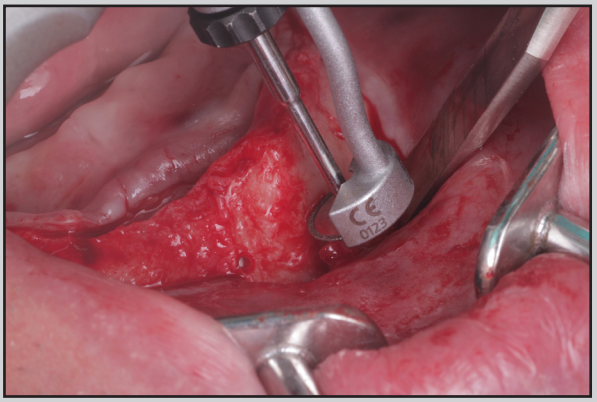
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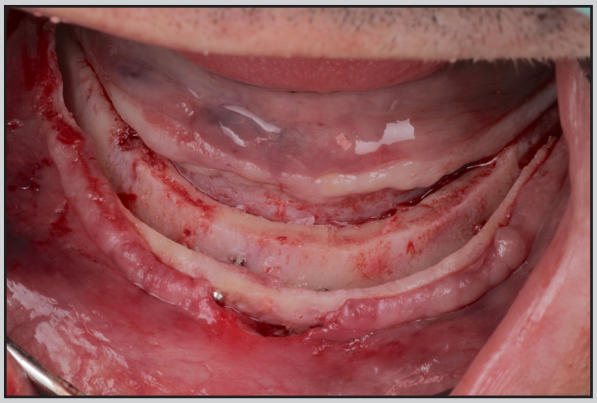
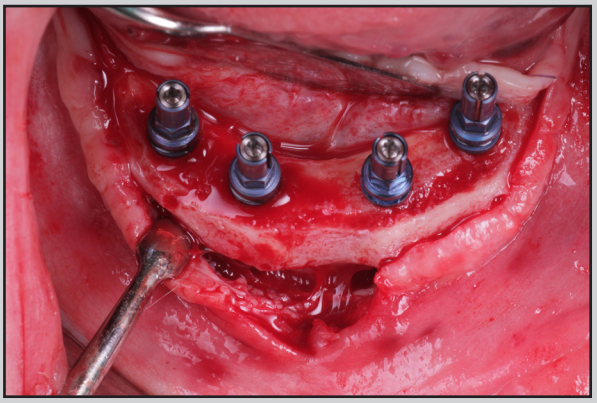
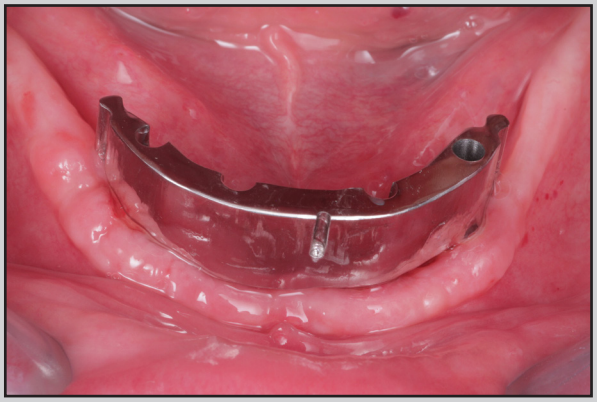
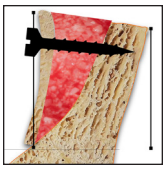






Bone Shell Technique with Relocated Crestal Ridge Segment for Anterior Horizontal Mandibular Ridge Atrophy: A Case Series



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Horizontal and vertical ridge augmentation by bone shell technique provides predictable outcomes. The external oblique ridge is the most-used donor site for bone plate harvesting, followed by the mandibular symphysis. The lateral sinus wall and the palate have also been described as alternative donor sites. This preliminary case series reports a bone shell technique that used the coronal segment of the knife-edge ridge as a bone shell in five consecutive edentulous patients (20 sites) with severe mandibular horizontal ridge atrophy and adequate ridge height. The follow-up period was 1 to 4 years. The average horizontal bone gains at 1 mm and 5 mm below the newly formed ridge crest were 3.6 ± 0.76 mm and 3.4 ± 0.92 mm, respectively. Ridge volume was sufficiently restored in all patients to enable implant placement in a staged approach. In 2 of the 20 sites, additional hard tissue grafts were required at implant placement. The advantages of utilizing the relocated crestal ridge segment are as follows: the donor and recipient sites are the same, no major anatomical structures are compromised, periosteal releasing incisions and flap advancement are not required for primary wound closure, and the risk of wound dehiscence is minimized due to reduced muscle tension.
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Implant-prosthetic rehabilitation of edentulous ridges with severe horizontal resorption can be challenging. Different ridge augmentation procedures that provide sufficient bone volume for restoratively driven implant placement have been described, including the barrier membrane, particulate bone grafting, block grafting, and ridge expansion techniques.[1] However, autogenous bone is still the gold standard as it shows osteogenic, osteoinductive, and osteoconductive potential.[2,3] Cortical bone provides mechanical and structural integrity; however, due to its limited revascularization potential, cortical bone blocks demonstrate slower integration than cancellous bone. The trabecular structure of cancellous bone facilitates rapid graft revascularization and integration, but the cancellous bone is resorbed rapidly.[4–7]

To maximize bone volume gain and minimize solid bone block resorption, Khoury and Khoury[8] introduced a bone shell technique (BST) that combines the advantages of using cortical and cancellous bones as a graft. The technique involves thin cortical bone plates that are screwed at a distance to the buccal and/or oral walls to rebuild the alveolar ridge contours, thus creating a bony envelope filled with bone chips. Particulate bone accelerates transplant revascularization

and graft regeneration, whereas the cortical bone plate provides mechanical stability.[8–11]

The external oblique line is the most-used donor site for BST plate harvesting, followed by the mandibular symphysis. Donor site morbidity is greater with the mandibular symphysis as a donor area.[12–14] Sensory problems may occur after harvesting graft material from both the external oblique line and the mandibular symphysis.[15–17]

Other studies have determined the hard plate and lateral maxillary wall as alternative donor sites for bone shell harvesting.[18–21] Bone plates can be harvested from the hard palate for smaller defects.

The reported prevalence of knife-edge ridge configuration in the anterior mandible that has an adequate height and inadequate width for implant placement (class IV according to the Cawood and Howell[22] classification of edentulous arches) is 75%.[23] A high and narrow ridge in an edentulous arch may simultaneously function as a donor and recipient site: The crestal ridge segment (CRS) is cut off, thinned out, relocated at the front of the remaining ridge, and fixed to serve as a scaffold in the BST. This novel approach may reduce postoperative morbidity, simplify surgical execution, maintain a blood supply, and minimize wound tension in this specific indication.

This study aimed to present and evaluate the preliminary results of five edentulous patients treated with the relocation of the CRS as part of the BST for horizontal ridge augmentation.

Materials and Methods

Overview of Clinical Cases

This case series presents a retrospective analysis of fiv e systemically healthy patients (three women and two men; ages ranging 59 to 68 years) diagnosed with class IV atrophy of the edentulous mandible. Each patient provided informed consent for surgery, data collection, and publication of intraoral photographs. The treatment plan included the BST, including CRS relocation before implant placement, and delivery of an implant-supported prosthesis. All patients were provided with four interforaminal implants, for a total of 20 sites. Three oral surgeons performed the surgi- cal procedures in a private clinic between September 2016 and January 2019, and the patients were reexamined 1 to 4 years after treatment completion.

Preoperative Planning

A CBCT scan of each patient was taken. Preoperatively, the height of the CRS for proposed transection and relocation was evaluated on the sagittal plane of the CBCT scan (Fig 1). The CRS height was thus estimated for the proposed CRS abutment on the prominent portion of the mandibular basal bone, such that the augmented ridge could accommodate placement of an implant at least 10 mm long.

Surgical Procedure

One hour before the procedure, patients were administered 2 g amoxicillin. Figure 2 shows a schematic representation of the procedure, and Fig 3 shows the surgical procedure and dental restoration of the mandible of a 59-year-old woman.

All patients were treated under local anesthesia. Following a crestal incision extending from the retromolar area of one side to the contralateral retromolar area, full-thickness mucoperiosteal buccal and lingual flaps were elevated to expose the alveolar ridge in the anterior and premolar regions (Fig 2a). The mental foramina were identified. The preoperatively determined CRS height was marked on the buccal aspect at three points using a small, round metal bur: one central point and two other points, each 6 mm anterior to the mental foramina (Fig 2b). The full-thickness bone cut comprised the following: *(1)* a horizontal osteotomy parallel to the ridge crest, which connected the three marked points, and *(2)* two oblique osteotomies at each end of the horizontal cut, which ascended in a posterior-coronal direction (Fig 2c). A diamond disk (Frios MicroSaw, Dentsply Sirona) or a piezosurgery tool (Mectron 3) was used for the osteotomy (Fig 3b). The harvested CRS (Fig 3c) was held with bone-holding forceps (Helmut Zepf Medizintechnik) and scraped with a bone scraper (Safescraper TWIST, Meta Technologies) to a thickness of 1 to 1.5 mm. Additional bone chips were harvested by beveling the ridge step that remained in the area where both oblique cuts met the ridge crest (Fig 2d).

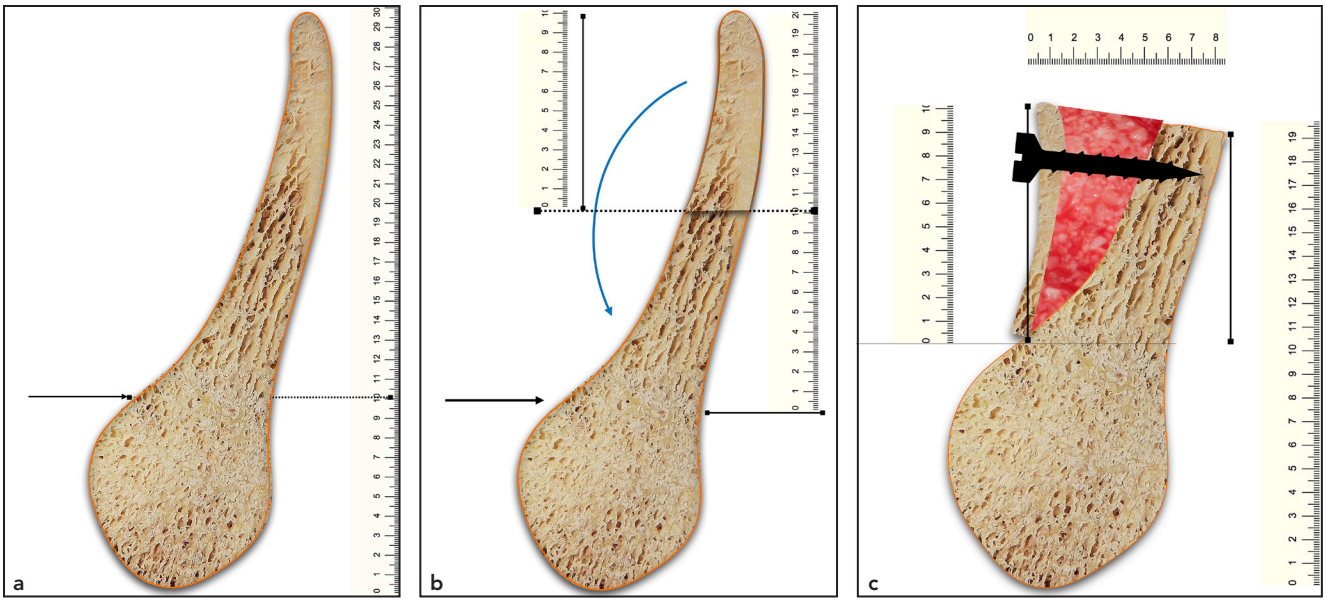

Fig 1 *Schematic illustration of radiographic planning for a relocated crestal ridge segment (CRS).* (a) *Sagittal view of the initial situation. The ridge height is measured, and the basal ridge prominence for CRS support is determined (black arrow).* (b) *The ridge above the prominence is evaluated for bisection. The blue arrow points to the site of planned CSR relocation.* (c) *The proposed ridge dimensions.*

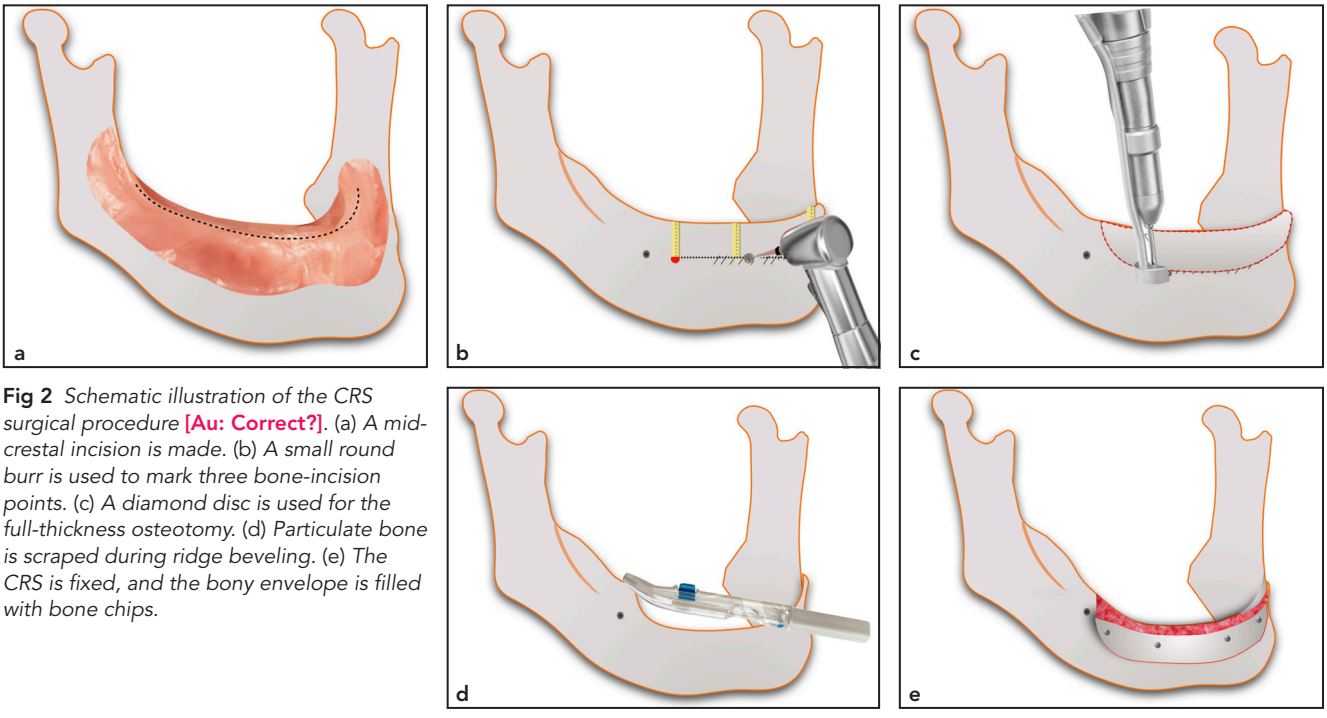

Fig 2 *Schematic illustration of the CRS surgical procedure* **[Au: Correct?]**. (a) *A mid-crestal incision is made.* (b) *A small round burr is used to mark three bone-incision points.* (c) *A diamond disc is used for the full-thickness osteotomy.* (d) *Particulate bone is scraped during ridge beveling.* (e) *The CRS is fixed, and the bony envelope is filled with bone chips.*

The bone plate was relocated to the recipient site at the newly formed ridge crest level and abutted on the prominent portion of the mandibular basal bone. Apically, the bone shell was in contact with or near the recipient site, and coronally, a distance was maintained to the recipient site. The CRS was anchored in this position using Stoma titanium microscrews (Fig 3d). The interlaminar envelope was filled with well-compacted particulate

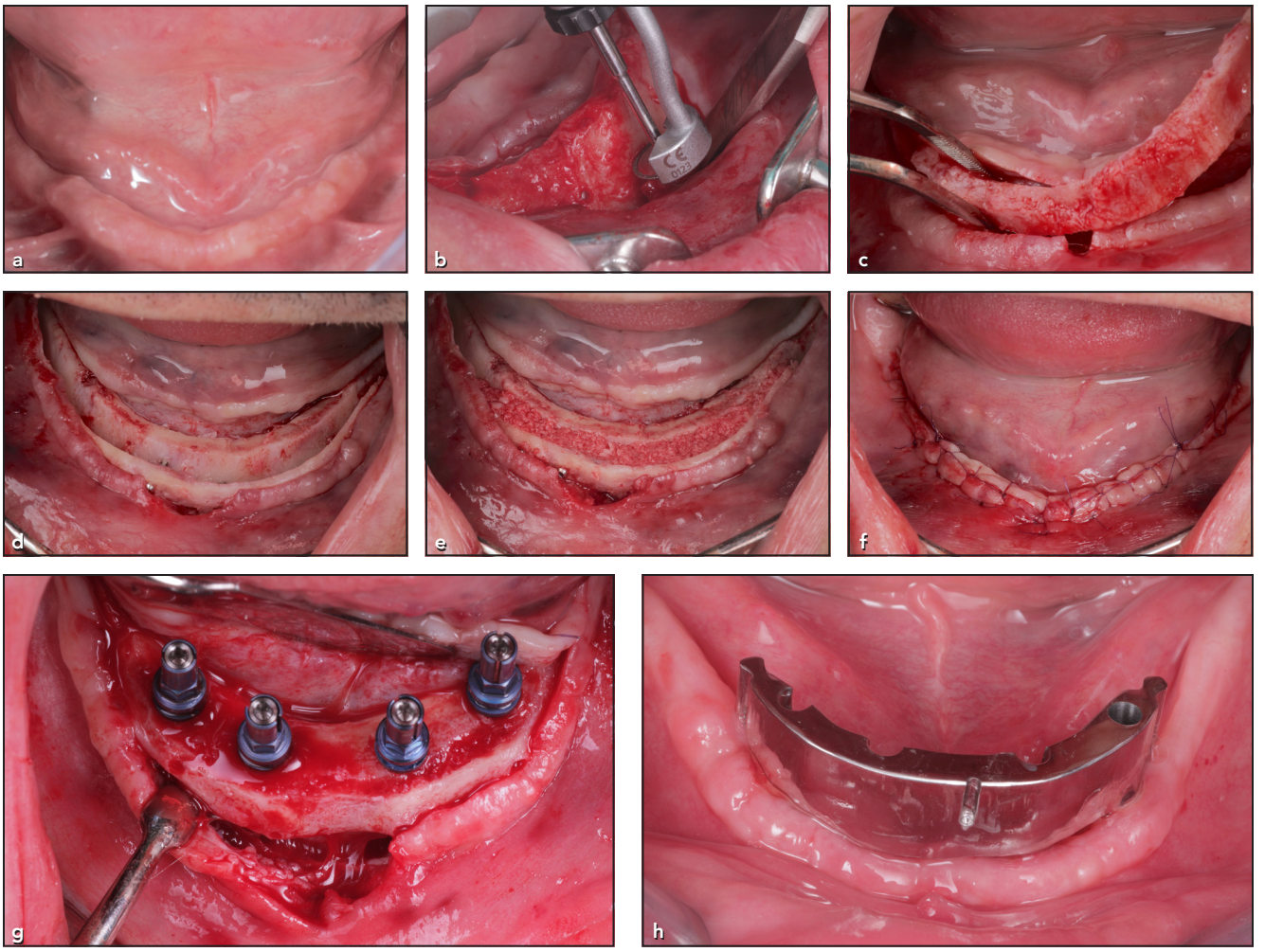

Fig 3 *Clinical view of the CRS surgical procedure* **[Au: Correct?]**. (a) *Initial situation*. (b) *The bone cut is performed*. (c) *The CRS is harvested and* (d) *anchored in the distance to the alveolar ridge*. (e) *Particulate bone is compacted in the bony envelope*. (f) *Wound closure*. (g) *Implant placement*. (h) *Situation 1 year after the prosthesis delivery*.

bone (Figs 2e and 3e). Primary wound closure was performed using horizontal mattress sutures and single or continuous sutures with 5-0 absorbable monofilament (Surgicryl Monofast, SMI) (Fig 3f). Due to a preexisting anterior ridge defect in one patient, two separate CRSs were harvested and fixed (Fig 4).

In two cases, the surgical protocol differed, as the patients were provided with fixed provisional prostheses supported on temporary implants to allow time for graft maturation and implant osseointegration (Fig 4). Provisional mini implants (Semados S or Semados RI, BEGO) were placed in the residual ridges after CRS harvesting, and impressions were taken before bone shell fixation and particulate bone grafting. The patients were provided with temporary fixed prostheses on the day of surgery; provisional implants were unscrewed when impressions were taken for definitive restoration. Patients who were not given provisional implants were instructed not to wear overdentures for 3 months.

Postoperative antibiotic therapy (1 g amoxicillin every 8 hours for 5 days) was prescribed to all patients. An analgesic (400 mg ibuprofen) was administered 30 minutes after surgery, and patients were advised to take analgesics as required.

Reentry for Implant Placement and Exposure and Prosthodontic Rehabilitation

CBCT scans were obtained before the implants were placed and 12 to 16 weeks after the first surgeries. Following crestal incision and mucoperiosteal buccal flap elevation, the microscrews were removed. Each patient received four interforaminal implants (Semados RSX, BEGO), either 3.75 mm or 4.1 mm in diameter and 11.5 mm or 13 mm in length. In two patients with fixed implant-supported prostheses as the final restorations, implants were loaded 24 hours after surgery. In three patients with bar-retained removable overdentures as definitive restorations, implants were submerged and allowed to undergo subgingival healing for 3 months. A crestal incision with minimal flap elevation was used for implant exposure. For two patients with insufficient peri-implant keratinized gingival widths, vestibuloplasties with free gingival grafts were performed at the time of implant uncovering.

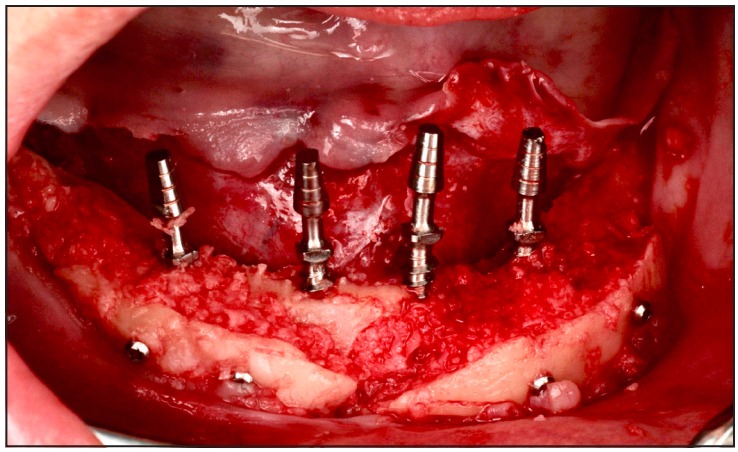

Fig 4 *In one patient, the CSR was anchored in two segments because of the preexisting defect in the anterior area. Provisional implants were placed.*

Ridge Dimensions and Bone Gain Measurements

On baseline and follow-up CBCT scans, ridge thickness and vertical bone height were measured on the axial plane's cross-sectional view using the software's ruler measuring tool. Measurements were performed at four points (two bilateral points) according to the planned implant positions: 6 mm anterior to the mental foramen and 7 mm lateral to the midline. Vertical bone height was measured as the distance from the alveolar crest to the base of the mandible. The buccolingual thickness was measured at 1, 5, and 10 mm below the ridge crest.

On a follow-up CBCT scan, the native bone was distinguishable from the newly formed bone. The follow-up ridge thickness, native (initial) ridge thickness, and bone gain were measured at 1, 5, and 10 mm below the new ridge crest, at the same anterior-posterior distances as baseline measurements (Fig 5). Owing to the small sample size, no further statistical analysis was performed.

Follow-up Evaluation

Patients participated in a regular maintenance program and were re-examined at 1 year (three patients), 3 years (one patient), and 4 years (one patient) after treatment completion. Patients were asked about any discomfort, and peri-implant tissue health was assessed based on the peri-implant Plaque Index, bleeding on probing, and peri-implant probing depths. The presence of plaque at the gingival margin was examined on each implant's four prosthetic suprastructure surfaces. The presence (1) or absence (0) of plaque was recorded in a simple binary chart; plaque incidence in the oral cavity is expressed as a percentage.

Similarly, the presence (1) or absence (0) of bleeding on probing was binarily assessed on all four surfaces. Crestal bone level changes were evaluated using a two-dimensional panoramic radiograph.

Statistical Analysis

The statistical analysis approach was based on implant sites as a unit. Data analysis was performed using Excel for Microsoft 365 for Windows.

Results

Wound healing was uneventful in all patients. Two patients reported using a single 400-mg dose of ibuprofen,

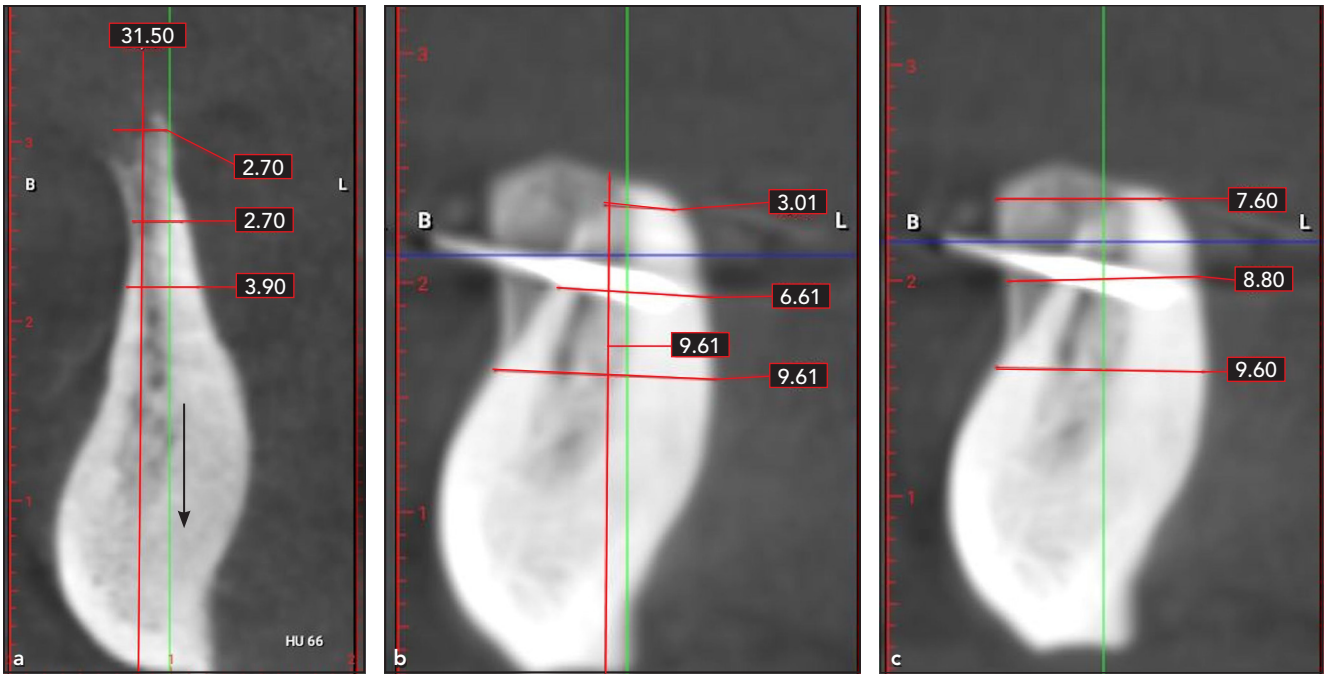

Fig 5 (a) *Basale ridge height was 31.5 mm, measured 7 mm lateral to the midline. Basale ridge widths were 2.7 mm, 2.7 mm, and 3.9 mm at 1, 5, and 10 mm below the ridge crest, respectively.* (b) *Native ridge height was 21.8 mm, measured 7 mm lateral to the midline . Native ridge width was 3.0 mm, measured 1 mm below the ridge crest.* (c) *Follow-up ridge widths were 7.6 mm and 8.8 mm at 1 and 5 mm below the ridge crest. No gain in ridge width was seen 10 mm below the crest.*

Table 1 Baseline Ridge Width and Height Before Ridge Height Reduction and Augmentation

	Bone width			
	1 mm below bone crest	5 mm below bone crest	10 mm below bone crest	Bone height
Minimum	1.1 mm	2.4 mm	2.7 mm	20.2 mm
Maximum	3.8 mm	4.0 mm	4.6 mm	31.5 mm
Mean ± SD	2.5 ± 0.7 mm	3.2 ± 0.5 mm	3.8 ± 0.7 mm	26.5 ± 3.7 mm

Measurements were performed in 5 patients with 4 sites each, for a total of 20 sites.

which was administered 30 minutes postsurgery. Three patients took an additional 400 mg of ibuprofen on the same day.

The initial ridge dimensions are listed in Table 1. The average horizontal bone gains at 1 and 5 mm below the newly formed ridge crest were 3.6 ± 0.76 mm and 3.4 ± 0.92 mm, respectively (Table 2). The ridge height was reduced from the initial average height of 26.5 mm to 19 mm. Accordingly, the CRS height was 6 to 10 mm. Twenty implants were placed as planned; 18 implants were placed without additional bone grafting.

At the 1- to 4-year follow-up, there were no clinical or radiologic signs of peri-implant marginal bone loss or peri-implantitis. Plaque at the gingival margin was detected on 20% of all examined surfaces; 15% of all examined sites were positive for bleeding on probing. Peri-implant probing depths ranged from 2 to 4 mm. Compared to the initial situation, there were no changes in bone level

Table 2 Ridge dimensions and bone gain (mm) at follow-up after ridge height reduction and augmentation (N=20)

	1 mm below new ridge crest			5 mm below new ridge crest		
	BW before	BW post	BG	BW before	BW post	BG
Minimum	3.0 mm	4.8 mm	1.8 mm	2.9 mm	7.0 mm	2.2 mm
Maximum	4.8 mm	8.5 mm	4.8 mm	6.6 mm	10.0 mm	4.9 mm
Mean ± SD	3.4 ± 0.5 mm	7 ± 0.8 mm	3.6 ± 0.8 mm	4.6 ± 0.1 mm	8.0 ± 0.9 mm	3.4 ± 0.9 mm
	10 mm below new ridge crest					
	BW before	BW post	BG	RH post	RH reduction	
Minimum	2.0 mm	3.5 mm	0.0 mm	14.5 mm	5.7 mm	
Maximum	9.6 mm	9.6 mm	2.3 mm	22.3 mm	10.3 mm	
Mean ± SD	6.6 ± 2.2 mm	± 1.7 mm	0.6 ± 0.7 mm	19.1 ± 2.8 mm	7.5 ± 1.4 mm	

BG = bone gain; BW = bone width after ridge reduction, either before augmentation (before) or after augmentation (post); RH = ridge height, either measured as bone height after reduction (post) or as a change from baseline (reduction).

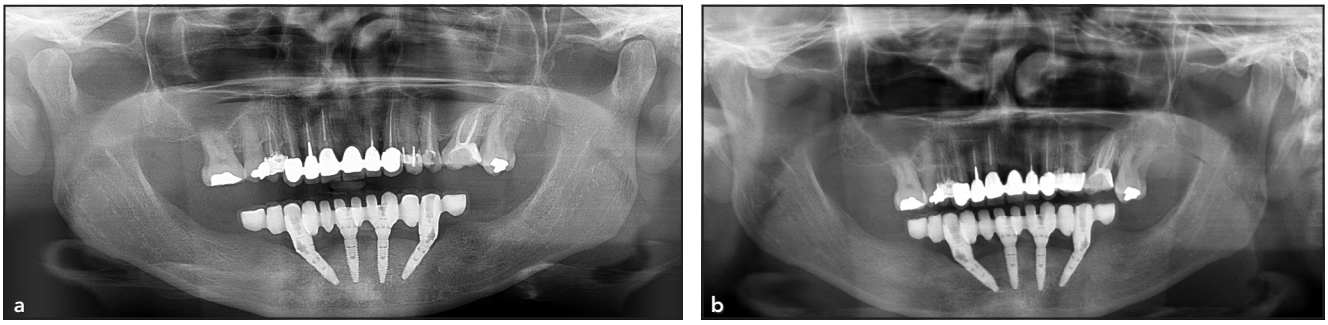

Fig 6 *Representative radiographic views taken* (a) *after implant-prosthodontic rehabilitation and* (b) *at the 3-year follow-up visit.*

on orthopantomography at follow-up (Fig 6). One patient who was given a bar-retained denture presented with denture-related stomatitis 2 years after denture delivery.

Discussion

Utilizing the relocated CRS as a scaffold in the BST is applicable for edentulous knife-edge ridges with adequate height and intended ridge height reduction. This technique does not compromise any major nerves or blood vessels during CRS harvesting. In addition, the treatment duration is shortened for two reasons. First, the second surgical site is omitted, and the CRS fits in a tailor-made manner, facilitating plate fixation. Further, the CRS follows the shape of the recipient area: The bone segment curvature corresponds to the curvature of the ridge to be augmented in the mesiodistal direction, providing a constant gap dimension. Because the abutment is on the more-prominent basal bone, the bone shell provides an apical enclosure containing the particulate bone. Autologous bone particles are harvested by thinning the plate and beveling the neighboring bone ridge, eliminating an additional donor site.

Second, the reduced vertical dimension enables tension-free primary wound closure without requiring a periosteal-releasing incision and

coronal flap advancement. Reduced muscle stretching and bone shell curvature that follows the ridge curvature without sharp edges may reduce the risk of wound dehiscence. Ridge height was reduced by an average of 7.5 mm, which provided the space for the prosthodontic suprastructure. Extreme ridge reduction that would allow implant placement without horizontal augmentation was avoided. In the present cases, no attempt was made to digitally plan the surgical guide based on the reconstructed CBCT scan data. The surgical guide for bone reduction has been proven to be safer and more precise, with greater efficiency and predictability of results than those of traditional freehand bone reduction.[24]

In the present case series, the average horizontal bone gain was 3.6 mm (measured 1 mm below the ridge crest), similar to the average bone gain reported by Stimmelmayr et al.[25] Two sites required minor bone augmentation during implant placement. CBCT scans were performed initially and for implant planning after graft maturation. In standard situations of horizontal ridge augmentation, the lingual bone height does not change significantly, and bone gain can be calculated by subtracting the initial ridge thickness from the follow-up ridge thickness. When a technique using relocation of the CRS is performed, a stable lingual reference point is missing. Therefore, a different method was applied to evaluate bone gain. On the follow-up CBCT scans, new bone was distinguishable from the native bone, enabling the measurement of native bone thickness, ridge thickness after graft maturation, and bone gain.

All patients were offered interim provisional implant-supported fixed prostheses to protect the grafted area from masticatory forces; however, only two patients were provided with the prosthesis, as three declined for financial reasons and thus remained without any prosthesis at graft maturation. Temporization of these cases can be challenging due to the large interarch distance and limited retention on the supragingival parts of the provisional implants.

Conclusions

Study limitations include the small number of examined sites and the retrospective study design. This case series demonstrates the potential efficacy of the presented technique, which should be evaluated in a larger number of treatment centers through well-designed studies. Horizontal ridge augmentation that uses CSR as a bone shell is limited to very restricted indications of edentulous ridges with sufficient height and planned vertical ridge reduction.

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