Keywords: polytetrafluoroethylene, titanium mesh, tenting pole, vertical augmentation.

Summary
Background: Vertical bone resorption begins as soon as the tooth is extracted and, if not stopped, continues until the alveolar bone is completely atrophic. Various materials and techniques are used to rebalance the bone, which helps to restore the stable height of the alveolar bone. Three techniques are reviewed in this study: polytetrafluoroethylene membrane (PTFE), titanium mesh (Ti-mesh), and tenting pole. This systematic review aimed to evaluate the effectiveness of three different vertical augmentation techniques.

Methods: A systematic review of the literature was performed according to the PRISMA guidelines in search of clinical trials published between 2017 and 2022. Electronic literature searches were conducted independently by two authors.

Results: Studies indicate a vertical gain of alveolar bone from 2.36 ± 0.28 mm to 5.6 ± 2.6 mm, when using PTFE, and the mean vertical gain of alveolar bone was from 1.5 ± 1.6 mm to 6.36 mm when using Ti-mesh, and 1.72 ± 0.78 mm to 2.87 ± 0.79 mm bone gain using tenting pole technique.

Conclusion: Three used techniques: polytetrafluoroethylene membrane (PTFE), titanium mesh (Ti-mesh), and tenting pole showed acceptable results in the process of vertical augmentation. However, this study did not find robust evidence of which technique is the most effective.

Introduction
Bone resorption begins just after extraction. Buccal bone plate causes the biggest alveolar ridge defects, because of its thinness. Major changes are observed in aesthetic and premolar areas, and defect size decreases in the posterior area of the jaw [1]. It is observed that in 6 months after tooth extraction alveolar bone loss can reach 11-22% of bone height and 29-63% of bone width [2]. Likewise, after 12 months 40-60% of alveolar bone volume could be lost if not treated. [3, 4, 5].

There are various surgical procedures and materials proposed for alveolar bone defects. For horizontal ridge gaining, there is an expansion of the alveolar crest; guided bone regeneration (GBR), while for vertical augmentation GBR; autogenous block graft; osteogenic distraction [6, 7, 8].

Materials and methods used in the augmentation process are crucial for long-term success [9]. One of the methods used for augmentation is non-absorbable membrane high-density polytetrafluoroethylene (d-PTFE). The d-PTFE membrane is biocompatible and suitable for bone augmentation because can provide space maintenance and serve as a barrier. The drawback of d-PTFE is that it needs to be removed, therefore more surgical interventions are needed. Likewise, in the period of healing, there is a plausibility of early wound dehiscence, which leads to bacterial colonization and inflammation, and bone disintegration [10].

An alternative method used for the restoration of alveolar bone height is the tent pole technique. This procedure is based on the prevention of soft tissue compression to the bone graft and the micromovement of graft elimination [11].

Another method used for augmentation is titanium mesh. The main difference between the PTFE method and titanium mesh is because of titanium mesh porosity in case of exposure it often has an infection resistance. The titanium mesh membranes also allow for better blood supply because of their porous structure. However, this type of non-absorbable as well as a d-PTFE membrane should be removed [12, 13].

The aim - of the study was to evaluate the effectiveness of the above three techniques for vertical bone augmentation.
Table 1. The focus question development according to the PICOS study design.

<table>
<thead>
<tr>
<th>(P) Population</th>
<th>People with vertical alveolar bone defects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I) Intervention</td>
<td>Vertical augmentation using different techniques.</td>
</tr>
<tr>
<td>(C) Control</td>
<td>The evaluation of the effectiveness of different vertical augmentation techniques: polytetrafluoroethylene membrane (PTFE), titanium mesh (Ti-mesh), and tenting pole.</td>
</tr>
<tr>
<td>(O) Outcome</td>
<td>The evaluation of vertical bone gain and histomorphometric analysis.</td>
</tr>
<tr>
<td>PICO</td>
<td>Which vertical augmentation technique is the most effective in terms of vertical bone gain and histomorphometric analysis?</td>
</tr>
</tbody>
</table>

Materials and methods

Protocol and registration. This systematic review aimed to evaluate the effectiveness of three different vertical augmentation techniques based on the height of the augmented bone. The systematic review protocol was documented in advance. The reporting of this systematic analysis adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement [14].

Focus question. The focus question of this review was developed according to the population (P), intervention (I), control (C), and outcome (O) study design method (PICO): Which vertical augmentation technique is the most effective in terms of vertical bone gain and histomorphometric analysis? (Table 1, which demonstrates focus question development according to the PICOS study design)

Information sources. An electronic search was performed for articles in the English language published from 2017 to 2022, by two reviewers using MEDLINE (PubMed), The Cochrane Library, and ScienceDirect databases. Reference lists of studies were also hand-searched for relevance.

Search. The search strategy incorporated the examination of MEDLINE (PubMed), The Cochrane Library, and ScienceDirect electronic databases. The following query was used: ((titanium mesh) OR (tent pole) OR (tent screw) OR (Ti-mesh) OR (titanium mesh) OR (PTFE) OR (Polytetrafluoroethylene Membrane)) AND (vertical augmentation).

Selection of Studies. The resulting articles were independently evaluated by 2 researchers. Selected articles were compared and differences were matched by discussion. All articles were screened and excluded after investigating abstracts and titles. In the final stage, full-text analysis and selection of complete articles for careful reviewing and analysis according to the eligibility criteria were made: in vivo studies published in the English language. Letters, editorials, literature reviews, in vitro, animal studies, case reports, case series, systematic reviews, meta-analyses, and abstracts were excluded.

Results

Study selection. The primary database search showed 1688 records, an additional search through other sources added 19 more records, and after the filter was applied and duplicates removed 1137 of them were removed (Figure 1, which demonstrates the PRISMA flow diagram). After the title and abstract screening 22 potentially relevant studies were retrieved in full text for eligibility evaluation. 15 studies were rejected because of the reasons: the type of article was case-series (n = 8); the article did not evaluate values of vertical gain in millimeters (n = 3); the same patients were described in a few different articles (n = 4). Therefore, the search process returned 7 relevant prospective or retrospective clinical trials, which were included in qualitative data synthesis.

Study Characteristics. 7 studies were included in the qualitative synthesis (Table 2). Overall studies involved 184 patients. The largest amount of 40 patients was observed. Considering the number of defects, the greatest amount of 71 defects were monitored. Two of the studies included PTFE observation one - titanium mesh, and two tent pole techniques. Comparative studies between PTFE and Ti-mesh techniques were two. Studies included the maxilla and mandible, six of them observed anterior and posterior defects; however, one study included only posterior defects of the mandible.

The vertical bone gain was evaluated in follow-ups from 6 to 9 months. Four studies were evaluating bone height change after 6 months, one after 8 months, and two after 9 months

PTFE membrane studies. Four studies were observing PTFE membrane usage in vertical bone augmentation [15-18]. Overall 104 defects were treated with PTFE membrane. Studies examined from 5 to 52 defects. In one of the studies, an autogenous graft procured from the mandibular ramus areas was used for vertical bone augmentation [18]. The remaining three used 50% autogenous bone chips with 50% deproteinized bovine bone mineral particles [15-17]. Studies indicate a vertical gain of alveolar bone from 2.36 ± 0.28 mm to 5.6 ± 2.6 mm [17, 18]. PTFE is compelling for vertical alveolar ridge augmentation in maxillary and mandibular regions.

Titanium mesh studies. Three studies were observing Ti-mesh membrane usage in vertical bone augmentation [15, 16, 19]. These studies monitored 50 patients and 91 defects. Autogenous bone was used with xenograft in a 1:1 ratio [15, 16, 19]. The defects were restored with the mix of bone and
the Titanium mesh. The mean vertical gain of alveolar bone was from $1.5 \pm 1.6$ mm to $6.36$ mm [16, 19]. These studies revealed that custom-made titanium mesh membrane with or without collagen membrane could be suitably used for vertical bone augmentation.

**Tenting pole technique studies.** Two studies were observing tenting pole technique [20, 21]. Overall 31 patients of which 53 sites of defects were investigated. Particulate allograft in combination with injectable platelet-rich fibrin with 1.3 mm diameter titanium screws and beta-tricalcium phosphate synthetic bone graft with 1.5 mm diameter titanium screws were used. Both studies evaluated vertical bone height after 6 months of operation [20, 21]. Histological percentage of bone change evaluated. The vertical bone gain was observed from $1.72 \pm 0.78$ mm to $2.87 \pm 0.79$ mm [20, 21]. Based on the study’s results, tenting pole technique may be considered a practicable technique for alveolar ridge augmentation.

İşik G et al. analyzed the histomorphometric results in this study and pointed out that using the tenting pole as the
technique for vertical augmentation 18.08% ± 2.17% of newly formed bone could be formed (p <0.001) [21].

Comparative studies. Two studies were investigated, comparing PTFE and Ti-mesh techniques [15, 16]. Thirty-five patients were examined, with overall 40 defects. Both studies compared vertical alveolar ridge augmentation using PTFE and Ti-mesh techniques in anterior and posterior regions of the maxilla and mandible. Defects in both studies were divided into two groups where Ti-mesh and PTFE membranes were used separately. The graft consisted of 50% autogenous bone chips harvested from the retromolar region and 50% deproteinized bovine bone mineral particles. Patients were examined from 8 to 9 months after the operation, and the change in vertical bone level was evaluated [15, 16]. PTFE group showed results from 2.36 ± 0.28 mm to 4.2 ± 2.2 mm., and Ti-mesh from 1.5 ± 1.6 mm to 4.1 mm [15, 16]. Maiorana C. et al. carried out the histomorphometric analysis in their study [16]. This study has indicated 48.28% of mineralized tissue in the PTFE group and 35.54% of mineralized tissue in the Ti-mesh group [16]. Clinical results approved that both techniques were effective in achieving vertical bone growth. No statistically significant differences were observed, between PTFE and Ti-mesh groups (p < 0.05) [16].

Discussion

Augmentation of the alveolar ridge is necessary to achieve the good height and aesthetics of the alveolar arch. This can be achieved by using various augmentation techniques, such as GBR or autogenous block graft; osteogenic distraction. Various techniques use a variety of materials or membranes to ensure good augmentation performance and long-term success. Usage of

<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Methods</th>
<th>Defect site</th>
<th>Materials</th>
<th>Results</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cucchi A, et al. [15]</td>
<td>-PTFE - Ti-mesh</td>
<td>Posterior regions of the mandible</td>
<td>A gr. PTFE (A) B gr. Ti-mesh+collagen (B) membrane A and B gr. 4 mini titanium screws A and B gr. 50% autogenous bone+50% deproteinized bovine bone mineral particles</td>
<td>A group: 4.2 mm B group: 4.1 mm</td>
<td>A: 0.0004 B: 0.0012</td>
</tr>
<tr>
<td>2.</td>
<td>Maiorana C, et al. [16]</td>
<td>-PTFE - Ti-mesh</td>
<td>Posterios regions of the mandible</td>
<td>1 gr. d-PTFE 2 gr. Titanium grid 1 and 2 gr. 50% autogenous bone+50% deproteinized bovine bone mineral particles</td>
<td>1gr. 4.2 ± 2.2 mm 2gr. 1.5 ± 1.6 mm</td>
<td>1, 2 gr. 0.22</td>
</tr>
<tr>
<td>3.</td>
<td>Amaral Valladão CA Jr, et al. [17]</td>
<td>PTFE</td>
<td>Anterior and posterior regions of maxilla and mandible</td>
<td>d-PTFE 50% autogenous bone chips +50% deproteinized bovine bone mineral particles PRF</td>
<td>5.6 ± 2.6 mm</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>4.</td>
<td>Vaibhav V, et al. [18]</td>
<td>PTFE</td>
<td>Anterior and posterior regions of maxilla and mandible</td>
<td>PTFE Autogenous bone graft</td>
<td>2.36 ± 0.28 mm</td>
<td>0.8500</td>
</tr>
<tr>
<td>5.</td>
<td>Cucchi A, et al. [19]</td>
<td>Ti-mesh Ti-mesh+collagen membrane</td>
<td>Anterior and posterior regions of maxilla and mandible</td>
<td>1 gr. Ti-mesh without cross-linked collagen membrane. 2 gr. Ti-mesh with a cross-linked collagen membrane. 50% of autogenous bone+50% high porosity xenograft</td>
<td>1 gr. 4.74 mm 2 gr. 6.36 mm</td>
<td>0.11</td>
</tr>
<tr>
<td>6.</td>
<td>Daga D, et al. [20]</td>
<td>Tent pole</td>
<td>Anterior and posterior regions of maxilla and mandible</td>
<td>1.5 mm titanium screws β TCP synthetic bone</td>
<td>2.87 ± 0.79 mm</td>
<td>0.0001</td>
</tr>
<tr>
<td>7.</td>
<td>İşık G, et al. [21]</td>
<td>Tent pole</td>
<td>Posterior mandible</td>
<td>1.3 mm titanium screws Allograft L-PRF</td>
<td>1.72 ± 0.78 mm</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Table 2. Data of interest
the membranes in augmentation procedures preserves the graft, moreover, it improves the isolation of the grafted area and space retention, granting the migration of osteogenic cells into the defect zone, bone remodeling, and healing [22, 23, 24]. Regeneration and final bone volume may be influenced by securing the membranes with thumbtacks or screws, which stabilizes and immobilizes the augmented region of defect [25].

The main issue of the present study was to evaluate vertical bone gain after three methods were used in the augmentation process. During the review of scientific literature, an analysis of 7 publications was carried out [15-21]. In all studies, procedures were conducted in humans using membranes in bone augmentation techniques. Four studies were using PTFE, three Ti-mesh, and two tenting pole techniques.

In systematic reviews, the authors reveal that using the GBR methodology, the height of the alveolar bone increases from 2 to 8 mm when using the PTFE membrane [26]. This study observed four studies where PTFE membrane was used, and all of them showed similar results, ranging from a minimum of 2.36 ± 0.28 mm in Vaibhav V et al. study [18] to a maximum of 5.6 ± 2.6 mm in Amaral Valladão CA Jr et al. study [17]. All four studies recorded the results achieved by bone augmentation at various slots, from 6 to 9 months [15-18].

It is important to note that in the process of augmentation, similar methodologies were used in all studies and the bone mix of 50% autogenous and 50% allograft was the same. In addition, no significant difference was found between vertical augmentation of posterior and anterior sites [18-21].

Roccuzzo M et al. point out that the height of bone tissue changes from 4 to 7 mm when using the Ti-mesh membrane [27]. In Cucchi A et al. [15] and Cucchi A et al. [19] studies, the results were in line with the results obtained by Roccuzzo M et al. [27], respectively 4.1 mm and 4.74 mm, but in Maiorana C et al. [16] study the results did not reach the minimum amount of augmented bone observed by this author and were only 1.5 mm. This could be explained by the fact that, according to the author, the defects in the bone under the membrane were not filled with graft, as a result of which membrane was exposed and a good result of augmentation was not achieved [16].

Another technique used for the mechanical preservation of augmented bone is a tenting pole. Caldwell et al. [28] and Chasioti et al. [29] point out that the screws reliably protect the augmented area from external forces. However, another author points out that this method is not suitable for use when the immense defect is in the posterior area [30]. One of the studies which were selected for this review observed anterior and posterior regions of the maxilla and mandible [20] and the other observed only posterior regions of the mandible [21]. The authors did not exclude differences between results in posterior and anterior regions. Studies indicated an alveolar bone gain of 2.87 mm and 1.72 mm., which is the smallest results among all three techniques used [20, 21].

All studies assessed the frequency of complications [15-21]. The complication assessed at the base was membrane exposure when PTFE or Ti-Mesh was used, and screw exposure when tenting pole technique was observed. Cucchi et al. point out two groups of complications: surgical complications (including flap damage, neurological damage, and/or vascular damage) and healing complications (membrane exposure without purulent exudate, membrane exposure more than 3 mm without purulent exudate, membrane exposure, with purulent exudate and/or abscess without membrane exposure) [15]. According to Cucchi et al. study, 7 out of 30 patients experienced postoperative complications, four when PTFE membrane was used and five when Ti-mesh membrane was used [15]. Significant healing complications lead to the loss of bone height, non-vital bone, and loss of implant [15]. PTFE membranes have a lower incidence of complications, according to Amaral Valladão CA Jr et al., who point out that no complications were observed in this study [17]. Maiorana C et al. study [16] confirms Amaral Valladão CA Jr et al. [17] findings and points out that there were no complications from using the PTFE membrane for all treated patients while using the Ti-mesh membrane two out of ten patients resulted in complications. The complication evaluated in Maiorana C et al. study was the exposure of a titanium grid [16]. However, the complication was not crucial, so membranes were left in their place and the patients were instructed to apply 0.2% chlorhexidine digluconate gel twice a day [16]. As for the tenting pole technique, Daga D et al. [20] point out that no screw exposure was observed, but the Işık G. study [21] noted that two out of five patients were observed to have a screw exposure. The authors do not indicate what was done in the event of complications.

Nowadays regardless technique that was used for the augmentation process, platelet-rich fibrin (PRF) or leukocyte and platelet-rich fibrin (L-PRF) is associated with bone grafts for better bone augmentation results [31]. Amaral Valladão CA Jr et al. [17] PTFE study and Işık G. et al. [21] tenting pole study was observing the augmentation process using PRF and L-PRF accordingly. The highest volume of augmented bone was found using PTFE and PRF, however lowest results were received using tenting pole and L-PRF among all the studies reviewed, Daga D et al. was observing tenting pole technique without L-PRF, and the results came out higher (2.87 ± 0.79 mm) than using the tenting pole with L-PRF [20]. Thus, it can be asserted that using the PTFE
membrane in combination with PRF can lead to achieving great augmentation results [17, 21].

In this review, it was noted that there is a lack of comparative studies between tenting pole and Ti-mesh, or tenting pole and PTFE studies, which does not allow to compare Tenting-pole well with other techniques, however, the comparison between PTFE and Ti-mesh was possible, because of the two articles found. Also, the studies themselves are not homogeneous, study using various methods, patients, and the sites of defects, which makes it difficult to compare all the studies with each other. After reviewing the results of all the studies, the maximum volume of the grown bone was obtained using Ti-mesh in combination with the collagen membrane, and the lowest result was shown by the use of the tenting pole technique. However, to avoid complications, it is worth using the PTFE membrane, because the use of this membrane could reduce the risk of membrane exposure or soft tissue/bone infection.

References


VIETOS UŽLAIKYMO VARŽTU, POLITETRAFLUORETILENO (PTFE) IR TITANINĖS MEMBRANŲ NAUDOJIMAS VERTIKALIAI KAULO AUGMENTACIJAI

A. Janovskienė, V. Pliauva, J. Zigmantavičius

Raktažodžiai: politetrafluoretileno membrana, titaninė membra, vietos užlaikymas varžtu, vertikali augmentacija.

Santvarka

Problemos aktualumas ir darbo tikslas. Vertikali kaulo rezorbcija prasideda vos ištraukus dantį ir, jei nėra stabdoma, tęsiasi tol, kol kaulas visiškai atrofuojasi. Įvairios medžiagos ir technologijos, naudojamos kaulo atkūrimui, padeda atkurti stabilų alveolinio kaulo aukštį. Šiame tyrime analizuojamos trys metodikos: augmentacijos metu taikant politetrafluoretileno membraną (PTFE), titaninę membraną (Ti-mesh) ir stabilų augmentuojamo kaulo tūrio užtikrinimą varžtu (angl. tenting pole). Tyrimo tikslas – įvertinti trijų minėtų technikų efektyvumą vertikalai kaulo augmentacijai.

Tyrimo rezultatai

Naudojant politetrafluoretileno (PTFE) membraną, buvo stebimas nuo 2,36 ± 0,28 mm iki 5,6 ± 2,6 mm kaulo aukščio pokytis, vidutinis kaulo priaugis naudojant Ti-mesh membraną nuo 1,5 ± 1,6 mm iki 6,36 mm, o naudojant vietos užlaikymo varžtu techniką, pastebėtas nuo 1,72 ± 0,78 mm iki 2,87 ± 0,79 mm vertikalus pokytis.

Išvados. Visi trys augmentacijos metodai (PTFE membranų, titaninės membranos naudojimas ir kaulo tūrio užtikrinimas varžtu) yra efektyvūs kaulo aukščio atkūrimui. Atliekant sisteminių straipsnių apžvalgą, nebuvo rasta pakankamai vienos technikos pranešimų įrašų autorių.

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