final prosthesis.
(2) absence of pain or any subjective sensation,
(3) absence of recurrent peri-implant infection, and
(4) absence of radiolucency around the implant.

**Implant Stability**

All implants were evaluated for mobility with an Osstell Mentor magnetic resonance device that uses resonance frequency analysis for determining implant stability. This method requires the placement of an electronic transducer on the implant head or prosthetic abutment with a retaining screw followed by the passing of a low voltage current through the transducer that is undetectable by the patient. Resistance to vibration of the transducer to the surrounding bone is registered in a small computer device, and these vibration measurements are recorded in units of hertz (Hz). Hertz measurements were calibrated for each transducer and converted to implant stability quotient (ISQ) units using the device computer. ISQ values of 40 or less indicated that the implant was compromised with the potential for complications and lack of stability (Figure 4).

In addition, implant stability was evaluated with the use of a hand wrench device that calibrated the torque of the implant resistance. The hand wrench device is operated manually by attaching it to the implant head and calibrating implant resistance to torque force with a specific manometer. These measurements were recorded in Newton (N) units. A torque of resistance greater than 35 N was considered indicative of the absence of implant mobility.

**Significant Bone Loss Around Implant Sites**

Radiographic evaluation of bone resorption was performed with the use of periapical radiographs. Radiographs were taken with a digital sensor and radiographic apparatus, PRO 70X Intra, with 70 kVp and 8 mA. Preoperative and postoperative periapical X rays were evaluated using Emago software and compared for evidence of crestal bone resorption during the clinical evaluations. Bone loss of more than 2 mm in a period of 4–6 months or bone loss of more than 4 mm in a period of 12 months after the initial surgery was considered significant for bone resorption with the potential of a negative effect on osseointegration (Figure 5).

**Evidence of Infection**

Clinical evidence of swelling, redness, or exudate around the implants, in combination with peri-implant pockets greater than 5 mm, as measured with a standard periodontal probe, was considered an indication of peri-implantitis. In addition, radiolucencies around the implant as detected on periapical postoperative radiographic evaluation were also considered indicative of peri-implantitis.

**Implant Function**

Clinical evidence that the implants remained in position and supported mastication function was used to determine overall implant function. Symptoms of pain or sensitivity upon implant palpation and percussion were considered evidence of peri-implantitis.

**Results**

Fifteen patients were reconstructed with final prosthesis. Thirty-two implants placed in 14 patients showed osseointegration success after insertion as determined by Buser’s Criteria. In this study, the osseointegration success rate of implants placed in areas which were augmented with the use of split ridge technique was estimated to be 97% (Figure 6). No differences of osseointegration were appreciated between the single-stage and two-stage split ridge bone augmentation techniques.

One patient presented with facial bone resorption and implant mobility 4 months after split ridge augmentation. This implant was removed and the area was grafted with...
Figure 2. Two-stage split ridge technique; maxillary augmentation with implant placement after 3–4 weeks. (a,b) Atrophic maxilla. (c) Initial corticotomies. (d) Second surgery expansion of buccal cortex. (e,f) Implant placement and bone graft. (g) Placement of final prosthesis.
autogenous onlay block graft harvested from the mandibular ramus. A second endosseous implant was inserted 4 months after the bone grafting procedure.

**DISCUSSION**

The ridge splitting technique includes lateral repositioning of the buccal cortex by greenstick fracture and, in some cases, simultaneous graft placement in the space created by the buccal-lingual cortical plate separation. Following ridge splitting procedures, perfusion of the buccal segment remains intact; however, it shifts from an internal supply from the spongy bone to an external perfusion from the periosteum. Blood supply from the periosteum allows for osseous tissue to develop, which eventually leads to the formation of lamellar bone. Even though some studies have placed graft material between the separated plates, most studies have shown this placement to be unnecessary.

The split ridge technique is an advantageous bone augmentation technique because it provides a shorter treatment period in comparison to conventional bone graft techniques since it does not require a waiting period of 4–6 months for bone consolidation prior to implant placement. In addition, it decreases the morbidity since it avoids a second surgical donor site for bone harvesting. However, this procedure can only increase the buccal-lingual bony

![Figure 3. Two-stage split ridge technique; mandibular augmentation with implant placement after 3–4 weeks. (a) Atrophic mandible. (b,c) Implant placement and bone graft. (d,e) Buccal cortical expansion after placement of implants. (f) Placement of final prosthesis.](http://meridian.allenpress.com/doi/pdf/10.1563/AAID-JOI-D-10-00028)
dimension and is not applicable if there is insufficient bone height for implant placement. Furthermore, implementing the technique on atrophic ridges less than 3.0 mm wide may result in unfavorable bone fractures that lead to bone resorption. In cases of significant bony ridge defects and unfavorable ridge relationships, patients may benefit from an onlay bone graft augmentation technique.

Previous studies have also shown success with the single-stage ridge splitting technique. Simion et al reported on 5 maxillary and mandibular cases with the use of nonresorbable membrane without bone grafting and immediate implant placement. The authors reported that in all cases, there was an increase in the buccolingual width with only minor loss of bone height. In our study, a significant difference was observed in implementing the technique in the maxilla vs the mandible. Mandibular ridge splitting may be more difficult to perform than maxillary because the mandibular bone presents with a thicker cortical plate and less flexibility, thereby making the buccal cortex more

Figures 4-6. Figure 4. Evidence of bone loss at 6 months, 12 months, and more than 12 months. Figure 5. Implant stability quotient measurements less than 40, 40–60, and greater than 60. Figure 6. Literature success rates in comparison with current study success rates for the split ridge bone augmentation technique.
susceptible to unfavorable fracture during bony expansion.\textsuperscript{1,2,5,6,12,13}

While many studies have shown positive outcomes with the single-stage split ridge technique, Elian et al\textsuperscript{14} and Enislidis et al\textsuperscript{1} reported that the two-stage approach is preferable to simultaneous ridge expansion with implant placement. The authors report that although it increases the necessary time until case completion, the two-stage approach reduces operative and postoperative complications and provides a generally more stable outcome. In comparison, our study implemented the two-stage procedure in cases where bone expansion of 3 mm or more was necessary in order to ensure no unfavorable fracture of the bone. In analyzing osseointegration, we found no difference between immediate and late implant placement.

\textbf{CONCLUSION}

Our study analyzed the osseointegration success rate of implants placed in areas that had been augmented with split ridge bone augmentation techniques. It demonstrated that the ridge splitting technique is effective in longitudinal expansion of the alveolar ridge in cases of alveolar atrophy and knife-shaped ridges. The implant success rate was found to be 97\%, which is comparable to reports in the existing literature.\textsuperscript{5,6,12,13} No differences of osseointegration were appreciated between the immediate and late placement of implants after split ridge bone augmentation. These results indicate that the split ridge technique is a valid procedure for augmentation of atrophic and knife-shaped alveolar ridges. In contrast to traditional techniques, it allows for immediate implant placement following surgery and eradicates the possible morbidity from a second surgical site.

\textbf{ABBREVIATIONS}

CT: computerized tomography 
ISQ: implant stability quotient

\textbf{NOTE}

This study was presented as a poster presentation at the annual Academy of Osseointegration meeting in Boston, Mass in 2008.

\textbf{REFERENCES}