A Three-Stage Split-Crest Technique: Case Series of Horizontal Ridge Augmentation in the Atrophic Posterior Mandible

Guei-Hua Hu, DDS, MS¹
Stuart J. Froum, DDS²/Abdullah Alodadi, DDS³
Fuyuki Nose, DDS, PhD⁴/Yung-Cheng Paul Yu, DDS³
Takanori Suzuki, DDS, PhD⁴/Sang-Choon Cho, DDS⁵

This paper introduces a three-stage split-crest (TSSC) technique for horizontal ridge augmentation in the atrophic posterior mandible. The first stage consists of splitting the ridge. Following a 3- to 4-week healing interval, the second stage consists of expansion of the cortical plate (without elevating the periosteum) and placement of a bone replacement graft material. After 3 to 4 months of healing, the implants are placed. The advantages of this three-stage technique are increased vascularization to the surgical area, a decrease in procedure complications, and improved implant survival rates. An extended treatment time is the main disadvantage. The purpose of this retrospective case series is to review and discuss a new step-by-step surgical procedure of a TSSC technique using a delayed implant placement protocol. The results, advantages, and limitations are also presented.


In patients with longstanding edentulism, extreme bone resorption (vertically, horizontally, or a combination of both) is frequently observed.¹,² The use of augmentation techniques is often necessary to create adequate bone volume for implant placement. The width of narrow posterior mandibular edentulous ridges can be increased by four different horizontal augmentation procedures: lateral augmentation using guided bone regeneration,³ block grafting,⁴ distraction osteogenesis,⁵ and interpositional augmentation.⁶ Guided bone regeneration is a predictable procedure for horizontal ridge augmentation, but its dependence on the blood supply of the underlying bone⁷ limits its use in an atrophic mandible where there is limited marrow between the buccal and lingual central plates. The same is true for block grafting, which requires a second surgery site if autogenous bone is used.⁸ Distraction osteogenesis is an effective technique for horizontal ridge augmentation but requires precise execution; complications can result in loss of large segments of bone.⁹ Interpositional augmentation is a technique-sensitive procedure for ridge expansion using bone expanders or osteotomes with an approach known as the split-crest (SC) technique.¹⁰

The SC technique consists of segmenting the vestibular cortical...
The use of an ultrasonic cutting device makes the SC procedure less traumatic when compared to conventional surgery using disks, burs, and chisels. Ultrasonic devices have the ability to cut mineralized hard tissues in a safe and precise way, with minor soft tissue damage. Clinical studies evaluating the potential of ultrasonic bone surgery with a split-crest expansion technique have reported satisfactory results.

The SC technique may be performed simultaneously with implant placement, resulting in a shortened treatment time. However, this approach has the potential for serious complications, including buccal bone fracture, prolonged pain or paresthesia, and loss of bone height. A minimum of 3 mm of bone width, including at least 1 mm of cancellous bone, is indicated for this approach. Implants placed in maxillary bone in which the width was increased by means of interpositional augmentation have demonstrated 5-year cumulative success rates between 86% and 99%. Attemps to use this procedure in denser bone, such as is present in the mandible, have shown limited success to date.

A staged approach presents a solution to the problems inherent in the use of the SC technique in the mandible. Consequently, a staged approach has been proposed with splitting and expansion performed followed by implant placement after a 3-week healing interval. This allows re-establishment of the blood supply to the surgical site. However, this staged technique was reported to have potential complications such as infection and separation of bony segments. To reduce the potential for complications, this study introduces a modified three-stage SC (TSSC) technique. The purpose of this retrospective case series was to describe this novel TSSC technique and report on patient outcomes when TSSC was used in the atrophic posterior mandible. The step-by-step surgical procedure using delayed implant placement is presented, along with the advantages and limitations of this technique.

Materials and Methods

Clinical data used in this study was obtained from the Implant Database (ID) of the Ashman Department of Periodontology and Implant Dentistry at New York University College of Dentistry (NYUCD). This data set was extracted as deidentified information from the routine treatment of patients in the department. The ID was certified by the Office of Quality Assurance at NYUCD. This study is in compliance with the Health Insurance Portability and Accountability Act (HIPAA).

A total of 10 patients were consecutively selected from the ID for this case series based on the inclusion and exclusion criteria. Inclusion criteria were as follows:

- All patients received implants placed using the modified TSSC technique.
- Preoperative periapical radiographs and cone beam computed tomography (CBCT) scan images of the posterior mandible were available prior to surgery for case assessment.
- Patients required single or multiple implants in the posterior mandible.
- A ridge width of < 4 mm was present in CBCT images as measured 2 mm apical to the crest of the ridge.
- A ridge height of > 10 mm was present as measured from the superior border of the mandibular canal to the crest of ridge.
- The ridge had healed for at least 3 months following tooth extraction.

Exclusion criteria were as follows:

- Presence of uncontrolled diabetes, immunologic diseases, or other systemic conditions that contraindicated surgery.
- Radiation therapy to the head and neck region in the 12 months prior to the proposed therapy.
- Chemotherapy within a 12-month period prior to the proposed therapy.
- Patients currently on or with a history of bisphosphonate therapy.
- Presence of periodontal disease, or unwillingness to
undergo needed periodontal therapy, around the remaining teeth.

- Pregnancy or wish to become pregnant within 1 year of therapy.

- Smoking habit of one pack or more per day and unwillingness to enter a smoking cessation protocol.

- Psychologic problems that, in the opinion of the surgeons, would have rendered the delivery of comprehensive therapy untenable.

- Unwillingness to commit to a long-term posttherapy maintenance program.

To be included for evaluation, implants and prostheses were required to survive and function for a minimum of 6 months from time of completion of the final restoration. A lack of neurosensory problems or other complications was also required for evaluation.

Following screening and examination, an institutional review board–approved written and oral informed consent was obtained from each patient. All necessary periodontal and caries treatments were performed prior to surgery.

Prior to surgery, a CBCT scan of the surgical site was taken for each patient (Figs 1 and 2).

Surgical Procedure

The surgical procedures were standardized and were performed in three stages.

First Stage

Patients were prescribed 2 g of amoxicillin or, if allergic, 600 mg of clindamycin 1 hour prior to surgery and told to continue them (three times a day if amoxicillin 500 mg and four times a day if clindamycin 150 mg) for 10 days postsurgery. Local infiltration anesthesia of xylocaine (Lidocaine HCl, Henry Schein) 2% containing epinephrine at a concentration of 1:100,000 was administered, or carbocaine (Mepivacaine HCl, Carestream Health) 3% in cases where a vasoconstrictor was contraindicated. A midcrestal incision was made along the ridge crest slightly lingual to the midline, and two vertical incisions were made at the termination of the crestal incision (Fig 3). Alveolar ridge width was measured at the time of surgery at the crest of the planned implant position from buccal to lingual with an electronic caliper (Absolute 700-113-10, Mitutoyo) to the nearest 0.5 mm. A full-thickness mucoperiosteal flap was elevated to expose the buccal aspect of the mandibular alveolar ridge. Rectangular corticotomies were made using a piezoelectric saw (Mectron). A crestal horizontal corticotomy was started 2 mm mesial or distal to the adjacent teeth. The length of the horizontal cut was determined based on the number of implants and the space between the existing teeth or implants. The depth of the horizontal inferior cut was 2 mm coronal to the inferior alveolar canal as measured on the CBCT scan. This apical cut averaged 10 mm in depth. Vertical osteotomies were deepened 1 to 2 mm using the piezoelectric
saw through the cortical bone to intersect with the horizontal inferior cut (Fig 4). These cuts were made through the cortical bone leaving only the cancellous bone to be part of the greenstick fracture. A #301 elevator (E301, Hu-Friedy) was used to expand the buccal segmented bone approximately 3 mm, provoking a greenstick fracture. This segment remained stable due to the underlying cancellous bone. The greenstick fractured buccal segment was readapted with finger pressure, and the mucoperiosteal flap was sutured using 4-0 chromic gut resorbable material (635-CG, Henry Schein). Tension-free soft tissue closure was achieved in all cases (Fig 5).

**Second Stage**
Following a 3- to 4-week healing period, ridge expansion and placement of the grafting material was performed as part of the second-stage surgery (Fig 6). A crestal incision to expose the initial crestal cut was performed without elevation of a buccal flap. This allowed conservation of the blood supply on the buccal aspect of the displaced buccal plate. The displacement of the buccal plate to expand the ridge was achieved by using a 3.3-mm-diameter split crest chisel and a 15c blade.

A xenograft material (small particle Bio-Oss, Geistlich) was packed in the created space (Fig 8). Tension-free soft tissue closure was achieved with 4-0 chromic gut (Fig 9).
Third Stage
After 3 to 4 months, a CBCT scan was taken prior to implant placement (Fig 10). A full-thickness flap was reflected, and landmarks such as the mental foramen and inferior alveolar nerve were identified (Fig 11). Alveolar ridge width was measured to the nearest 0.5 mm and recorded again at the crest of the ridge using the same method described in the first-stage procedure. A round bur was used to mark the initial osteotomy, and a Lindemann drill (EBI) was used to achieve a depth of 6 mm into the bone. Depending on the width of the bone, standard-width implants (3.3 to 4.1 mm) were inserted in the area, achieving primary stability, and the surgical site was sutured with 4-0 chromic gut and allowed to heal (Fig 12).

Restorative Procedure
The implants were allowed to integrate for 3 to 4 months. Impressions were then taken using polyether material and sent to the lab for fabrication of porcelain-fused-to-metal crowns, which were splinted, cemented, or screw retained according to the restorative dentist’s preference (Fig 13). A CBCT scan was taken after prosthesis delivery and compared to the presurgical scan (Fig 14).

Fig 10 (left) A CBCT scan was taken prior to implant placement.

Fig 11 (below) Reentry after 4 months of healing showing an enhanced bone width of 4 mm.

Fig 12 (below) Two Straumann bone-level implants (3.3 × 10 mm, mandibular right second premolar and first molar) were placed.

Fig 13 (a) Clinical occlusal view of the mandibular right second premolar and first molar porcelain-fused-to-metal bridge. (b) Clinical buccal view of the mandibular right second premolar and first molar porcelain-fused-to-metal bridge.

Fig 14. CBCT scan images taken before treatment, after the second stage, and 4 months after delivery of the final restoration, showing the desirable result.
The technique as performed is illustrated in Fig 15.

Results

In this retrospective study, a total of 10 subjects received 20 implants placed using the TSSC technique. All patients showed substantial reconstruction of alveolar crest deficiencies with an average increase in ridge width of 2.5 to 4 mm, which allowed successful implant placement. All implants were loaded for a minimum of 6 months, and all implants and prostheses survived. No implant failure or neurosensory impairment was reported. There were no complications with the surgery or the restorations (such as broken, fractured, or chipped restorations) during the follow-up period (6 to 24 months) during which the final restorations were in function (Table 1).

Discussion

The TSSC technique as described was applied in severely buccolingually atrophied posterior mandibular edentulous regions as a three-stage procedure. The outcomes of the 20 implants in 10 patients presented were all positive, with a 100% implant survival rate and no reported complications.

The lateral ridge expansion technique with simultaneous...
immediate implant placement is often performed because it shortens the total treatment time.\textsuperscript{15–19,21–23} However, the risk of fracture of the osteomized segment is increased in the mandible because the mandibular bone has a more rigid cortical bone and a thicker cortical plate. Several complications have been reported for ridge expansion with simultaneous implant placement, such as a lack of initial stability for the implants, fracture of the buccal segmented bone, and compromised implant placement in the buccolingual and/or apicocoronal direction.\textsuperscript{12,16,18} Some studies recommend a staged approach to avoid postoperative complications such as bone sequestrum of the buccal segment.\textsuperscript{24,25} Although a two-stage approach increases treatment time, it also allows for subsequent evaluation of the expanded ridge and avoidance of other complications. With this approach, the location of the greenstick fracture is predetermined, and blood supply for the buccal segment remains intact. However, buccal bone resorption was reported using a two-stage procedure\textsuperscript{20} and Scarano et al.\textsuperscript{13} reported an early implant failure rate of 3.12% at 3 months using the two-stage procedure in the posterior mandible. Moreover, there is uncertainty as to the amount of bone the clinician can expect prior to stage 2 of two-stage technique.

The TSSC technique described in this case series provides a substantial improvement in diagnosing and planning implant positioning, reducing potential implant complications and failures. Enhanced

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bone volume during implant placement provides a greater potential for implant stability and long-term results. In addition, a more robust blood supply is expected within 3 weeks to achieve revascularization. Some studies described revascularization at 9 days with normal histologic and microvascular appearance at 14 days. This is the rationale for the 3-week waiting period used in this protocol to ensure sufficient blood supply to the mucogingival flap and underlying bone. The use of a crestal incision only, avoiding flap reflection and preserving the periosteum during the second surgical procedure, when the bone substitute graft is performed, avoids scar tissue formation and improves the healing response. This technique differs from the piezoelectric hinge-assisted ridge split technique in that it adds an additional surgical step but avoids the use of a membrane barrier, which eliminates possible complications. Moreover, in the TSSC technique, grafting and further widening of the ridge are performed during stage 2 surgery without flap reflection. This allows the healing of the graft and ridge to take place under an intact periosteum, connective tissue, and epithelium cover, providing an improved blood supply during this critical step in healing.

The use of ultrasonic cutting devices is advocated with the TSSC procedure due to their ability to cut mineralized hard tissues with minor soft tissue damage. Vital soft tissue structures such as nerves and blood vessels are not damaged by the cutting tip because of their ability to oscillate at the same speed and amplitude as the cutting tip of the instrument. Successful results have been reported using these cutting instruments with a split-ridge technique.

However, the TSSC technique increases the time until final prostheses delivery and surgical exposure. Additionally, the clinical cases in this report were treated by surgeons experienced in implant placement and ridge-splitting techniques. It is unclear whether these results can be obtained by less experienced operators. In the present study, the TSSC technique was proven to be safe and merits further studies. Randomized clinical trials are needed to validate the effectiveness of this procedure.

The preliminary results of this investigation indicated that the modified staged split-crest technique can be a safe and successful procedure and may reduce the reported complications associated with single- or two-stage split crest procedures without causing significant delay in treatment.

Conclusions

The TSSC technique used in this study in 10 patients with 20 implants proved to be an effective method for horizontal augmentation in severely atrophic posterior mandibular ridges. The TSSC technique can be used safely and predictably in patients with dense and thick cortical bone and narrower ridges in the posterior mandible. However, this technique requires planning, knowledge, skill, and experience on the part of the operator. Further studies are recommended to determine whether these results can be achieved in additional cases.

Acknowledgments

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

References


