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Pedicled segmental rotation techniques for posterior mandible augmentation: a preliminary study

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Abstract. Rehabilitation of the atrophic posterior mandible is a challenge in dental practice. Conventional treatments include the segmental sandwich osteotomy or inlay bone grafting (IBG), onlay bone grafting (OBG), short implants, distraction osteogenesis, and inferior alveolar nerve transposition (IANT), each with its downsides. This case series is reported to introduce a modification of IBG – pedicled segmental rotation (PSR) for the reconstruction of co-existing vertical and horizontal defects in the posterior mandible. Ten healthy patients with vertical–horizontal defects (no vertical bone walls and basal bone width <5 mm) were included. Posterior mandibular defects were treated with PSR, PSR + IANT, or PSR + OBG. In PSR, a pedicle-preserved segment is up-fractured superiorly and then flipped 90° to a vertical position. The segment is then supported with inorganic bovine bone and autogenous bone particulates. Cone beam computed tomography was performed preoperatively and at the 4-month follow-up, in addition to clinical examinations. Soft tissue healing was uneventful. Radiomorphometric analysis showed a mean new bone volume of 647.79 ± 81.31 mm^3 ($\Delta H = 7.13$ mm), 836.99 ± 119.14 mm^3 ($\Delta H = 7.8$ mm), and 640.20 ± 50.13 mm^3 ($\Delta H = 6.59$) in the PSR, PSR + OBG, and PSR + IANT groups, respectively. The proposed PSR technique used in this case series showed promising results for vertical and horizontal augmentation of the atrophic posterior mandible before placement of dental implants.

Key words: alveolar bone loss; dental implants; bone graft; inferior alveolar nerve; posterior mandible.

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Rehabilitation of the atrophic posterior mandible is a great challenge[1]. Dental implant placement requires a minimum of 2 mm bone above the inferior alveolar nerve (IAN)[2]. Short implants (<8.5 mm), IAN transposition (IANT), distraction osteogenesis, and alveolar ridge splitting/expansion techniques have been utilized in these cases[3–6]. Nonetheless, the risks of transitory or permanent neurosensory dysesthesia (NSD) and mandible fracture, the prerequisite minimum bone height and

width, and insufficient bone gain are among the drawbacks[4,7].

Autogenous onlay bone grafting (OBG) is considered the gold standard for the regeneration of atrophic jaws, despite donor site morbidity and an unpredictable amount of graft resorption[8]. This secondary graft resorption was reported to be 17.4% at 4–6 months postoperative when lateral ramus cortical bone (LRCB) was harvested.[9] A bone gain of 5.75 mm which was later reduced to 4.75 mm at 6 months has also been reported with the use of LRCB[10]. Furthermore, an increased amount of resorption is documented with the use of extraoral sources. Bone loss of 24.16% (±8.47%) and 8.44% (±3.64%) has been measured in iliac crest grafts and calvarial grafts, respectively[11,12].

Guided bone regeneration (GBR) methods have also gained attention, especially when combined with block grafting. The clinical application of GBR using either resorbable or non-resorbable membranes has been reported in the literature[13]. However, maintaining a stable protective space during healing can be a challenge with GBR. The amount of vertical bone gain following GBR is reported to be 2–8 mm; however, 1.27–2 mm resorption may occur over a period of 1–7 years[14].

Another alternative that favours better vascular connection is the segmental sandwich osteotomy[11]. In 1966, Barros-Saint-Pasteur described this as a technique including a horizontal osteotomy in the mandible, then raising the mobilized bone segment while maintaining the lingual soft tissue attachments and filling the gap with particulate bone materials[15]. Although technically difficult, this method eliminates the need for autografts and facilitates bone regeneration as the graft is surrounded by bone and periosteum on all sides[11]. On the other hand, augmentation of height is limited to the soft tissue stretch and only vertical augmentation can be achieved[13].

In the case series presented herein, a modification of the segmental sandwich osteotomy, called pedicled segmental rotation (PSR), is reported. This involves a horizontal osteotomy, then flipping the segment 90 degrees and supporting it with particulate bone materials. The aim of this method is to expand bone both vertically and horizontally while maintaining the vascular supply.

Materials and methods

Case presentation

The patients were categorized into three groups according to the main modalities of the proposed treatment. A total of 10 patients (five male and five female) aged between 48 and 72 years (mean age 62.2 years) were referred to the first author for alveolar ridge augmentation of an atrophic posterior edentulous region of the mandible prior to implant placement (Table 1). In some of these particular cases, the defects had both a vertical and a horizontal bone deficiency, categorized as C2 and C3 according to Khojasteh et al.[14] (i.e., there are no surrounding vertical bone walls and there is a basal bone width of less than 5 mm); such cases require a bulkier segment of LRCB for block grafting. This was confirmed by preoperative cone beam computed tomography (CBCT) imaging and clinical examinations, with a vertical deficiency defined as an alveolar ridge height lower than that necessary for the placement of 8-mm dental implants with a safe margin of 2 mm above the IAN.

After providing a comprehensive explanation of the procedure, possible complications, and alternatives, written consent was obtained from each patient. A thorough medical and dental history was conducted for each patient to rule out any systemic contraindication to surgery. All procedures were performed by the same surgical team (A.KH). The premedication prescription included 500 mg amoxicillin (Tehran Chemie Pharmaceutical, Tehran, Iran), 400 mg ibuprofen (Rouz Darou Pharmaceuticals, Tehran, Iran), and 2 mg dexamethasone (Iran Hormone Pharmaceutical, Tehran, Iran). Local anaesthesia was achieved by lidocaine 2% with adrenaline 1:100,000 IAN block (Darupakhsh Pharmaceutical, Tehran, Iran). Postoperatively, patients were prescribed an antibiotic regimen (amoxicillin 500 mg three times a day, for 7 days) and analgesics (ibuprofen 400 mg alone or with acetaminophen–codeine 300/10 mg, for moderate and severe pain, respectively), as well as a single intramuscular injection of 8 mg dexamethasone (Alborz Darou Pharmaceuticals, Tehran, Iran). The patients were also instructed to use chlorhexidine mouthwash 0.2% (Behsa Pharmaceutical, Tehran, Iran) for a week for plaque control. The patients were visited every 2 weeks during the first month, and follow-up examinations were then continued at a monthly interval before implant placement. A 4-month healing period was considered for graft integration before implant surgery.

The three treatment groups, categorized according to the main modalities of the proposed treatment, are described below.

PSR

A panoramic view and CBCT imaging of a C1 defect area treated by PSR are shown in Fig. 1. A curved vestibular mucosa incision was made on the edentulous alveolar ridge with vertical releases in the posterior extension. A full-thickness flap

Table 1. Demographic and clinical data of the patients, and bone formation volumes and height in the different surgical groups.

Case number	Sex	Age (years)	Defect type[a]	BFV (mm^3)	BFV, mean ± SD (mm^3)	Mean ΔH (mm)[b]	Mean implant diameter × length (mm)	Surgical technique
1	M	61	C1	612.52	647.79 ± 81.31	7.13	4 × 8	PSR
2	M	64	C1	760.22			3.75 × 9	
3	F	56	C1	570.64			3.8 × 8	
4	F	71	C2	952.12	836.99 ± 119.14	7.8	4.1 × 8	PSR + OBG
5	M	66	C2	852.21			4 × 9	
6	M	72	C2	873.33			3.75 × 9	
7	F	64	C2	670.31			3.8 × 8	
8	F	69	C3	673.22	640.20 ± 50.13	6.59	3.6 × 10	PSR + IANT
9	M	48	C3	664.88			3.8 × 9	
10	F	51	C3	582.51			3.75 × 9	

BFV, bone formation volume; F, female; IANT, inferior alveolar nerve transposition; M, male; OBG, onlay bone grafting; PSR, pedicled segmental rotation; SD, standard deviation.

[a] According to Khojasteh et al.[14].

[b] Mean ΔH = H2 – H1 (measured from the IAN).

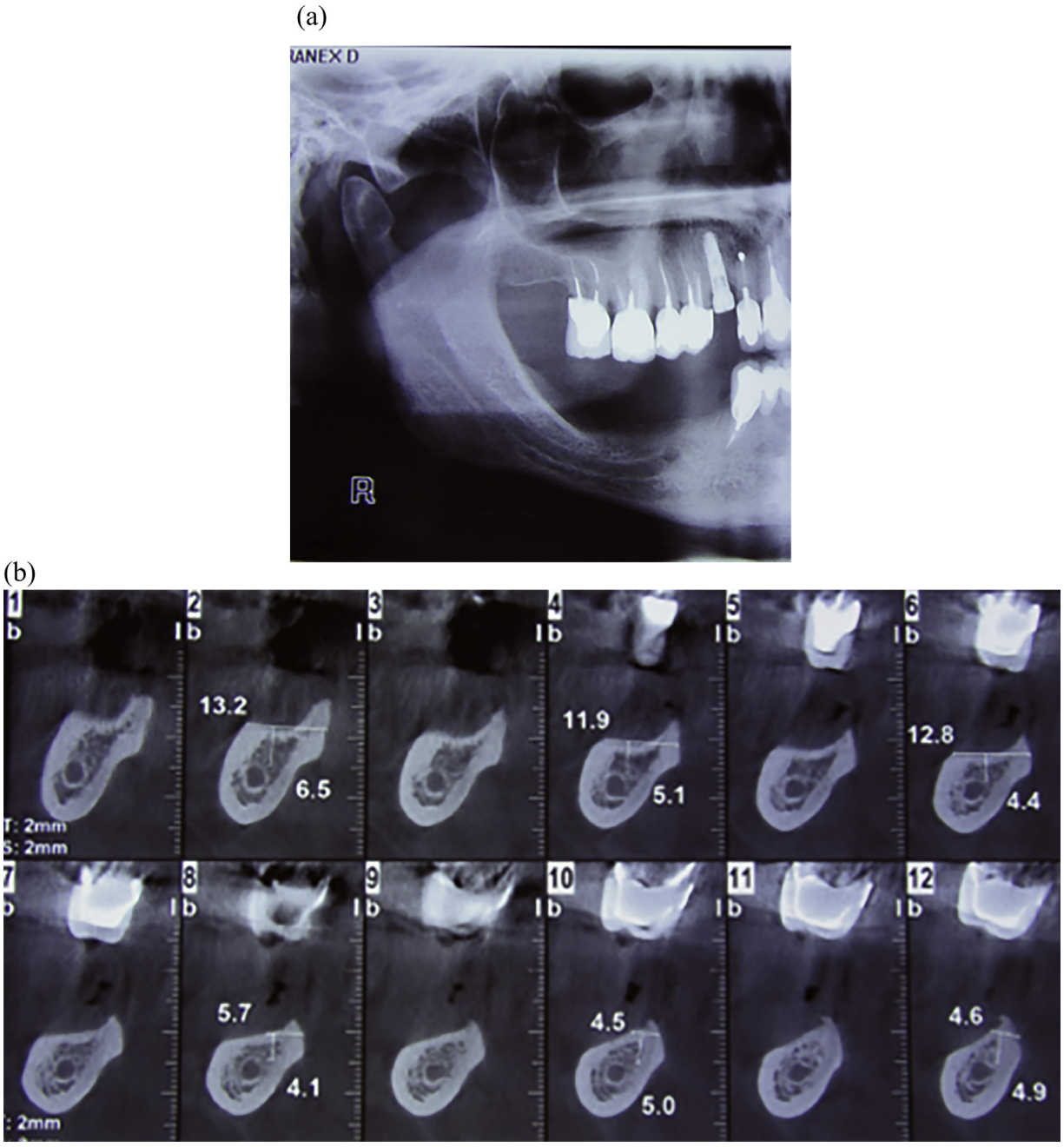

Fig. 1. (a) Panoramic radiograph of a C1 defect area (PSR group). (b) Sagittal sections of a C1 defect area; CBCT imaging (PSR group).

was fully retracted without detaching the lingual mucoperiosteum to expose the anterior wall of the atrophic mandible. Subsequently, vertical cuts were made on each side in the upper third of the mandibular bone with a piezoelectric surgery device (Megatron Elektronik AG, Putzbrunn, Germany). These cuts were connected horizontally (Fig. 2a). The osteotomy lines were inclined slightly downwards, towards the lingual soft tissues. The segment was up-fractured superiorly after all bone cuts were completed and then flipped 90 degrees to a vertical position (Fig. 2b). Care was taken to maintain the soft tissue pedicled on the lingual surface. Next, the rotated segment was fixed with three 12-mm endosteal microscrews (Jeil Medical Corporation, Seoul, South Korea) (Fig. 3). The periphery was filled with a mixture of particulate inorganic bovine bone mineral (Cerabone; Botiss Biomaterials GmbH, Zossen, Germany) and particulate autogenous bone graft. The mucosa was meticulously closed with continuous horizontal mattress sutures (5–0 Vicryl; Ethicon, Inc., Sint-Stevens-Woluwe, Belgium). Sutures were removed 10 days after surgery. To measure the amount of bone gain, CBCT images were obtained preoperative and postoperative (after 4 months) at a radiology facility, and clinical examinations were also performed at these time points. Sensory changes to the lip and chin were evaluated by touching the skin with a cotton pellet.

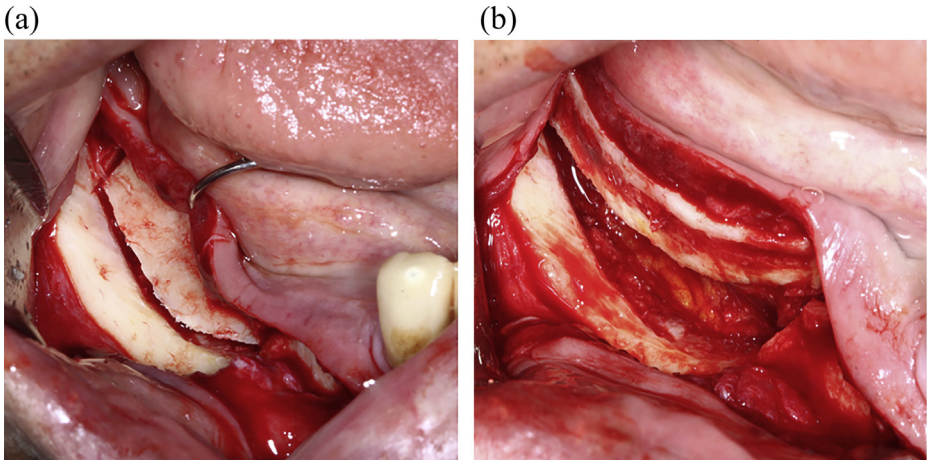

Fig. 2. (a) Vertical cuts made in the upper third of the mandibular bone with a piezoelectric surgery device and connected horizontally (PSR group). (b) The segment flipped 90° to a vertical position; care was taken to maintain the soft tissue pedicled on the lingual surface (PSR group).

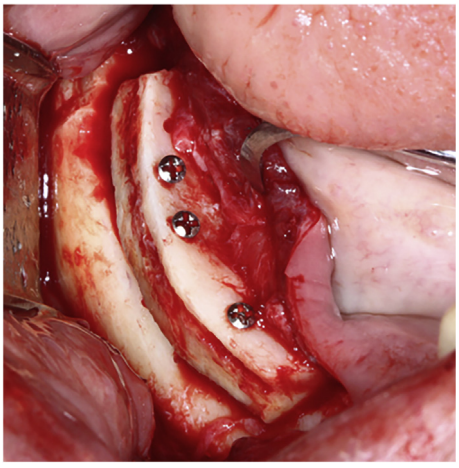

Fig. 3. The rotated segment fixed with three 12-mm endosteal microscrews (PSR group).

PSR with concomitant OBG

This variation of surgery was performed in four cases requiring greater horizontal bone augmentation as the rotated segment could not provide enough bone width (categorized as a C2 defect) (Fig. 4). The same surgical protocol for PSR was followed (Fig. 5). To obtain LRCB blocks from the same side, the mucosal incision was extended over the lateral oblique ridge to provide access to the lateral ramus area for cortical bone harvesting. Vertical and horizontal osteotomies limited to the cortical bone were performed using a piezoelectric surgery device (Megatron Elektronik AG) under copious irrigation with saline. Extreme care was taken to avoid any IAN injury. The outlined graft was subsequently levered and disengaged from its bed by means of careful application of a chisel. The ipsilateral harvested graft was rounded and trimmed to adapt to the recipient bed using a large round bur. Fixation screw holes were created in the blocks with a drill. The rotated segment was fixed with three 12-mm endosteal microscrews. To achieve the required amount of augmentation, two bone block was horizontally fixed adjacent to the flipped inlay bone graft by means of fixation screws (6 mm; Jeil Medical Corporation). The remaining gap was filled with bone substitute and the area was sutured (Fig. 6). The patients were discharged after being placed on the same postoperative protocol and follow-up schedule.

PSR combined with IANT

This modification of the surgical procedure was applied in three patients with a severe vertical deficiency and less than 3 mm of available bone above the IAN (categorized as a C3 defect) (Fig. 7). Therefore, PSR alone could not provide enough vertical and horizontal bone gain for implant placement. In order to provide more available height for dental implant insertion, PSR was combined with an IAN repositioning technique. The osteotomy lines were the same as in the PSR technique (Fig. 8). The up-fractured segment provided a unique access to the IAN canal by removing the remaining cancellous bone over it with a round diamond bur (Meisinger, Neuss, Germany) or round piezoelectric surgical blade. The neurovascular bundle was then freed and moved medially with a nerve hook (Fig. 9a). A previously described collagen–platelet rich fibrin (PRF) conduit was then positioned around the IAN[15] to fix it to the lingual periosteum (Fig. 9b). For better augmentation purposes, onlay bone grafts from the lateral ramus were also placed in areas of deficiency (Fig. 10). The overlying tissue was closed with a continuous horizontal suture.

Volume measurement technique

The software Mimics version 20.0 (Materialise, Leuven, Belgium) was used to calculate the volume alteration data. To obtain the volume of the region of interest (ROI), the preoperative and postoperative models were first superimposed and registered. Next, the ROI areas of the superimposed models were cut in the same way. Finally, the volume of each model was calculated and the augmented volume was defined by subtracting the preoperative ROI volume from the postoperative ROI volume. The difference between the new height over the inferior alveolar nerve and the height before surgery (ΔH) was mea-

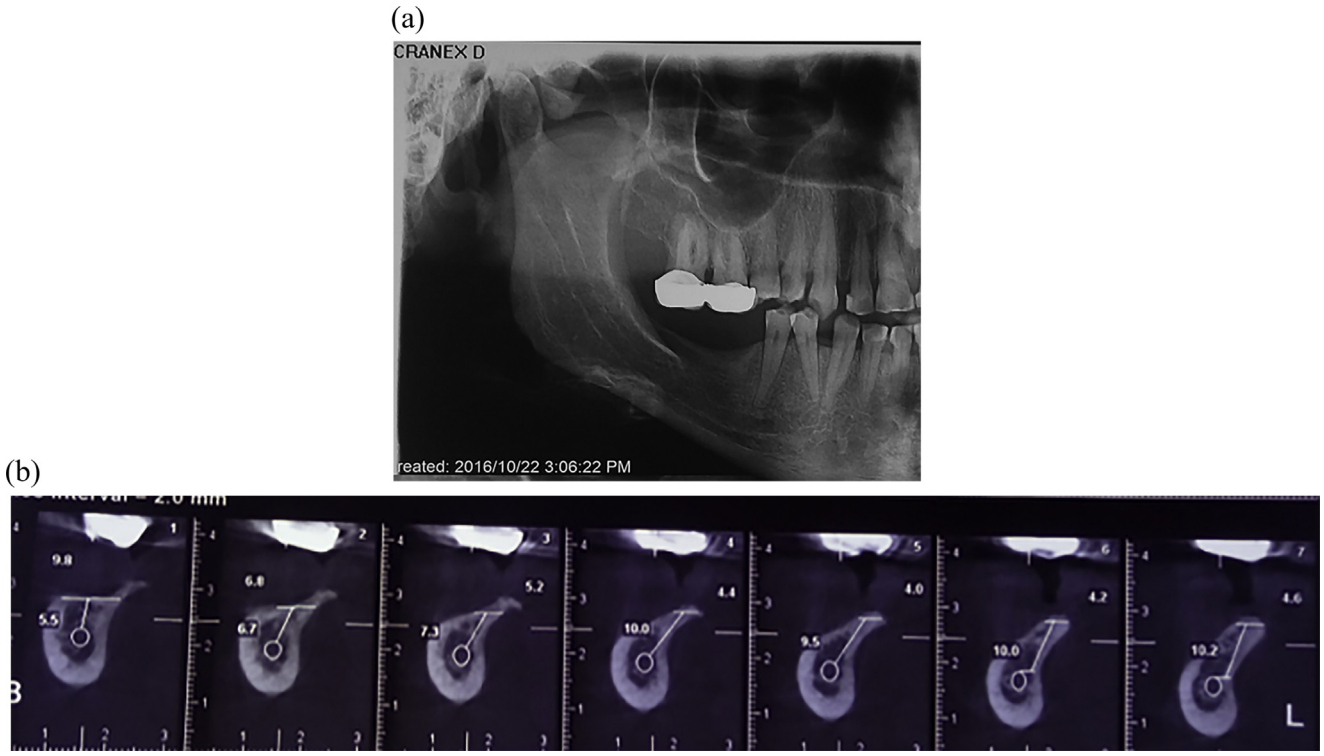

Fig. 4. (a) Panoramic radiograph of a C2 defect requiring horizontal and vertical bone augmentation (PSR + OBG group). (b) Sagittal sections of a C2 defect area; CBCT imaging (PSR + OBG group).

sured in the area where the dental implants were going to be placed.

Results

Soft tissue healing was uneventful and postoperative radiographic evaluation showed appropriate volumetric changes in all three groups (Fig. 11). The rotated pedicled segments had become integrated into the basal bone and minimal resorption was apparent in the upper border of the segments according to the out-of-bone part of the fixation microscrews (Fig. 12). In the case of concomitant OBG, the LRCB could be seen attached to the rotated segments with minimal resorption (Fig. 13). The new regenerated bone had enough stability to tolerate the implant drilling procedure (Fig. 14).

In the PSR group, a mean new bone volume of 647.79 ± 81.31 mm^3 and a mean height gain (ΔH) of 7.13 mm were achieved. In the PSR + OBG group, the new bone formation was 836.99 ± 119.14 mm^3 with a mean height gain of 7.8 mm, and lastly in the PSR + IANT group, 640.20 ± 50.13 mm^3 of new bone was formed and 6.59 mm of bone height was gained (Table 1). Also, there was no remaining alteration of sensation in any patient after 6 months. The 1-year survival rate for all implants placed in the PSR grafted sites was 100%.

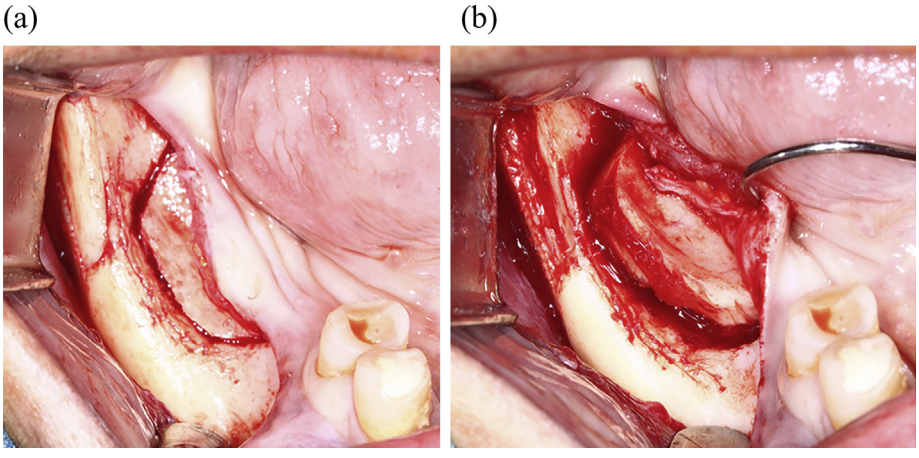

Fig. 5. (a) A full-thickness flap retracted without detaching the lingual mucoperiosteum to expose the anterior wall of the atrophic mandible (PSR + OBG group). Vertical cuts made in the upper third of the mandibular bone with a piezoelectric surgery device and connected horizontally (PSR + OBG group). (b) The rotated segment fixed by three endosteal 12-mm microscrews (PSR + OBG group).

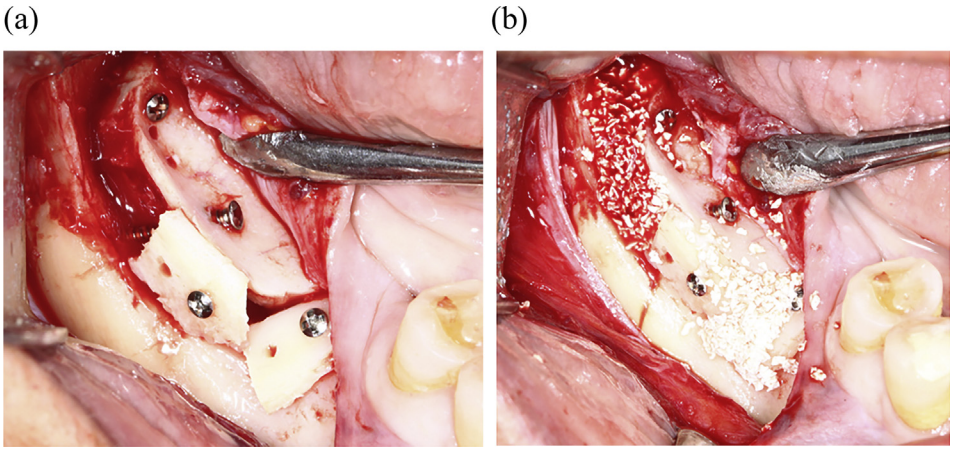

Fig. 6. (a) To achieve the required amount of augmentation, one bone block was fixed horizontally adjacent to the flipped inlay bone graft by means of fixation screws (PSR + OBG group). (b) The remaining gap was filled with bone substitute (PSR + OBG group).

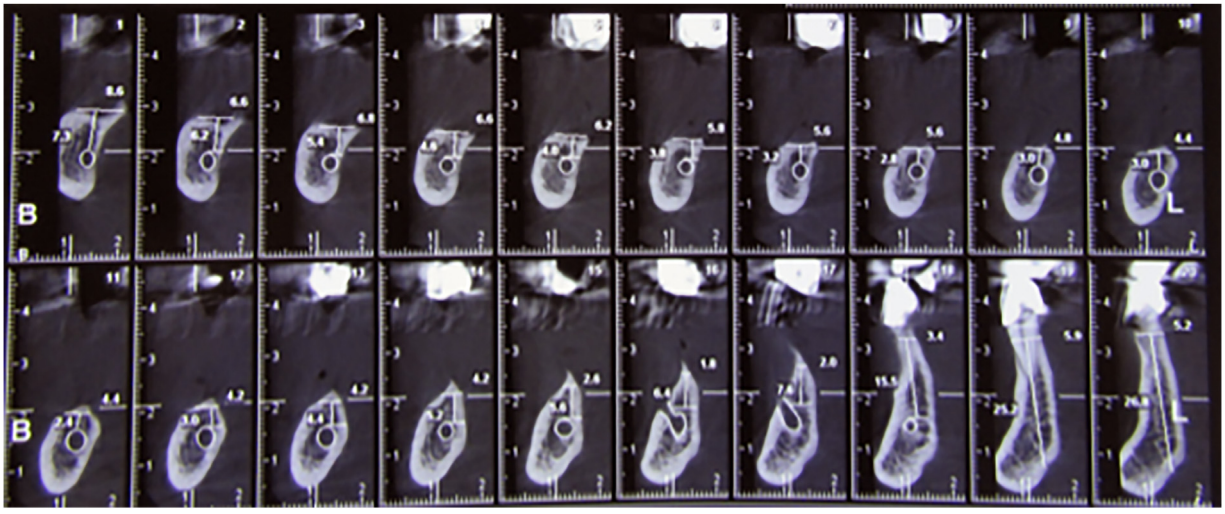

Fig. 7. Sagittal sections of a C3 defect area; CBCT imaging (PSR + IANT group).

Discussion

Surgical treatment to repair the atrophic posterior mandible is necessary before prosthetic implant treatment. The clinician must opt for a technique that yields the required amount of bone based on the type of bone deficiency and with minimum morbidity and complications. The case series presented herein demonstrates that grafting an autogenous flipped segment of cortical bone with a preserved periosteal pedicle and supported with inorganic bovine bone material and autogenous bone particulates, may be considered a safe and effective procedure for vertical and horizontal augmentation of the atrophic posterior mandible. The PSR method is feasible both alone and in combination with other conventional techniques, namely IANT or OBG, in more severe cases.

Fig. 8. Segment up-fractured superiorly after all bone cuts were completed (PSR + IANT group).

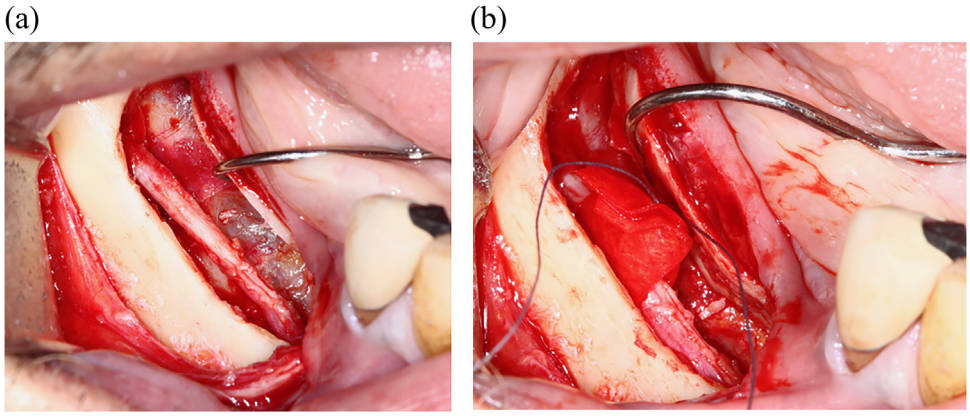

Fig. 9. (a) The neurovascular bundle exposed and freed (PSR + IANT group). (b) Collagen–PRF conduit positioned around the IAN to fix it to the lingual periosteum (PSR + IANT group).

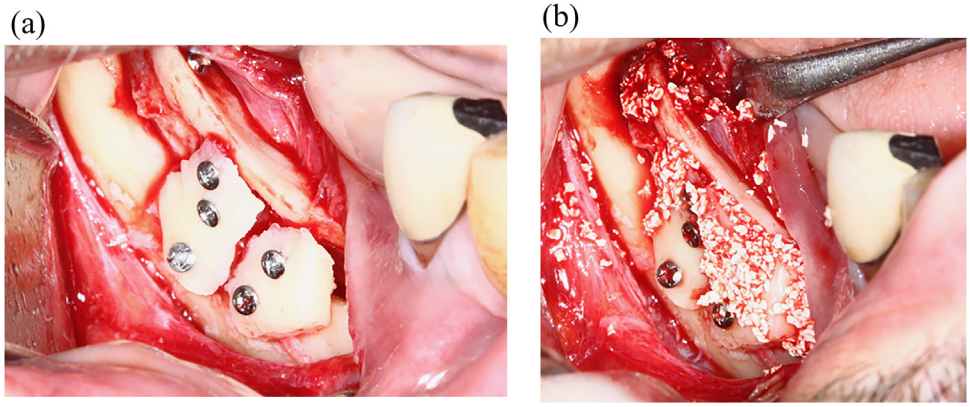

Fig. 10. (a) Onlay bone grafts from the lateral ramus were also placed in areas of deficiency (PSR + IANT). (b) The remaining gap was filled with bone substitute (PSR + IANT group).

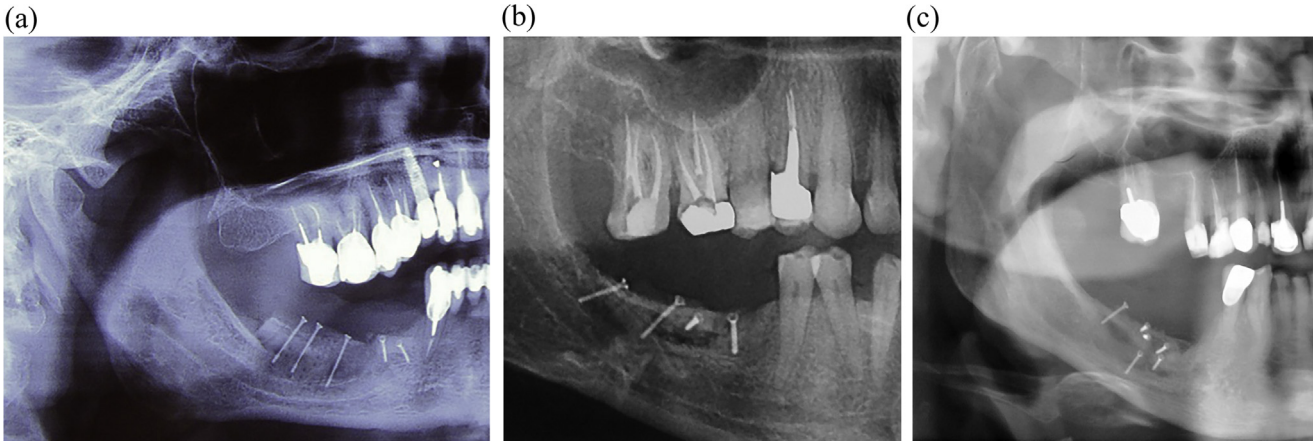

Fig. 11. Postoperative panoramic radiographs showing appropriate volumetric changes in all three groups: (a) PSR group; (b) PSR + OBG group; (c) PSR + IANT group.

Healing at the surgical sites was uneventful in all patients in this prospective case series. No graft exposure, infection, or other complications were observed at the surgical sites. Panoramic radiographs taken 4 months postoperatively showed integration of the grafts into the recipient bone. Cordaro et al. achieved vertical and horizontal bone gains of 3.4 ± 0.66 mm and 6.5 ± 0.33 mm, respectively, using intraorally harvested block bone grafts[16]. In the present study, the bone height gain averaged 7.13 mm in the PSR group. The PSR technique has the advantage of preserving the pedicle and the blood supply,

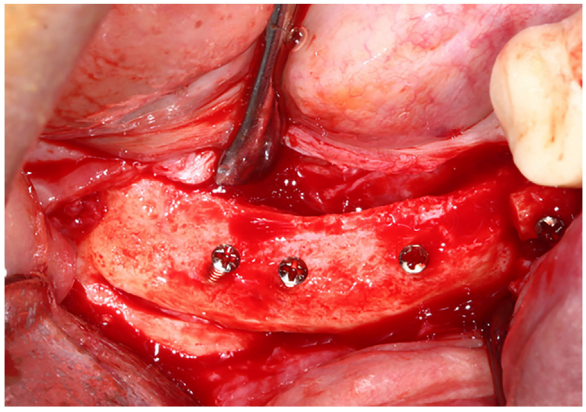

Fig. 12. The rotated pedicled segments integrated into the basal bone with minimal resorption (note the out-of-bone part of the fixation microscrews showing the minimal bone resorption at the upper border of the segments).

thus favouring the process of revascularization and osteogenic cell migration. Also, it has been proven that neoangiogenesis is established more rapidly with particulate bone grafts than with blocks of bone graft[17]. Thus entrapping particulate bone between the flipped segment and the recipient site might facilitate osteoregeneration.

In a study by Triaca et al., a 'double-sandwich osteotomy' was presented in which a three-dimensional scaffold was created for filling with particulate bone. A horizontal osteotomy was performed in the buccal aspect of the mandibular edentulous bone while preserving the attached crestal and lingual periosteum. The fractured segment was then cut horizontally into buccal and lingual fragments, each anchored to the pertaining periosteum[18]. The modification used in the present study differs, in that the buccal aspect was left intact while the pedicled lingual side of the bone was rotated 90 degrees to form the roof of the defect. This was achieved by exposing the bone defect at the crest.

Applying PSR did not increase the risk of donor side morbidity or permanent NSD as seen in the OBG and IANT techniques, respectively[4]. The results also showed that more new bone formation was achieved when PSR was combined with OBG (mean bone volume gain 836.99 ± 119.14 mm^3 and mean bone height gain 7.8 mm). The onlay autogenous bone graft harvested from the intraoral source provided the required width of bone for the severely atrophic mandibles, while serving as a protective membrane preventing the displacement of particulate materials and halting graft resorption. In addition, combining these two techniques will lessen the need for harvested autogenous bone and may eventually lead to decreased morbidity and therefore increased patient comfort and satisfaction with these regenerative procedures. This is in agreement with previous studies that have reported lower morbidity in cortical autogenous tenting (CATT) as compared to conventional procedures[1,19].

In this study, the IAN was repositioned before PSR using a collagen–PRF membrane. Neurosensory testing at the 6-month follow-up did not reveal any permanent NSDs. Khojasteh et al. compared the neurosensory disturbance among patients receiving IANT in the conventional manner or supported by a collagen–PRF conduit[20]. Their observations at the 6- and 12-month follow-up visits demonstrated that although comparable results were obtained at 12 weeks, the modified IANT accelerated neural healing and showed improved results at 6 months[20]. Performing IANT with PSR is easier, as the up-fractured segment provides a unique access to the IAN canal. In this series, the IAN was transposed medially and sutured to the lingual periosteum, thus epineural traction, which is one of the main causes of NSD, was prevented[21]. IANT alone avoids graft-related difficulties such as a vestibular depth reduction, elapsed time for graft integration, donor side morbidity, and soft tissue coverage[22]. However, the alveolar bone tends to resorb three-dimensionally in most cases after tooth extraction, rendering a narrow ridge and thus a less than

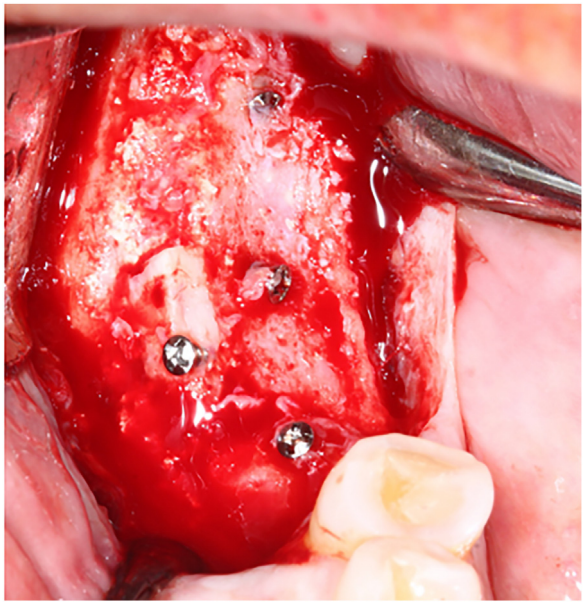

Fig. 13. Lateral ramus cortical bone attached to the rotated segments with minimal resorption (PSR + OBG group).

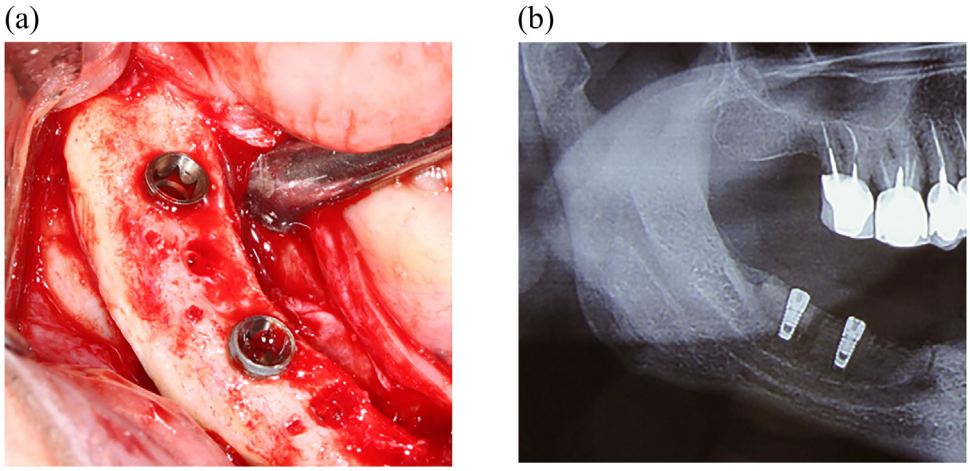

Fig. 14. (a) The newly regenerated bone had sufficient stability to tolerate the implant drilling procedure. (b) Post operative panoramic view of the Implants that have been installed in New regenerate bone.

ideal bony bed for implant placement. Eventually, higher prosthetic failure is foreseen. Thus in cases with both horizontal and vertical resorption, the combination of IANT with PSR is suggested.

The absence of major complications supports the potential benefit of PSR alone or in combination with OBG or IANT for the regeneration of the atrophic posterior mandible. This prospective case series demonstrates the feasibility of the technique introduced. Nonetheless, the positive results obtained in this case series need to be further proved in larger randomized and controlled clinical trials (RCT), with the assessment of long-term stability of the regenerated bone, as well as implant placement and survival. Based on the results of this study, the treatment of atrophic defects of the posterior mandible using an autogenous pedicle-preserved and rotated segment of bone supported with bovine bone and autogenous bone particulates was found to be a predictable procedure with promising results in all patients. Although the number of patients included in this study was limited, no complications or permanent NSD were observed at the surgical sites. Adequate horizontal and vertical bone dimensions were restored that allowed implant placement, and minimal bone resorption was seen on radiological examination. Within the scope of this study, the PSR technique could be a successful alternative; however, further evidence is necessary through RCTs.

Funding

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Competing interests

The authors have no conflict of interest.

Ethical approval

The study was a retrospective analysis of an alternative treatment for posterior mandibular augmentation and was permitted by the Shahid Beheshti University of Medical Sciences.

Patient consent

All patient consents are available and can be provided upon journal request.

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