Managing Titanium Mesh Exposure With Partial Removal of the Exposed Site: A Case Series Study

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INTRODUCTION

Dental implants have become a successful treatment modality for the totally1 or partially2 edentulous patient. Bone augmentation techniques have been introduced for clinical situations in which there is inadequate bone volume to successfully place dental implants.3–5 Titanium mesh (TiMe) is a device for guided bone regeneration that has been used with the most desirable outcome in osseous wound space maintenance.5,6 TiMe has been used successfully in alveolar ridge augmentation,7–11 sinus augmentation,12 treatment of cleft palate,10,13 and in situations with simultaneous placement of dental implants.14,15 Several authors have used the TiMe in conjunction with a variety of graft materials. Autogenous bone graft,16,17 xenograft,16 allograft,16 hydroxyapatite,19 and bone morphogenetic proteins17,20 have been used successfully with TiMe for alveolar ridge augmentation procedures. The rationale of using a TiMe as a barrier during alveolar ridge augmentation is its rigidity and biocompatibility that provide dimensional stability and isolation to the graft particles.5,21

Systematic reviews,3–6 clinical studies,9–16,19,22 and clinical case reports/series8,20,23–26 have reported that exposure of the TiMe is the most commonly occurring complication. There is a wide range of frequency of exposure that has been reported in the literature, ranging from 5%14 up to 50%27 (Table 1). Average bone regeneration with TiMe was 4.91 mm (2.56–8.6 mm) vertically and 4.36 mm (3.75–5.65 mm) horizontally.5

Clinical studies have suggested that a certain amount of bone loss might be associated with exposure of the TiMe.8 The proposed treatment of an exposed TiMe involves topical application (brushing) of chlorhexidine gel to reduce the possibilities of infection of the surgical site.5 However, in 20% of clinical situations in which exposure of the TiMe occurred, the decision was made to surgically remove the TiMe.5

Surgical removal of the TiMe was associated with an early 3-to 4-week exposure.5,36 Some authors proposed the use of a resorbable29 or nonresorbable27 membrane and/or platelet-rich plasma22 combined with TiMe in an attempt to reduce the frequency of exposure. However, to the authors’ best knowledge, there has been no published article in the literature reporting that exposure of the TiMe resulted in bone loss significant enough to prevent placement of dental implants3–5 or in subsequent loss of dental implants placed in the augmented sites.5

The purpose of this clinical series report is to introduce a new treatment modality for treating the exposed TiMe. The technique involved removing the exposed portion of the TiMe while leaving the rest of the TiMe in place until bone graft healing and maturation occurs. Removing the portion of the TiMe that has been exposed might allow the soft tissue to migrate over the exposed graft material without disrupting bone healing. The purpose of this treatment approach is to reduce the amount of trauma and maintain the advantages of the TiMe as a space maintenance device.

CLINICAL REPORTS

A total of 4 patients were treated at the Center for Prosthodontics and Implant Dentistry at Loma Linda University by the same surgeon (A.A.) between 2015 and 2017. Patients were referred by their restorative doctor to have a staged alveolar ridge augmentation procedure performed along with subsequent implant placement. All included patients had received at least 2 previous failed alveolar ridge augmentations at the pertaining site. All patients received a cone beam computed tomography (CBCT) before alveolar ridge augmentation procedures and another CBCT after bone maturation and healing before proceeding with implant surgery. A removable Essix interim provisional was placed in all clinical situations after ridge augmentation was completed. The interim prosthesis was supported by the adjacent teeth and trimmed to have no contact with the soft tissue to avoid interference with tissue healing. All patients were prescribed antibiotics after ridge augmentation procedure (amoxicillin 500 mg every 8 hours for 8 days) and instructed to rinse twice a day with 0.12% chlorhexidine gluconate.
Case 1

A 50-year-old female patient was referred for localized alveolar ridge augmentation at the area of teeth Nos. 9 and 10 (Figure 1). A preoperative cone beam confirmed the lack of sufficient bone volume for implant placement in that area. After discussing various treatment options, the decision was made to treat the partial edentulism with bone grafting and subsequent implant placement (Table 2).

After a crestal incision was performed, full-thickness labial and palatal flaps were reflected. The buccal flap was extended beyond the mucogingival junction to facilitate primary closure. In addition, the recipient site was perforated to induce bleeding and promote the incorporation of the graft. A 50/50% mix of cortical 1.0–2.0 mm and 0.25–1 mm particulate bone allograft (Puros, Zimmer Biomet, Carlsbad, Calif) was used. The TiMe was trimmed to fit the edentulous area, while contact of the mesh with the adjacent teeth was avoided. The graft was loaded on the TiMe (Titanium Augmentation Micro Mesh, ACE Surgical Supply Co, Brockton, Mass) and placed at the recipient site. Periosteal fenestration was performed along the labial flap to enable primary closure. The mesh was secured in place with fixation screws (truSCREW, ACE Surgical Supply Co). A resorbable bilayered collagen membrane (Bio-gide, Geistlich Parma AG, Wolhusen, Switzerland) was used over the TiMe, and the flap was then sutured.

Exposure of the TiMe was observed during the fourth week after the initial alveolar ridge augmentation procedure. The exposure occurred at the palatal aspect of the edentulous area. Exposure was measured with a periodontal probe to be 4 x 4 mm. The portion of the exposed TiMe was removed using carbide burs (Nos. 557 and 8 carbide bur, Brasseler Dental Instrumentation, Savannah, Ga) and scissors at the 12th week after the initial grafting procedure and 8 weeks after the exposure was noted (Table 2). The remaining portion of the mesh was left submerged until 6.5 months after grafting.

Full-thickness labial and palatal flaps were reflected, and the mesh was removed. The graft appeared well integrated. There was some minimal amount of granulation tissue at the area. Postoperative CBCT was performed after mesh removal to evaluate bone availability for implant placement. A comparison of the preoperative and postoperative CBCTs revealed 4.1 mm of horizontal and 4.5 mm of vertical ridge augmentation. The flaps were then sutured, and the patient was scheduled for subsequent implant surgery. The obtained bone volume was adequate for implant placement.
Case 2

A 47-year-old male patient was referred for localized alveolar ridge augmentation at the area of tooth No. 8 (Figure 2). A preoperative CBCT confirmed the lack of sufficient bone volume (Table 2). Surgical technique and bone graft material were identical to that described in case 1, with the exception of replacing the resorbable bilayered collagen membrane (Bio-gide, Geistlich Biomaterials) with a platelet-rich fibrin (PRF) membrane over the TiMe.

Exposure of the TiMe was observed during the first week after the initial grafting procedure. The exposure occurred at the crestal aspect of the edentulous area and extended toward the labial aspect. The exposure was measured to be 6.3 mm.

The portion of the exposed TiMe was removed the 10th week after the initial grafting procedure. The remaining portion of the mesh was left submerged until 6.5 months after grafting. During the surgical removal of the TiMe, the graft appeared well integrated. Similarly to case 1, there was some minimal amount of granulation tissue at the area. A comparison of the

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**Table 1**

<table>
<thead>
<tr>
<th>Article</th>
<th>Type of Edentulism</th>
<th>Number of Patients/Sites</th>
<th>Type of Bone</th>
</tr>
</thead>
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<tr>
<td>von Arx et al&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>20/20</td>
<td>Autogenous</td>
</tr>
<tr>
<td>von Arx et al&lt;sup&gt;15&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>18/18</td>
<td>Autogenous</td>
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<td>Malchiodi et al&lt;sup&gt;28&lt;/sup&gt;</td>
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<td>25/25</td>
<td>Particulated autogenous</td>
</tr>
<tr>
<td>Leghisia et al&lt;sup&gt;29&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>10/10</td>
<td>Blood clot only</td>
</tr>
<tr>
<td>von Arx et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>15/19</td>
<td>Particulated autogenous</td>
</tr>
<tr>
<td>Assenza et al&lt;sup&gt;30&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>22/22</td>
<td>Blood clot only</td>
</tr>
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<td>Mariorana et al&lt;sup&gt;31&lt;/sup&gt;</td>
<td>5 edentulous, 9 partially edentulous</td>
<td>14/23</td>
<td>Autogenous + DBBM (50:50 ratio)</td>
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<tr>
<td>Artzi et al&lt;sup&gt;23&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>10/10</td>
<td>DBBM</td>
</tr>
<tr>
<td>Degidi et al&lt;sup&gt;32&lt;/sup&gt;</td>
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<td>7/7</td>
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<td>Partially edentulous</td>
<td>17/17</td>
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<td>Molly et al&lt;sup&gt;34&lt;/sup&gt;</td>
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<td>Louis et al&lt;sup&gt;21&lt;/sup&gt;</td>
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<td>44/45</td>
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<td>Acellular collagen sponge (rhBMP-2)</td>
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<td>Various bone graft material with different patients</td>
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<td>de Freitas et al&lt;sup&gt;17&lt;/sup&gt;</td>
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<td>Autogenous VS rhBMP-2</td>
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<td>Funato et al&lt;sup&gt;26&lt;/sup&gt;</td>
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<td>19/19</td>
<td>Human platelet-derived growth factor BB (rhPDGF-BB) mixed with DBBM and autogenous</td>
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<td>13/13</td>
<td>Autogenous + DBBM (50:50 ratio)</td>
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<tr>
<td>Chan et al&lt;sup&gt;24&lt;/sup&gt;</td>
<td>Partially edentulous</td>
<td>5/5</td>
<td>Allograft</td>
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<td>Human platelet-derived growth factor BB (rhPDGF-BB) mixed with DBBM</td>
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<td>Autogenous mixed with hydroxyapatite (50:50 ratio)</td>
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<td>Partially edentulous</td>
<td>15/15</td>
<td>Allograft and rhBMP-2</td>
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</tbody>
</table>

* CT indicates computed tomography; CBCT, cone beam computed tomography; DBBM, deproteinized anorganic bovine bone; H, horizontal; max., maxilla; mand., mandible; PA, periapical radiograph; PRP, platelet-rich plasma; rHBMP-2, recombinant human bone morphogenic protein–2; TiMe, titanium mesh; V, vertical.
preoperative and postoperative CBCTs revealed 7.8 mm of horizontal and 4.6 mm of vertical ridge augmentation. The obtained bone volume was sufficient for implant placement.

**Case 3**

A 44-year-old female patient was referred for bone grafting at the area of teeth Nos. 9–11 (Figure 3). All surgical procedures for TiMe placement and removal were identical to that described in case 1, except that fresh frozen allograft was used (Osteocell Plus, ACE Surgical Co), a resorbable thick spongious scaffold collagen membrane (Mucograft, Geistlich Pharma AG) instead of the resorbable bilayered collagen membrane, and TiMe used was Ridge-Form Mesh (OsteoMed, Addison, Tex; Table 2).

Exposure of the mesh occurred the sixth week after initial surgery. The exposed portion was removed 4 weeks later. The exposure area of the TiMe was measured to be $11 \times 4$ mm, and it was located along the crest of the edentulous area. The remaining portion of the TiMe was left submerged and surgically removed 6.5 months after the initial bone-grafting procedure.

During the surgical procedure for removing the TiMe, the graft appeared well integrated. Similarly to previous cases, there was some minimal amount of granulation tissue present.

### Table 1

Extended Follow-up Period—Removal, mo | Percentage of Exposure | Bone Gain Outcome and Mean of Evaluation
--- | --- | ---
4.7 | 50 | Measuring bone graft at reentry; 25 were type A and 2 as type B by Misch ridge morphology classification
5.2 | 0 | Edentulous ridge expansion with TiMe and implant placement; evaluation with histology and measuring at reentry $H = 5.65$ mm
8 | 4 | Following extraction, placement of implant and grafting; evaluation with histology and PA radiographs
5 | 0 | Grafting around implants; evaluation at reentry $V = 5.8$ mm
6.6 | 5.26 | Grafting around implants; evaluation at reentry with histology and PA radiographs
4 for mand., 6 for max. | 18.18 | Used for maxillary sinus when indicated; evaluated with histology
5 | 14.28 | Reentry for histopathology and histochemistry; $V = 5.2$ mm
9 | 20 | Placement of implant and mesh; evaluated at reentry for histology
4 for mand., 6 for max. | 0 | Evaluated with CT ($V = 2.86$ mm, $H = 3.71$), laboratory evaluation (stone casts): (volumetric $= 1.07$ mL/mean $V = 2.57$ mm, $H = 3.86$ mm) and histology
6–9 | 57.14 | Evaluated with CT with $V = 4.8$ mm
4–6 | 22.2 | Evaluated with CT ($V = 2.56$ mm, $H = 3.75$), laboratory evaluation (stone casts)—volumetric $= 0.73$ cc, mean $V = 2.59$ mm, $H = 3.88$ mm), histologic and histomorphometric evaluation
5–13 | 35.3 | 2 with very early and 5 late exposure
9–17 | 63.63 | Evaluated with CT (average $H = 4.4$ mm and $H = 4.6$ mm)
1–21 | N | Evaluation at reentry by periodontal probe; $V = 5.7$ mm
4–6 | 33.3 | Exposure treated with absorbable collagen membrane; evaluation with CT ($V = 3.71$ and $H = 4.16$)
8–9 | 6.25 | Evaluated at reentry; mean of $V = 13.7$ mm and histology
6.9 | 52.7 | Evaluated at reentry: no mesh exposure with PRP
8–9 | 14.8 | Evaluated at reentry histology and CT; no mesh exposure with PRP
6 | 13.95 | No significant difference between type of graft and TiMe exposure
6 | 0 | Evaluated with CBCT scans; mean bone gain with horizontal and vertical defect was $H = 3.7$ mm and $V = 5.4$; for horizontal defect, $H = 3.9$ mm
6 | 36% within a week, resuturing | Evaluated at reentry and CT; no significant difference between the 2 groups ($H = 3.2$, $V = 3.7$ mm)
6 | 12.5 | TiMe was covered with resorbable collagen membrane; evaluated at reentry and histology; $V$ gain $= 8.6$ mm
5.26 | Evaluated at reentry and panoramic radiograph with software
6 | 7.69 | Evaluated with CBCT scan and histomorphometric examination; mean vertical gain $= 3.4$ mm
5 | 0 | Evaluated at reentry with histology
0 | 0 | Not reported
3–7 | 70% (they mentioned criteria for risk of exposure and infection) | Evaluated with use of CBCT; bone gain $V = 8.53$ mm
6 | 0 | Evaluated with use of CBCT; bone gain $V = 8.53$ mm
Radiographic analysis revealed 4.6 mm of horizontal and 7.0 mm of vertical ridge augmentation.

**Case 4**

A 27-year-old male patient was referred for ridge augmentation at the area of tooth No. 9 (Figure 4). Surgical procedures were performed as described in case 1, except that a PRF membrane was used also over the resorbable bilayered collagen membrane (Bio-gide, Geistlich Biomaterials). Cancellous particulate bone allograft (Puros, Zimmer Biomet) was used as the graft material.

Exposure of the TiMe was observed during the third week after the initial surgery. The exposure occurred at the palatal aspect of the edentulous area. The exposure was measured to be 5 mm. The portion of the exposed TiMe was removed the fifth week after the initial grafting procedure (Table 2).

![Figure 2. Showing case 2. (a) Facial view of defect at time of surgery. (b) Occlusal view of defective alveolar ridge following full-thickness flap reflection. (c) Occlusal view of titanium mesh (TiMe) in position following fixation. (d) Facial view of TiMe exposure at the crest of the ridge with facial extension. (e) Occlusal view of TiMe exposure. (f) Facial view at time of partial removal of exposed TiMe. (g) Occlusal view at time of partial removal of exposed TiMe. (h) Occlusal view showing healing after partial removal of exposed TiMe. (i) Occlusal view of regenerated alveolar ridge at time of implant placement.](image)

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Patient and defect data pre- and postgrafting providing location and size of titanium mesh exposure and end result following the described clinical protocol</th>
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</thead>
<tbody>
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<tr>
<td>1</td>
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<td>3</td>
<td>44</td>
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<td>4</td>
<td>27</td>
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</table>

* Measured from pre- and postgrafting cone beam computed tomography after titanium mesh removal.
remaining portion of the mesh was left submerged until 6 months after grafting.

Upon surgical removal of the TiMe, the graft appeared well integrated while the presence of granulation tissue at the area was consistent as with previous cases. Radiographic measurements revealed 5.4 mm of horizontal and 3.1 mm of vertical ridge augmentation. The obtained bone volume was adequate for implant placement.

The significance of the current case series report is that it provides a suggested treatment modality for addressing a frequent complication associated with utilization of the TiMe as a barrier for localized alveolar ridge augmentation. The current report indicated an average 4.8 mm of vertical alveolar ridge augmentation and 5.5 mm of horizontal augmentation. The obtained augmentation is consistent with the typical alveolar

<table>
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<tr>
<th>Exposure Size, mm</th>
<th>Week of Removal of Exposed Titanium Mesh</th>
<th>Total Healing Period</th>
<th>Achieved Horizontal (H) Augmentation, mm*</th>
<th>Achieved Vertical (V) Augmentation, mm*</th>
<th>Clinical Appearance of Graft Material</th>
<th>Additional Bone Graft Placed With Implant Surgery</th>
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<tr>
<td>4 × 4</td>
<td>4th</td>
<td>6 months</td>
<td>4.1</td>
<td>4.5</td>
<td>Well integrated</td>
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<td>6 × 10</td>
<td>10th</td>
<td>6.5 months</td>
<td>7.8</td>
<td>4.6</td>
<td>Well integrated</td>
<td>No</td>
</tr>
<tr>
<td>11 × 4</td>
<td>10th</td>
<td>6.5 months</td>
<td>4.62</td>
<td>6.98</td>
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<td>5 × 3</td>
<td>5th</td>
<td>6 months</td>
<td>5.4</td>
<td>3.1</td>
<td>Well integrated</td>
<td>No</td>
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</table>
ridge augmentation that has been reported in the literature.\(^5\) Racia-dal Polo et al\(^5\) in a systemic review indicated that utilization of a TiMe as a barrier resulted in 4.91 mm of vertical ridge augmentation and 4.36 mm of horizontal augmentation. It should be noted that comparing various studies should be performed with caution because different graft materials and different techniques have been implemented in the published literature. However, despite the divergence of grafting materials and techniques, the preliminary findings indicate that removing the exposed portion of the mesh and allowing the remaining portion to be submerged may not compromise the final clinical outcome.

An interesting finding in this case series study was that all of the patients with TiMe exposure had received at least 2 failed alveolar ridge augmentations previously. In addition, each patient had received a different surgical technique in terms of the type of membrane used to cover the TiMe. In cases 2 and 4, a PRF membrane was used. Cases 1 and 3 were without a PRF membrane and yet all had TiMe exposure. The PRF membrane failed to prevent TiMe exposure with the presented cases. There could be a cause-and-effect relationship between multiple-site entry and future TiMe exposure. It would be of great interest to explore this theory with a future study that has a broader sample size.

There is a controversy in the literature regarding the effect of TiMe exposure on bone volume. While several authors have reported no effect of the exposure on the volume of bone grafting,\(^10,23,36\) others have reported that bone loss occurs when the TiMe is exposed.\(^9,11,14,16,27,35\) Despite the reported loss of bone volume, when this occurred, the obtained bone volume was sufficient to place implants.\(^11,14,35\) However, von Arx et al\(^27\) experienced a clinical situation in which the exposure of the TiMe resulted in significant bone loss that precluded placement of implants. The effect of the size of the exposure, the timing of the exposure after the initial ridge augmentation procedure, and the type of graft material on the final clinical outcome are elements that need to be studied.

There is a scarcity in the literature regarding the quality of the obtained osseous tissue when exposure of the TiMe occurs. Proussaefs et al\(^16\) published a case series report in which histologic specimens were obtained and analyzed from alveolar ridges where a localized alveolar ridge augmentation procedure was performed by using a TiMe as a barrier. In their study, in which histomorphometric analysis was performed, the exposed sites had lesser bone formation while a bigger portion of connective tissue was present at the augmented sites associated with mesh exposure. It might be suggested that in addition to the reduced bone volume, exposure of the mesh may result in
decreased quality of the augmented alveolus. While further research is needed to validate this hypothesis, the preliminary results of the current case series report indicate that treating the complication of TiMe exposure by removing the exposed portion of the mesh may result in bone-grafting results similar to clinical situations in which the mesh had not been exposed.

In the current case series, the remaining portion of the TiMe was removed 1 to 2 months before placement of the implants. Removal of the mesh was performed as a separate surgical procedure. Boyne et al.7 observed the presence of a newly formed connective layer along with granulation tissue under the mesh (“pseudo periosteum”). The presence of abundant granulation tissue underneath the mesh may indicate placement of implants at a later stage.7,9,15 The clinical significance of this connective and granulation tissue layer is unknown. Proussaefs et al.8 suggested that the micromovement of the titanium barrier could induce the formation of this layer of connective and granulation tissue. While this suggestion has not been validated, removing the portion of the exposed mesh may result in lesser TiMe micromovement and lesser amount of granulation tissue formation.

The limitations of the current cases series report are the limited number of patients and the lack of long-term follow-up. In addition, histologic analysis of the augmented alveolus would have offered valuable information regarding the quality of the augmented alveolus.

In summary, the proposed removal of the exposed portion of the TiMe might offer results similar to results associated with nonexposed sites. Further clinical research and increased use of the augmented alveolus would have offered valuable information regarding the quality of the augmented alveolus.

In conclusion, the authors report no conflicts of interest related to this study.

CONCLUSION

Removing the exposed portion of the TiMe did not have a negative effect clinically on the integration of the grafted bone and the bone volume available for implant placement. Furthermore, it allowed for easier hygiene maintenance by the patient at the grafted site. Further research is needed before definitive conclusions can be made.

ABBREVIATIONS

CBCT: cone beam computed tomography
DBBM: deproteinized anorganic bovine bone
PRF: platelet-rich fibrin
rHBMP-2: recombinant human bone morphogenetic protein–2
TiMe: titanium mesh

NOTE

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

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