Sinus floor elevation is a surgical procedure that is performed to increase the vertical bone dimension in the posterior maxilla to allow for the placement of dental implants. Boyne and James\(^1\) presented maxillary sinus elevation techniques with a lateral approach, in which a bone window was opened through the lateral wall of the maxillary sinus and the sinus cavity was filled with autogenous bone marrow from the iliac crest. This surgical procedure was rather complex and invasive; therefore, an alternative method—a transcrestal approach—was presented by Tatum\(^2\) in 1986. The technique consisted of a “greenstick fracture” of the sinus floor, which was performed by hand tapping a socket former in a vertical direction until the sinus floor fractured. Subsequently, Summers modified this technique, suggesting the use of a specific set of osteotomes to prepare the implant site and elevate the sinus floor.\(^3,4\)

Several clinical studies\(^5-7\) that used the transcrestal approach for sinus elevation achieved considerable long-term implant stability, with implant survival rates ranging from 93.5% to 98.3% over different follow-up periods. The procedure consisted of elevating the sinus membrane with osteotomes through a crestal approach and placement of the bone grafting material (simultaneous with implant placement when primary stability is possible). Recently, the need to place a graft material for sinus elevation procedures has been questioned in crestal approaches; several studies have observed bone formation beyond the original limits of the sinus as bone spontaneously filled the graft-free area.\(^8-13\)

Osteotomes present several significant advantages over the traditional graded series of drills. Because bone is viscoelastic, it can often be compressed and manipulated.\(^14\) Because they are pushed rather than drilled into soft bone, osteotomes compress the bone apically and laterally, creating a denser bone bed for the implant. The osteotome technique also generates no heat, in contrast to drills, which can heat the bone significantly and impair osseointegration.

**Sinus Floor Elevation by Osteotome: Hand Mallet Versus Electric Mallet. A Prospective Clinical Study**

Roberto Crespi, MD, MS\(^1\)/Paolo Capparè, MD\(^2\)/Enrico Gherlone, MD, DMD, PhD\(^3\)

*Purpose:* The aim of this clinical study was to compare a hand mallet with an electric mallet in osteotome-assisted sinus elevation. *Materials and Methods:* Eighty patients, all of whom were edentulous in the maxillary premolar and molar regions, were included in this prospective study. The patients were divided into two groups. In one group (40 patients, control group) sinus floor elevation was performed with an osteotome pushed by a hand mallet, and in the second group (40 patients, test group) sinus floor elevation was performed with the use of an electric mallet. One-hundred twenty dental implants (60 test, 60 control) were positioned. *Results:* After 24 months, a survival rate of 98.33% was reported. Three control group patients developed benign paroxysmal positional vertigo following the use of osteotomes and percussion with the hand mallet. The mean alveolar bone gain at 6 months after implant placement was 2.64 ± 1.21 mm in the control group and 2.45 ± 1.55 mm in the test group. After 12 months, the bone height had increased in both groups, and at 24 months it was stable (4.17 ± 1.70 mm in the control group and 4.07 ± 1.03 mm in the test group). No statistically significant differences were seen between groups. *Conclusions:* A significant increase in bone height was achieved between 6 and 12 months, and bone levels remained stable at 2 years. The use of an electric mallet provided some essential advantages during surgery in comparison with the hand mallet. Int J Oral Maxillofac Implants 2012;27:1144–1150

**Key words:** dental implant, electrical mallet, sinus elevation
The aforementioned studies were carried out with a hand mallet, a technique that may provoke benign paroxysmal positional vertigo (BPPV) as a consequence of working the implant bed with osteotomes. During the placement of maxillary dental implants through the osteotome technique, the trauma induced by percussion with the surgical hammer, along with hyperextension of the patient’s neck during surgery, can displace otoliths and induce BPPV. In the present clinical study, a new electric mallet was used for osteotome tapping. The purpose of this prospective study was to compare the use of a hand mallet with that of a new electric mallet in osteotome-assisted surgery for sinus elevation.

MATERIALS AND METHODS

This prospective clinical study included patients who presented to the Department of Dentistry, San Raffaele Hospital, Milan, Italy, for evaluation and management of posterior maxillary edentulism between January 2007 and February 2009. Each patient presented with edentulism in the maxillary premolar and molar regions, inadequate bone height in the posterior maxilla, and type 3 or 4 bone, as well as good health, no smoking habit, and an absence of any chronic systemic disease and acute or chronic sinus problems. Patients with coagulation disorders, signs of acute infection around the alveolar bone at the surgical site, and alcohol or drug abuse were excluded from participation. The diagnosis was made clinically and confirmed radiographically. The patients were treated by one oral surgeon and one prosthodontist at the Department of Dentistry, San Raffaele Hospital, Milan, Italy.

Surgical Protocol

One hour prior to surgery, patients received 1 g amoxicillin. Surgery was performed under local anesthesia (Optocaine, Molteni Dental; 20 mg/mL with adrenaline 1:80,000). The patients were divided into two groups. In the control group (n = 40 patients), implant site preparation was performed with an osteotome pushed by a hand mallet (Sweden Martina), and in the test group (n = 40 patients), implant sites were prepared with the use of an electric mallet (Magnetic Mallet, Meta-Ergonomica). Group assignment was performed by lots in closed envelopes.

Implants (Outlink, Sweden Martina) with a machined 0.8-mm neck and a rough titanium plasma spray surface, a body with a progressive thread design, and an external-hexagon implant-abutment junction were placed. The locations for implant placement were established according to the prosthetic treatment planning. During planning, the residual bone height in the locations was measured on periapical radiographs as the distance from the bone crest to the sinus floor (Fig 1a).

Surgery began with exposure of the bone crest with a modified partial-thickness flap with the tip of a no. 64 Beaver blade (Becton Dickinson Acute Care). The edentulous bone crest was covered by the preserved suprabony connective tissue and the underlying periosteum. The proposed implant site was first clearly marked with a 2.0-mm round drill, followed by a 2.0-mm twist drill. The 2.0-mm twist drill was then taken to a depth of 0.5 to 1.5 mm from the sinus floor (ie, the working depth), as measured from the preoperative radiographs.

In the control group, expansion of the osteotomy was carried out with a combination of drills and concave-tipped osteotomes; these were chosen based on residual bone density. The implant site was created by expanding the bone tissue both laterally against the preexisting lateral walls and apically by moving it up and compressing it with a progressive series of bone expanders (Sweden Martina). The osteotomy was gradually expanded in 0.5-mm increments using osteotomes inserted to the working depth. The final diameter of the osteotomy was 0.5 to 1.2 mm less than the anticipated implant diameter, depending upon local bone density. Sinus elevation was delayed until the final apical diameter of the osteotomy had been achieved at the desired working depth. Using the technique reported by Cavicchia et al, the surgeon punched out the cortical plate of the sinus floor with the adherent membrane with the final osteotome. Immediately after fracture, the implant site was tested for perforation of the sinus membrane by the Valsalva maneuver.

In the test group, expansion of the osteotomy was carried out following the same procedure reported in the control group, with similar osteotomes, but the osteotomes were directly attached to and pushed by the electric mallet (Figs 1b to 1g). The Magnetic Mallet is a dynamic magnetic device assembled into a handpiece; this is energized by a power unit that defines the force and timing of application (Fig 1b). The connection of the osteotomes to the handpiece sends a magnetic wave to the tip. The magnetic wave and the subsequent shock wave are calibrated with respect to the timing of application of the force, inducing axial and radial movements on the tip of the osteotome, with a fast force of 90 daN/8 µs. The Magnetic Mallet imparts a longitudinal movement along the central axis of the osteotome, providing a driving mechanism for longitudinal movements. The engaged surfaces progressively act upon and force the internal wall of the initial hole outward radially with respect to central axis, resulting in high-density bone tissue along a substantial portion of the bone wall.
In both groups, no additional grafting material was introduced at the recipient site. The implant was placed into the bone site to the planned depth. Subsequently, the soft tissues were sutured. The buccal flap was apically repositioned and stabilized with sutures tied to the margin of the palatal flap and anchored buccally.
with a loose loop to the periosteum at the level of the alveolar mucosa. This suture design released any tissue tension in the repositioned buccal flap. The gap between the superficial margin of the buccally repositioned tissue and the lower part of the palatal tissue was allowed to heal by secondary intention to increase the volume of keratinized mucosa.

Patients took 1 g of amoxicillin twice a day for a week after surgery to prevent infection.

**Radiographic Assessments**

Intraoral digital radiographic examinations (Schick CDR, Schick Technologies) were made at baseline and at 6, 12, and 24 months after implant placement. The periapical radiographs were taken perpendicular to the long axis of the implant with a long-cone parallel technique using an occlusal template. A blinded radiologist measured the changes in marginal bone height over time.

The following measurements were made from the periapical radiograph:

- The presurgical distance from the alveolar crest to the floor of the maxillary sinus (Fig 1a)
- The amount of new radiopacity between the sinus floor and the alveolar crest, measured from the mesial and distal surfaces of each dental implant surface (Fig 2a)

A mean value for initial and gained alveolar bone height was obtained from these readings with specific software (Schick Technologies) and evaluated at 6, 12, and 24 months after implant placement.

**Prosthetic Protocol**

Three months after implant placement, provisional restorations were placed in all patients. A transfer coping was inserted into the external hex of the implant with a seating instrument and secured with abutment screws. Impressions were made with a silicone material using individual impression trays. All provisional crowns were screwed onto dental implants and were in full contact in centric occlusion. Two months later, the definitive metal-ceramic restorations were screwed directly on the implant (Figs 2b and 2c). The occlusion was checked using 8-µm foil (Shimstock, Hanel), which should resist withdrawal only under maximal clenching.

**Follow-up Evaluation**

The following clinical parameters were checked at each follow-up examination: pain, occlusion, and prosthesis mobility. Success criteria for implant survival included implant stability and an absence of radiolucency around the implants, mucosal suppuration, and pain. Examinations were performed at baseline and at 6, 12, and 24 months. Probing depth (PDs), modified Plaque Index, and modified Bleeding Index were determined on the mesial, distal, buccal, and palatal surfaces of the implants with a periodontal probe (PGF-GFS, Hu-Friedy).

**Statistical Analysis**

A dedicated software program was used for all statistical analyses (SPSS version 11.5.0, IBM). Data were presented as means ± standard deviations. Comparisons of mean values for bone height at different time points (baseline, 12 months, and 24 months) and comparisons
between the test and control groups were made with the Student t test, with \( P < .05 \) considered the threshold for statistical significance.

**RESULTS**

Eighty patients (44 women and 36 men) were enrolled in this clinical study (n = 40 per group). The mean patient age was 52.7 years (range, 37 to 74 years). One-hundred twenty implants were positioned (60 in the test group and 60 in the control group). Sixty implants had a diameter of 5 mm and a length of 13 mm, 32 implants were \( 5 \times 10 \) mm, and 28 implants were \( 4.2 \times 13 \) mm (Table 1).

### Surgical and Prosthetic Outcomes

After 24 months, a survival rate of 98.33% was achieved. Two implants failed within 1 month of implant placement (one implant in each group). Their dimensions were both \( 5 \times 13 \) mm; the control group implant was in the left second premolar position, and the test group implant was in the right first molar position. No sinus membranes perforated. No pain or mobility of the definitive prostheses was recorded. There was suitable wound healing around the provisional abutments and good adaptation to the provisional crowns. Minor swelling of the gingival mucosa was present in the first days after surgery, and no mucositis or flap dehiscence with suppuration was observed.

In the control group, three patients developed BPPV following the use of osteotomes and percussion with a hand hammer. Upon sitting up after surgery, one patient experienced intense vertigo, with dizziness and disorientation accompanied by distress, nausea, vomiting, and the sensation of objects moving around her. The vertigo remitted spontaneously after 2 days.

The patients in the test group presented no symptoms of BPPV, and the implant bed preparation was more precise with the Magnetic Mallet.

### Clinical Results

The mean PD was obtained from averaging PD measurements on the mesial, distal, buccal, and palatal surfaces of each implant. The mean PD values were \( 1.41 \pm 0.50 \) mm and \( 2.06 \pm 0.43 \) mm at baseline and 24 months, respectively.

### Radiographic Findings

Changes in radiographic bone levels were calculated at 6, 12, and 24 months after implant placement (Table 2). Baseline mean bone levels (initial alveolar bone height) were \( 6.71 \pm 1.55 \) mm in the control group and \( 6.54 \pm 1.67 \) mm in the test group. Alveolar bone gain after 6 months of healing, evaluated as the presence of radiopacity around exposed mesial and distal implant surfaces within the created space at the floor of the maxillary sinus, was a mean of \( 2.64 \pm 1.21 \) mm for the control group and \( 2.45 \pm 1.55 \) mm for the test group. After 12 months, the radiopacity around exposed mesial and distal implant surfaces increased in a similar manner in both groups (Table 2). At 24 months after implant placement, the mean bone height measurements were similar to the 12-month values (\( 4.17 \pm 1.70 \) mm in the control group and \( 4.07 \pm 1.03 \) mm in the test group) (Table 2).

No statistically significant differences in alveolar bone levels were seen between the test and control groups. However, a statistically significant difference \( (P < .05) \) between 6-month and 12-month values for both groups was reported, whereas the differences

### Table 1 Implant Positions and Dimensions in the Treated Patients

<table>
<thead>
<tr>
<th>Group/position</th>
<th>Implant size (mm)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group</td>
<td>( 5 \times 13 )</td>
<td>12</td>
</tr>
<tr>
<td>R first molar</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>L first molar</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>R second premolar</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>L second premolar</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>R second molar</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>L second molar</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>13</td>
</tr>
</tbody>
</table>

#### Table 2 Radiographically Measured Increases in Alveolar Bone Height

<table>
<thead>
<tr>
<th>Time since implant placement (mo)</th>
<th>Mean increase in alveolar bone height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group</td>
</tr>
<tr>
<td>6</td>
<td>2.64 ± 1.21</td>
</tr>
<tr>
<td>12</td>
<td>4.14 ± 1.66</td>
</tr>
<tr>
<td>24</td>
<td>4.17 ± 1.70</td>
</tr>
</tbody>
</table>
between 12 and 24 months were not statistically significant. These results demonstrated a significant increase in bone height between 6 and 12 months, followed by stable bone levels up to 2 years.

**DISCUSSION**

When the alveolar bone is soft or when the ridge has resorbed enough to compromise implant placement, dentists will seek to preserve existing bone, improve its quality, and manipulate its shape. When the bone at the implant site is soft and trabecular, osteotomes can be used to increase the density of the bone around the osteotomy site. Osteotome-mediated sinus floor elevation has been associated with an implant survival rate that is directly related to the height of the remaining subsinus bone, since the initial stability of implants is provided only by the residual alveolar ridge. In the present study, implant sites were prepared by the use of osteotomes that compressed the native bone, as reported in the literature, for vertical bone expansion and cortical sinus floor elevation, and a survival rate of 98.33% was achieved at 24 months.

The increase in alveolar bone height reported in this study after 6 months of healing, expressed as the presence of radiopacity around exposed implant surfaces within the created space at the floor of the maxillary sinus and increased radiopacity after 12 months, may be attributed to the osteotome procedure. Osteotomes expand the ridge buccolingually in a less invasive manner than traditional bone-spreading techniques.

Manipulation of bone with osteotomes requires that the practitioner be acutely aware of bone quality. With osteotomes, type 4 bone can be changed into type 3 bone and type 3 bone can generally be compacted to resemble type 2 bone, so that implants may also be placed, with good success, in type 4 bone, similar to that found in the maxillary tuberosity, especially when the bone width (at least 8 mm) and height are sufficient. In such cases, direct initial preparation with a 2.2-mm cylindric osteotome without any initial mechanical drilling is recommended. This procedure compacts the trabecular bone, and it improves the clinician’s tactile sensation of the presence of the posterior cortical wall of the maxillary sinus.

Tapping of expansion osteotomies with a hand mallet represents the greatest inconvenience of the technique, and it may induce BPPV in patients who have never experienced this form of vertigo. In the present study, three patients in the control group experienced vertigo when trying to sit up immediately after surgery and were diagnosed with BPPV. In clinical practice, the incidence of this complication may be higher. Because implant treatment is being carried out more frequently in older patients, and because of the widespread use of the bone expansion technique with osteotomes, the incidence of BPPV can be expected to increase. In the patients of the test group, no symptoms were noted and no distress was seen.

The low force of bending waves produced by the hand hammer (40 daN/2 ms) is dependent on the density, area moment of inertia, and density-dependent elastic constants of bone. It is important to account for the changes in these quantities in the bone, because such changes, along with hyperextension of the neck during surgery, can displace otoliths. The magnetic wave and the subsequent shock wave are calibrated regarding the timing of application of the force, and the electrical mallet induces axial and radial movements applied on the tip of the osteotome with a fast force of 90 daN/8 µs. This procedure probably minimizes trauma to the craniofacial bones as much as possible, meaning that the forces are exerted only on the target area.

As reported in this study, the use of an electric mallet provided some essential advantages during surgery in comparison with a hand mallet. The Magnetic Mallet supplied more precise control of the entry direction (or directionality) of the tip of the osteotome into the bone. This is an important concept, since bone is generally made up of parts with different densities and since an expander tends to be deflected when it moves from a bone area with a specific density to another area with a different density. Furthermore, the handling of the magnetic device was very simple, since the mechanical oscillations generated by the actuator, which are transmitted via the hydraulic linkage to the osteotome, are transmitted without difficulty to the handpiece. Further clinical trials are mandatory to evaluate the efficiency of this new tool for osteotome sinus elevation, but these results are encouraging.

**REFERENCES**