Advanced Vertical Bone Augmentation with Modified Large-head Tenting Technique in Posterior Mandible

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Abstract

Purpose: The objective of this study was to investigate the clinical effect of guided bone regeneration (GBR) combined with modified large-head tenting screws in the reconstruction of a mandibular advanced vertical bone defect.

Materials and methods: Patients who met the inclusion criteria were included in the study. Deproteinized bovine bone was filled alone underneath the large-head tenting screws as grafting material, and the collagen membrane was covered as a barrier. About 10 months after surgery, cone-beam computed tomography (CBCT) was employed to access linear and volume changes in the augmented area, and biopsy was harvested for micro-computed tomography (micro-CT) and histological analysis during staged-implant placement. Implant survival rate and surgical-related complications were recorded. Descriptive analysis was done using Statistical Package for the Social Sciences (SPSS) software.

Results: From May 2017 to September 2021, a total of 20 patients fulfilled the inclusion criteria and received large-head tenting screw-enforced GBR. There were no postoperative complications or adverse events that occurred during the healing phase. Approximately 10 months after surgery, the average linear vertical bone gain was 5.76 ± 3.14 mm (0.05–11.77 mm), with the mean linear horizontal width gain being 3.42 ± 2.56 mm (0.56–9.11 mm). The bone volume/total volume (BV/TV) and bone mineral density (BMD) were 27.55 ± 4.59% and 0.28 ± 0.05 g/cm³, respectively. Histological analysis of the regenerated alveolar bone revealed that the new bone percentage was 25.95 ± 6.07% (17.4–36.7%), and the percentage of the remaining scaffold was 30.95 ± 3.79% (23.1–37.0%) at 10 months, postoperatively. All implants were placed according to preoperative planning, and no implants failed after the healing phase.

Conclusion: With the limitations of the study, the combination of large-head tenting screws with deproteinized bovine bone and collagen membrane appears to be a promising and exceptional technique in the reconstruction of advanced vertical bone defects in the posterior mandible.

Keywords: Guided bone generation, Tenting screw, Vertical bone augmentation, Vertical bone defect.


Introduction

Alveolar bone defects are the most common issue in oral rehabilitation with dental implants.1,2 In particular, the regeneration of alveolar bone with severely vertical bone defect (with/without horizontal bone augmentation) remains a nodus.3 Several techniques, including autogenous bone block onlay grafting, Guided Bone Regeneration (GBR) with titanium (Ti) reinforced nonresorbable membrane, Ti mesh, and distraction osteogenesis, have been applied in the construction of it.4 The success of these techniques highly depends on the stability of osteogenic space, a totally tension-free suture for primary closure, and the clinician’s skill and experience.5

For minor vertical bone defects (vertical linear bone loss of <3 mm), GBR with tenting screw may reconstruct the bone architecture through particulate bone graft materials in combination with resorbable membranes, as the demand for space main and blood supply of minor vertical bone defect is relatively lower.6,7 As for moderate and large vertical bone defects (vertical linear bone loss of >5 mm), the adjunctive tenting screw could not provide sufficient support for space maintenance stably; enhancing techniques like Ti mesh and nonresorbable membrane would be employed simultaneously for bone augmentation.8,9 However, these techniques require excellent surgical skills, prolonged operation time, and high patient tolerance, while it has been reported that they might result in a higher incidence rate of membrane exposure in the early 1–2 weeks after surgery.9,10

The tentative technique was first proposed by Fugazotto PA in 1993.11 According to the type of supports used for maintaining osteogenic space, the tenting technique can be divided into three types, including the tentpole technique, cortical autogenous tenting technique, and tenting screw technique. Tenting screw is widely used for their low technically demanding and high patient tolerance. Various studies12,13 have reported this technique and demonstrated that the additional utilization of tenting screws enhances horizontal

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bone regeneration in comparison to conventional GBR, especially in crestal regions. However, for vertical augmentation, the vertical bone gain of screw tenting was lower than the autogenous block bone graft in the posterior mandible. It was also confirmed that in lateral bone augmentation, tenting screws could provide strong support to encounter the compressive forces of the augmented site in the operation and healing process. They highly affirmed the efficiency of tenting screws in the reconstruction of horizontal bone defects, but the authors claimed that this technique was inappropriate for the regeneration of large vertical bone defects as high pressure from mucosa results in relatively high bone resorption.

Conversely, tenting screw with a large-head may considerably improve the bone gain in vertical bone regeneration, as an enlarged screw head could increase the supporting ability of the tenting screw and decrease the pressure on tissue flaps, which may improve the vertical bone gain and decrease the chance of postoperative wound dehiscence. Yet, there was no literature evaluating the potency of large-head tenting screws in vertical bone regeneration. The purpose of this study was to evaluate the efficiency of large-head tenting screws for advanced vertical ridge augmentation.

**Materials and Methods**

The study was approved by the Ethics Committee of Shanghai Ninth People’s Hospital, and all procedures were conducted following the principles outlined in the Declaration of Helsinki (SH9H-2020-T109-1). From May 2017 to September 2021, the patients undergone ridge augmentation using large-head tenting screws with deproteinized bovine bone mineral (DBBM) alone (Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) were selected. The patients were subjected to radiographic screening with CBCT (ProMax three-dimensional (3D), KaVo, Germany; 110 kVp, 3–8 mA; scan time—27 seconds; the size of slices—776 × 776 pixels; pixel size—0.2 × 0.2 mm) to assess the quantity of remaining alveolar bone height and width in the target site.

**Patients Were Included and Excluded Based on the Following Criteria**

Systemically healthy patients with a minimum age of 18 years having medium to large-sized vertical bone defects in the posterior mandible and wanting fixed implant-supported restorations were included. Patients who had at least 4 mm linear alveolar ridge augmentation vertically/horizontally in at least one implant site were included. Patients with good physical health and the ability to maintain good oral hygiene were only included.

Patients in whom surgical procedures were contraindicated due to uncontrolled systemic conditions and uncontrolled periodontal disease were excluded. Patients who were heavy smokers (>10 cigarettes/day) and consumed more alcohol were excluded.

Patients who met the inclusion criteria and received large-head tenting screw-enforced GBR were included. All patients were treated in the Department of Oral and Maxillofacial Surgery

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**Figs 1A to H:** Schematic diagram of the tent peg operation; (A) Diagram of preoperation; (B) Incision was created, and a full-thickness flap was reflected with periosteal elevators; (C) The holes were drilled in the exposed area of the alveolar bone; (D and E) Tent pegs were implanted; (F) A Bio-Gide collagen membrane was placed and secured on the buccal aspect of the ridge with 3 nails; (G) The Bio-Oss was placed on the bone defect; (H) The Bio-Gide collagen membrane was folded over the bone defect; (I) The flap was sutured with tension-free closure using nonabsorbable sutures.
Patients were recalled 3, 7, and 14 days after surgery. The postoperative complications, including swelling, hematoma, infection, and wound exposure, were evaluated and recorded. Sutures were removed on the 14-day follow-up. After a mean waiting time of 10 months (mean ± SD—10.05 ± 0.76 months; range—9–12 months), patients were recalled for staged implant placement, and postoperative CBCT was applied for reevaluation (Figs 2G to L).

The new bone gain was analyzed by integrating the pre and postoperative CBCT data via software [Materialise Interactive Medical Image Control System (MIMICS) Research, version 19.0, Materialise, Belgium]. In the postoperative CBCT data, the “virtual” implants were placed by the simulation of restoration. The radiography matching before and after surgery was performed by integrating the pre and postoperative CBCT data using software (MIMICS Research, version 19.0, Materialise, Belgium) (Fig. 3A). Five-mark points were used in this research. (genion; mandibular lingula; spina nasalis anterior; angle of mandible; mandibular central incisor), then the postoperation model was finely adjusted to match the preoperation model. The postoperation model was adjusted to transparency when the two models were perfectly matched (Fig. 3B).

The linear changes in bone height and width were measured in CBCT slices along the “virtual” implant axis and perpendicular to the bone surface. The horizontal bone gain was defined as 2 mm from the top of the crest along the “virtual” implant axis (Fig. 3C). The area of regenerated bone is shown in Figure 3D.

As for the measurement of linear vertical/horizontal bone gain of the augmented site across several implant sites, the mean

(Shanghai Ninth People’s Hospital, Shanghai Jiao Tong University School of Medicine), and all surgical procedures were performed by one experienced clinician. Written informed consent was obtained from all participants prior to treatment in this study.

The diagrammatical illumination of the surgical procedure is shown in Figure 1. Patients included based on radiographic evaluation of bone defects undergone surgical procedure (Fig. 2A). A crestal incision extending from mesial to distal was made 1 mm lingually from the midline of the edentulous ridge, and additional releasing incisions were made vertically in the far outside or 5–10 mm from bone defects region. Next, a distant full-thickness flap was raised using periosteal elevators (Fig. 2B). Following the exposure of the surgical site; all attached granulation tissues were removed to entirely reveal the bone surface. Two to three large-head tenting screws as per the size of bone defects [diameters—6, 8, and 10 mm; lengths—7.9, 11, 13, and 15 mm, Shanghai Renjie Industrial Co., Ltd, Shanghai, China, (Fig. 2C)] were placed vertically in the alveolar ridge deficiency area with at least 5 mm threads exposed above the alveoli depending on the depth of the defect and desired volume of bone gain (Fig. 2D).

Grafting of DBBM (Fig. 2E) was applied, fully covering the screws. Then, an absorbable collagen membrane (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland) was placed over the graft and then secured on the buccal wall of the ridge with at least 2 mini pins (Fig. 2F). After the membrane was completely anchored, the tension of the mucoperiosteal flap was fully released to allow primary closure without tension. The flap was sutured using a combination of interrupted and mattress sutures with absorbable sutures.

Figs 2A to L: Flowchart of the surgical operations; (A) Radiography evaluation of bone defects before surgery; (B) A mesial-distal crestal incision was made, and a full-thickness flap was reflected, cortical perforation was performed to enhance revascularization; (C) Image of a wide-head tenting screw; (D) Tent pegs placed on the occlusal side of the alveolar ridge and of >5 mm bone defects; (E) Filling the bone defect with fully mixed anorganic bovine bone-derived mineral; (F) GBR membrane placement with membrane screw stability; (G) Radiography evaluation of augmented bone 10 months after surgery; (H) Augmented region after the tent peg placement; (I) Removal of a wide-head tenting screw; (J) Placement of implants; (K) Radiography evaluation of implants after secondary implant surgery; (L) Tomogram dental implants revealed satisfactory osseointegration after functional loading.
The study included 20 patients who fulfilled the inclusion criteria, with an average age of 41.9 years (range 27–56 years). Among the 20 patients, 14 patients had two or more missing teeth. Detailed information on included patients is provided in Table 1. There were no complications or adverse events during surgery or postoperative healing. A total of 20 consecutive patients were treated with the insertion of 36 dental implants after bone augmentation, and no dropouts were presented during the entire observation period. All 36 implants were firm, without obvious discomfort, and no failure or severe complication appeared after implantation.

Radiographic alterations regarding new bone gain are shown in Table 2. The linear vertical bone gain showed a statistically significant difference after 10 months of healing compared to the baseline, with an average bone gain of 5.76 ± 3.14 mm. Besides, the average linear horizontal width gain was 3.42 ± 2.56 mm. Some
# Table 1: Detailed information about the patients

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*Prosthetic-driven virtual implant site, from the alveolar ridge to inferior alveolar nerve; #2 mm underneath the alveolar crest

# Table 2: New bone gain (vertical and horizontal) around virtual implants in augmented sites with the merging of pre and postoperative CBCT

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<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Quartiles (Q1 and Q3)</th>
<th>95% confidence interval (CI)</th>
<th>Mean</th>
<th>Standard deviation</th>
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<td>Postoperative bone height (mm)*</td>
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<td>2.16</td>
<td>16.50</td>
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<td>(7.30–11.28)</td>
<td>9.29</td>
<td>4.24</td>
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<td>Postoperative bone Width (mm)#</td>
<td>8.8</td>
<td>4.83</td>
<td>18.86</td>
<td>(7.60 and 10.63)</td>
<td>(7.90–10.92)</td>
<td>9.41</td>
<td>3.23</td>
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<tr>
<td>Linear vertical bone gain (mm)</td>
<td>6.56</td>
<td>0.05</td>
<td>11.77</td>
<td>(3.11 and 7.68)</td>
<td>(4.29–7.23)</td>
<td>5.76</td>
<td>3.14</td>
</tr>
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<td>Linear horizontal bone gain (mm)#</td>
<td>3.21</td>
<td>0.56</td>
<td>8.91</td>
<td>(2.16 and 4.20)</td>
<td>(2.22–4.62)</td>
<td>3.42</td>
<td>2.56</td>
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</tbody>
</table>

*Prosthetic-driven virtual implant site, from the alveolar ridge to inferior alveolar nerve; #2 mm underneath the alveolar crest
implant sites with severe 3D bone defects were regenerated in this study.

Alveolar bone volumetric parameters were analyzed by micro-CT, which are shown in Table 3. The Tb. N was 3.28 ± 0.58 /mm, BV/TV was 27.55 ± 4.69%, Tb. Th was 0.083 ± 0.012 μm, BMD was 0.28 ± 0.05 g/cm³.

Masson trichrome staining demonstrated de novo bone 10 months postoperatively. The contour revealed the formation of new bone that united with the native bone, indicating bone integration at the interface of bone and grafted materials. Additionally, most of the DBBM particles were resorbed and substituted by newly regenerated lamellar bone (Fig. 4A). The percentage of new bone was 25.95 ± 6.07%, and the percentage of the remaining scaffold was 30.95 ± 3.79% at 10 months postoperatively (Figs 4B and C).

**Discussion**

A GBR technique described by Hurley et al. has been a successful treatment for local alveolar ridge defects consistently. Besides primary wound closure and angiogenesis, space creation/maintenance and stability are the other two key factors to achieve the success of GBR. The peripheral bone formation primarily depends on the space-making ability of the membrane. The rigid scaffold such as Ti reinforced nonresorbed membrane or Ti mesh could help with good space creation and maintenance. However, both methods add significantly the cost and not ease of manipulation. The tenting technique was first introduced by Marx in 2002, reporting the surgical technique utilizing dental implants as “tent poles” in the treatment of mandibles with severe bone resorption. Screw tenting has been widely applied as an adjunctive device in horizontal bone augmentation, and a range of 3–5 mm bone gain could get in many studies. In the reconstruction of vertical bone defect, due to limited space creation/maintenance with regular screw tenting, an approximate gain in bone height of 2–3 mm could achieve after healing of around 6 months. However, the bone height obtained with tenting underwent more bone remodeling and resorption than with onlay grafting. In the present study, our concern was to make a larger space underneath the large cap of the tenting screw; then, the grafts adapted readily and were not easy to collapse in this

**Table 3:** Micro-CT analysis of alveolar bone volumetric parameters of bone harvest

<table>
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<tr>
<th></th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Quartiles (Q1 and Q3)</th>
<th>95% CI</th>
<th>Mean</th>
<th>Standard deviation</th>
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<tr>
<td>Tb. N</td>
<td>3.34</td>
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<td>4.01</td>
<td>(2.82 and 3.82)</td>
<td>(3.01–3.55)</td>
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<tr>
<td>BV/TV</td>
<td>26.84</td>
<td>19.50</td>
<td>36.73</td>
<td>(21.26 and 31.27)</td>
<td>(25.36–29.75)</td>
<td>27.55</td>
<td>4.69</td>
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<tr>
<td>Tb. Th</td>
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<td>0.104</td>
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<td>BMD</td>
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<td>0.22</td>
<td>0.40</td>
<td>(0.23 and 0.31)</td>
<td>(0.25–0.30)</td>
<td>0.28</td>
<td>0.05</td>
</tr>
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</table>

Figs 4A to C: Histological analysis of the regenerated alveolar bone at 10 months postoperatively; (A) Masson staining of the regenerated alveolar bone (magnification 200x and 500x; scale bars, 100 and 400 μm); (B) Area of new bone formation (%); (C) Percentage of remnant scaffold area (%).
Alveolar Bone Augmentation with Tentpole

area, facilitating bone cell migration and proliferation. Meanwhile, fixing tent screws was much easier to execute compared to fixing the collagen membrane and nonresorbable membrane with mini screw pins. The measurement of the new bone height in the study was the position of virtual implants, which could present the real bone needed for implant insertion. As has been pointed out in many clinical studies, the postsurgical complications, such as membrane exposure, were much less with screw tenting than with Ti-reinforced nonresorbable membrane and Ti mesh. Even with a mean of 5.76 ± 3.14 mm bone height gain, the surgical-related complications were very low, and there was no tenting screw exposure and wound dehiscence in the healing phase.

In these cases, DBBM was used alone as the grafting material, and no additional autologous bone particles were added. Considering the negative effect on angiogenesis and osteoinductivity without autologous bone, the healing phase is prolonged to 10 months. Histological assessments were performed on bone cores harvested from patients, revealing excellent integrity with a well-defined cancellous bone pattern and strong connectivity among the trabeculae.

The new bone percentage was 25.95 ± 6.07%, lower than that of Daga et al.26 and Dellavia et al.27 similar to Felice et al.28 However, it seems that the percentage of regenerated bones had no influence on the prognosis of the dental implant, short-term implantation success rate was 100%, and no severe complications and bone resorptions were seen during our follow-up period.

The success of these cases indicated that even in cases involving significant 3D bone defects, the modified large tenting screw combined with a purely applied deproteinized bone substitute could provide a promising outcome.

The limitation of the study is the absence of a comparison of clinical outcome and complication incidence to control groups like the onlay technique or GBR combined with a nonabsorbable membrane. Besides, larger case samples are required to further analyze the treatment efficiency of the modified large tenting screw. Furthermore, whether the addition of autogenous bone can shorten the healing time and the maximum bone gain of this technique should be explored longer follow-up period was also needed for evaluation of the long-term bone resorption.

**Conclusion**

For reconstruction of advanced vertical bone defects (>4 mm) in the posterior mandible, a large-head tenting screw combined with DBBM and resorbable collagen membrane seems as a practical treatment. Meanwhile, this surgery is easily learned and not technically demanding; the rate of the postoperative membrane is also relatively lower. We believe this versatile and effective method can be widely applied in advanced vertical bone defects in the posterior mandible in the future.

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