The placement of dental implants in the posterior maxillary area is a well-discussed challenge in the literature. This challenge may be attributed to several factors, including reduced bone volume due to accelerated maxillary sinus pneumatization following maxillary tooth loss and the relatively porous cortical and fine trabecular bone phenotype of the posterior maxilla. These may result in an edentulous alveolar ridge at the planned site of implantation that may not enable the placement of dental implants due to lack of sufficient bone volume and/or implant primary stability. Several techniques have been developed to address these challenges, including open sinus augmentation, closed sinus augmentation, zygomatic implants, and short dental implants. None of these techniques has been proven to be ideal.

Pyramidion implants (DenTack Implants) are short dental implants with an expandable compressive design. These implants have an apical expansion mechanism that uses four titanium wings that spread out during its activation, changing the shape of the implants from a cylindrical shape to a pyramid shape, leading to dynamic compression of the cancellous bone at the bone-to-implant contact area, improved primary stability, and increased bone-implant surface area.

The aim of this study was to evaluate the use of short dental implants with an expandable apical compressive design as an alternative to sinus elevation procedures in selected cases of vertically deficient maxillary alveolar ridges.

**MATERIALS AND METHODS**

**Study Design**
In a retrospective cohort study, the records of patients treated with Pyramidion implants in the posterior maxilla between 2012 and 2018 were analyzed. The inclusion criteria were as follows:

1. Nonsmoking healthy patients
2. A total alveolar bone height of 5 to 7 mm as measured in the preimplantation CBCT
3. A minimum alveolar bone width of 6 mm as measured in the preimplantation CBCT
4. All bone quality subtypes according to the Misch classification
5. A documented radiographic follow-up of a minimum period of 12 months postrehabilitation

**Keywords:** atrophic maxilla, edentulous maxilla, minimal invasive implant surgery, short dental implants
Patients with missing records without adequate data regarding implants used, implant survival and/or rehabilitation information, as well as patients with insufficient or inconsistent follow-up, were excluded from this retrospective study.

The analyzed parameters included age, sex, alveolar bone height at the site of implantation, number of implants at the site of implantation, implant height and diameter, bone level around the implants, immediate clinical primary stability of the implants using an Ossstell device, and number of failed implants (defined as implants that had to be removed).

This study was approved by the Hadassah Medical Center institutional Helsinki committee (No. HMO 0354-19).

**Surgical Technique**

The surgical procedure includes a sequenced drilling protocol using designated drills for each implant length. The final drill diameter is chosen according to the bone quality at the implantation site (Table 1), and underdrilling is usually not recommended. This permits controlled insertion of the pre-expanded slightly conical implants as per common practice in a maximum torque ≤ 35 Ncm. The flat implant apex prevents the fracture of the sinus floor when using a correct insertion torque.

After implant insertion, an external expansion tool is attached to the upper platform of the implant, engaging in an internal element of the implant. Using a ratchet-torque, the internal element is moved apically, causing the four titanium wings to expand toward the osteotomy walls, converting the implant into a pyramid shape. The expansion torque should not exceed 35 Ncm to ensure that there is no fracture of the alveolus or other pathologic effects on the surrounding bone. The expansion process is complete when the expansion tool rings are in contact and the internal expansion element reaches a stopping point where it snaps back and then locks (Fig 2). This mechanism prevents overexpansion of the implant’s apical area and excess pressure to the surrounding bone, while at the same time preventing the internal moving element from being pushed out of the implant and obstructing the passage from the oral cavity to the apical portion of the implant.

**Bone Measurements**

The bone level around the implants was measured using Digora 2.8 Software (Soredex). The implant radiographs were uploaded to the software. The most apical and coronal points at the center of the implants were marked as the A and B points, respectively. The bone levels at the two sides of the implants were marked as points C and D, and a perpendicular line from the most apical lateral point to the midline between points A and B was drawn to mark point E, representing the bone level surrounding the implant. The distance from points

---

**Table 1** Final Drill Diameter According to Bone Quality (mm)

<table>
<thead>
<tr>
<th>Bone quality</th>
<th>Final drill, 4.1-mm diameter</th>
<th>Final drill, 3.75-mm diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.8</td>
<td>3.65</td>
</tr>
<tr>
<td>2</td>
<td>3.65</td>
<td>3.5</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>3.2</td>
</tr>
<tr>
<td>4</td>
<td>3.2</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Final drill diameter (in mm) according to the bone quality at the implantation site based on the Misch classification.20

---

**Fig 1** (a) Pyramidion implant in the cylindrical shape before implant expansion. (b) Pyramidion implant in the pyramid shape after implant expansion.
A to B was manually measured and, using the law of three, was automatically synchronized according to the implant length. Then, the distance between points E and B was measured, and using the same ratio, the true bone level loss was calculated. The bone level measurement process is shown in Fig 3.

Statistical Analysis
The data were recorded using spreadsheets and grouped for evaluation. The data are reported with descriptive statistics. Various parameters were examined to determine whether or not a correlation was found between them and the following bone loss. The two failed implants were excluded from the following evaluations to allow a proper calculation of the mean bone loss.

RESULTS
A total of 183 Pyramidion implants were placed in 112 patients during the examined period (116 implants in 78 patients in the maxilla and 67 implants in 34 patients in the mandible). Of the 78 patients treated in the maxilla, a total of 50 patients (30 women, 20 men) with a mean age of 57.3 (range: 34 to 82) years had adequate follow-up and sufficient data in their records to be included in the study. These patients underwent a total of 73 Pyramidion implants. Thirty-three patients had one implant, 13 patients had two implants, 2 patients had three implants, and 2 patients had four implants. Two implants failed and had to be removed, both before rehabilitation. The first implant was removed due to lack of osseointegration at uncovering. The second implant was removed due to severe bone loss, also diagnosed during uncovering. The overall success rate was 97.2%.

The clinical primary stability of all implants was measured immediately after implant expansion using an Osstell device. The mean implant stability quotient (ISQ) measurement was 69.2 (range: 58 to 81). All implants were rehabilitated with screw-retained fixed prosthetics.

The mean follow-up period was 38.9 months (range: 17 to 70 months). The mean bone loss was 1.03 mm (range: 0 to 3.4 mm). No difference in bone loss was found between sexes nor between age groups.

Table 2 shows the correlation between bone loss and implant size. Table 3 presents the correlation between bone loss and duration of follow-up in months.
The apical expandable design of Pyramidion implants assists the surgeon in overcoming the compromised primary stability in the posterior region of the maxilla by applying a compressive force at the implant preparation site. The clinical primary stability of the implants was measured using an Osstell device. This device measures the resonance frequency of a transducer attached to the implant body, which is stimulated by different frequencies and is considered a reliable indicator for identifying implant stability with assurance. The Osstell graphic display panel shows the ISQ values, which indicate the firmness at the bone-to-implant contact area. ISQ values > 65 are regarded as most favorable for implant stability, whereas ISQ values < 45 indicate poor primary stability. The ISQ values of the implants in the present study indicated that the implants had good primary stability, with most implants presenting ISQ values > 65. In several implants, the ISQ values were measured before implant expansion and immediately after. In one of the cases, the ISQ value was 25 before expansion and 75 after. More ISQ recordings are needed to calculate the exact contribution of the apical expansion system to the primary implant stability, but this preliminary testing shows that this contribution may be significant.

Sargon dental implants (Sargon Enterprises), later marketed as Ultratooth (Biodent), were introduced for improved immediate loading using an apical expansion mechanism. These implants use an inner frustoconical element (expansion nut), which is pushed upward over an expansion screw after implant placement, forcing the apical portion of the implant to move laterally against the surrounding bone. Jo et al reported a series of 286 Sargon implants with 98.9% and 93.9% success rates for immediately and delayed placed implants, respectively. Nevertheless, they reported that in 208 of the 286 implants (72.7%), a re-expansion was needed due to loss of primary stability and development of micromotion. This is attributed to the fact that the stability of the expansion mechanism after activation of these implants relies on friction between the expansion nut and expansion screw of the implants, which may be loosened by forces of mastication and the effect of intraoral thermal changes. The Pyramidion implants use a different expansion mechanism. A screwless internal element is moved apically by an externally attached expansion tool, pushing four wing-shaped elements outward and creating the desired pyramid shape. The internal expansion element then reaches a stopping point where it snaps back to reduce the total pressure on the surrounding bone and then locks in a final position. This locking mechanism preserves the long-term implant expansion layout and prevents a possible expansion retreat and implant loosening.

The mean bone loss around the implants in the present study was 1.03 mm in a mean follow-up period of
38.9 months. This bone loss value is consistent with the criteria for the success of implant therapy, suggested by Albrektsson et al in 1986, defining 1 to 2 mm of crestal bone loss around implants in the first year after placement, followed by ≤ 0.2 mm mean bone loss in subsequent years as normal.42

Of the 73 implants included in the study, two implants failed during the osseointegration period, with a total survival rate of 97.2%. This also may be considered equivalent to the normal survival rate of dental implants.

CONCLUSIONS

The results of this study suggest that short dental implants with an expandable apical compressive design are a good alternative for vertically deficient maxillary alveolar ridges. The improved primary stability of these implants may make them suitable even for the porous alveolar ridges of the posterior maxilla. In addition, the high ISQ values of the implants may make them suitable for immediate loading, and hence shorten the rehabilitation timetable. More data regarding the exact additional primary stability gained by the apical expansion mechanism, together with longer follow-up cohorts, are required. Nevertheless, this study offers consideration of these implants as part of the surgical armamentarium in cases of vertically deficient posterior maxillary edentulous ridges.

ACKNOWLEDGMENTS

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

REFERENCES