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Sinus floor elevation using osteotomes or piezoelectric surgery

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Abstract. The aim of this paper is to describe a technique for sinus floor augmentation with a 1-step crestal approach where the residual bone is ≤7.5 mm. 36 implants were installed in 25 patients in the atrophic posterior maxilla immediately after sinus floor elevation. Sinus floor elevation was performed with a crestal approach using either osteotomes and burs or piezosurgery. Standardized intraoral radiographs were taken prior to surgery and 1 year after surgery. The mean residual bone height was 5.61 mm (range 3–7.5 mm). The mean gain of sinus elevation was 6.78 mm (range 3.5–10 mm) at 1 year after surgery. Two patients dropped out of the study. Of the 23 patients completing the study, one implant failed, whilst the remaining 33 implants were stable 12 months after surgery (cumulative survival rate 97%). A statistically significantly higher bone height was achieved with tapered implants compared with cylindrical implants ($P < 0.05$). No statistically significant differences were found in bone level using osteotomes or piezosurgery. Piezosurgery was considered to provide less discomfort for the patient and greater convenience for the surgeon.

Keywords: sinus lift; piezosurgery; osteotomes; crestal approach.

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In the posterior maxilla, implant insertion is often limited due to maxillary sinus extension, especially in atrophic maxillae[7,15,19,39]. Sinus floor elevation is a well-recognized method of overcoming this problem and allows implant installation[7]. The most widely used techniques for maxillary sinus floor elevation are the classical lateral antrostomy introduced by Tatum in 1976[7,34], which consists of the preparation of a bony window in the lateral maxillary sinus wall, and the more recent osteotome technique that utilizes a crestal approach, proposed by Summers in 1994[33].

According to traditional protocols, in cases of good quality bone and subantral bone height ≥5–6 mm the implant is installed simultaneously with the sinus floor elevation, with or without adding bone graft material[21]. In contrast, in situations of poor quality bone or of subantral bone height <5 mm, lateral antrostomy is performed and the space under the elevated Schneiderian membrane is filled with bone graft material[7].

Lateral antrostomy may be performed using a 1- or 2-step approach. Implants are installed simultaneously with the bone graft (1-stage lateral antrostomy) or after a delay to allow for bone healing (2-stage lateral antrostomy). Residual bone thickness (whether it is greater or less than 5 mm) is the deciding factor between the two methods[19,39]. The 1-stage procedure is less time-consuming for the clinician and patient, but its success depends on the amount of residual bone[39].

The most common intraoperative complication with these surgical approaches is perforation of the Schneiderian Membrane[2,32]. Wallace et al.[38] state that the membrane perforation rate has been reduced from the average reported rate of 30% with rotary instrumentation to 7% using the piezoelectric technique.

Using piezoelectric ultrasonic vibration (25–30 kHz), the piezosurgery device precisely cuts only mineralized structures

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(bone) without cutting soft tissues, which remain undamaged even in case of accidental contact[37]. The typical cavitation effect induces a hydropneumatic pressure in the physiological saline solution that contributes to atraumatic sinus membrane elevation[37].

Another advantage of piezosurgery is its precision[5,37]. Compared with the oscillating micro-saw, the movement of the piezosurgery knife is very small, so the cutting precision is greater and causes less discomfort for the patient[31]. The absence of macrovibrations makes the instrument more manageable and allows greater intraoperative control, with a consequent safer action in anatomically difficult situations[37]. When using this instrument the clinician applies a very small amount of pressure which allows a very precise cut[31].

The piezosurgery device provides a clear surgical site, as it maintains a blood-free surgical field during bone cutting, due to the air–water cavitation effect of the ultrasonic instrument. This allows improved visualization of the surgical area.

The main advantage of the osteotome technique is that it is a less invasive procedure than lateral antrostomy[39]. It improves bone density, which allows greater initial stability of implants. After progressive preparation of the bone, elevation of the sinus floor by several millimeters is obtained with a reduced operative time compared with other sinus graft procedures. The disadvantage of the crestal approach required with the osteotome technique is that initial implant stability has to be substantiated if the residual bone height is <6 mm and implants are installed simultaneously with elevation of the sinus floor[35,39]. The chances of achieving a sufficient sinus floor elevation with the osteotome technique are limited. According to standard protocol, the osteotome procedure cannot be used to elevate the sinus membrane more than 5 or 6 mm[19,20,30]. Favourable results have been reported in cases with a residual bone height of 3 mm treated with a crestal approach[11,24].

This paper describes and evaluates a procedure for maxillary sinus elevation with a crestal approach in cases with residual bone height of 7.5 mm or less. This is a 1-step approach in which implants are inserted simultaneously with sinus grafting. The technique uses either osteotomes and traditional burs or a piezosurgery device to perform the antrostomy osteotomies with a minimally invasive procedure.

The aim of this prospective study is to describe the above-mentioned technique for sinus floor elevation with a 1-stage crestal approach and to evaluate if there is any difference in bone level augmentation at 1-year post-implant installation when osteotomes are used compared with piezosurgery following this technique.

Materials and methods

From April 2002 to January 2008, 25 patients (14 women; 11 men), with a mean age of 48.25 years (range 27–72 years) were treated for sinus floor elevation, to install dental implants in the atrophic posterior edentulous maxilla. The patients selected were all considered to be in good general health with no contraindications for oral surgery and the related prosthetic protocols. Exclusion criteria included: an uncontrolled medical condition such as diabetes mellitus, immune suppression, bisphosphonate medication, oro-facial cancer, chemotherapy or head and neck radiotherapy; infarct during the preceding 6 months; a pathologic lesion in the sinus (benign/malignant tumour, mucocele, or active sinusitis); untreated active periodontitis in neighbouring teeth. Healing time since tooth extraction was longer than 12 months.

Opposing dentitions were natural teeth or fixed prostheses supported by natural teeth or implants. Subjects with opposing removable prostheses were excluded. The mean height of the alveolar process in the intended implant sites was 5.61 mm (range 3–7.5 mm). Alveolar height was measured from the alveolar bone crest to the sinus floor. Each patient had at least one, but no more than two implants installed into an edentulous area. In total, 36 implants were evaluated. Baseline radiographs consisted of intraoral peri-apical films obtained with the parallel long cone technique.

All the subjects involved in this research, which was approved by the Scientific Ethical Committee of the University of Genoa, provided informed written consent prior to starting the study. All the patients underwent pre-surgery screening and initial periodontal therapy. They agreed to return for the required recall appointments.

Immediately prior to surgery, the patients were asked to rinse their mouths using a chlorexidine digluconate solution 0.2% for 1 min. The surgical protocol (Fig. 1) required a mucoperiosteal flap slightly palatal to the ridge crest, with two buccal releasing incisions. Full thickness flaps were elevated to visualize the bone crest.

In 17 implant sites (11 patients), traditional burs and the osteotome technique were applied. In the other 19 sites (16 patients) the osteotomy was performed using piezosurgery (27,000–30,000 Hz). Patients were randomly selected for one of the two groups. Two patients had both techniques at different sites.

In the first case, the perforation of the cortical bone was performed with a round bur with a diameter of 2 mm followed by the first spiral bur of the same dimension. The vertical dimension of the osteotomy reached a distance of 2 mm from the maxillary sinus (Fig. 2). At this time, osteotomes (Summers™ osteotomes kit, 3i Implant Innovations, Palm Beach Gardens, FL, USA) were used in increasing order. The first was used with gentle percussion with a hammer and a rotatory action of the osteotome to obtain infraction of the sinus cortical plate. In sequence, the second and third osteotomes were used in the same way, with the apical addition of graft material to elevate the Schneiderian membrane. Osteotome number 1 has a diameter of 1.6 mm at its apex and gradually enlarges to a diameter of 2.4 mm at 10 mm length, to permit the introduction of the second osteotome that has a diameter of 1.9 mm at its apex and 3.1 mm at 10 mm length. At this point, it is possible to finish the site with the third osteotome (diameter 2.8 mm apically and 3.3 mm at 10 mm length) or to insert a 3.75 mm implant. All the osteotomes used have a conical shape, this is justified because an implant site underprepared with respect to the implant size allows improved lateral compactness, to obtain a better bone–implant interface. All the osteotomes used have a concave form, to drive the graft material apically.

In the clinical cases where piezosurgery was applied, the Piezosurgey® device (Mectron Medical Technology, Carasco, Italy)[37] was used. The osteotomy began with the conical insert OP5 (diameter 0.6–1.3 mm; granulometry 30 μm) to arrive at 2 mm from the sinus cortical floor. The following insert was the IM2 (diameter 2 mm) and the osteotomy continued with the OT4 insert (diameter 2.4; granulometry 150 μm). Finally, the osteotomy was completed with IM3 (diameter 3 mm) reaching about a 2 mm distance from the sinus cortical floor. With OT4 it was possible to perfect the preparation and come into contact with the sinus membrane. At this time, the bone graft material was inserted. Once the osteotomy was ready, an intraoral radiograph was taken as a control before implant installation.

The graft material used was BiOss (Geistlich Pharma AG, Wolhusen, Switzerland) mixed with autologous bone and antibiotic (hydrochlorate tetracycline, Ambramicina, Scharper SpA, Italy). The

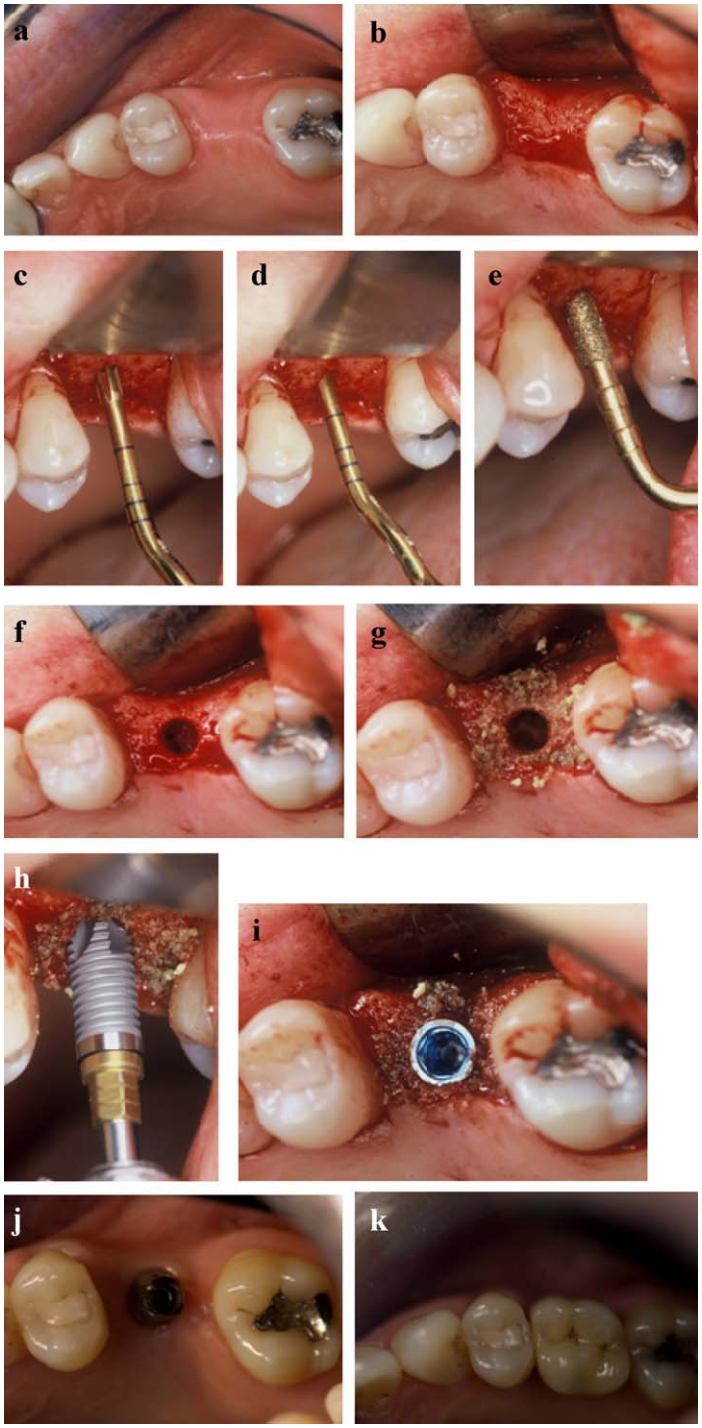

Fig. 1. Surgical procedure. (a) Initial situation. (b) Flap elevation. (c and d) In the initial phase, the IM2 insert was used. (e) OT4 was used to prepare the osteotomy up to the Schneiderian membrane. (f) The osteotomy site completed. (g) BioOss® mixed with autologous bone inserted. (h and i) The implant has been installed. (j) Prosthetic phase. (k) Definitive restoration.

composite graft consisted of 50% autogenous bone and 50% BiOss.

Osseotite® implants (Biomet 3i, Palm Beach Gardens, FL, USA) were installed. Implants with an internal (Osseotite® Certain™) and an external hexagon (Osseotite® Standard) were used. The implant diameter varied between 3.75 and 5 mm and the lengths were 10 or 11.5 mm, depending on the amount of bone available (Table 1). The insertion torque for implants was 30–32 N cm.

When the residual bone was poor in quality and in vertical and horizontal dimensions, tapered implants (Osseotite NT) were inserted. In the other cases, cylindrical implants (Osseotite STD) were used in the hope of providing less trauma to the sinus membrane. Implant restorative platforms were placed at the level of the osseous crest.

Table 1. Type and number of implants installed.

	10 mm	11.5 mm
Cylindrical implants	9	15
Tapered implants	5	7

All the implants were assigned specific codes for blinding. The first number of the code (from 1 to 25) indicated the patient, the second indicated the implants inserted in a single patient. For each patient, the implants were numbered starting from the distal region of the first quadrant up to the distal part of the second quadrant, with no distinction between tapered and cylindrical implants.

Antibiotics (amoxicillin 1 g, twice a day) were prescribed for 6 days and analgesics as required. All patients were instructed to rinse twice daily for 10 days with chlorhexidine 0.2% solution (Curasept 0.2; Curaden Healthcare Srl, Saronno, VA, Italy).

Recall appointments were scheduled 7 days after surgery for reevaluation and 15 days after surgery for removal of any remaining sutures.

The second surgical phase for abutment connection and the impression for the provisional prosthesis were performed 7 months after implant insertion.

Radiographic examinations assessed the increase in sinus elevation at the 1-year follow-up appointment. The radiographs were recorded using a long-cone paralleling technique with fast speed films (Ultra-Speed Kodak, Eastman Kodak Company, Rochester, NY, USA). The distance between the implant shoulder and the new sinus floor was measured on the distal and mesial aspect of the implant. A comparison of this radiograph with the preoperative film provided a quantitative assessment of the newly formed mineralized tissue. A radiologist independent of the study performed the radiographic readings, using a diaphanoscope and magnifying lens.

An implant was classified as surviving if it fulfilled its prosthesis supporting function, it was clinically stable when tested individually and no pain or signs of infection were detected during clinical examinations. Bone–implant contact had to be present on the radiographs, with no evidence of radiolucency at the bone–implant

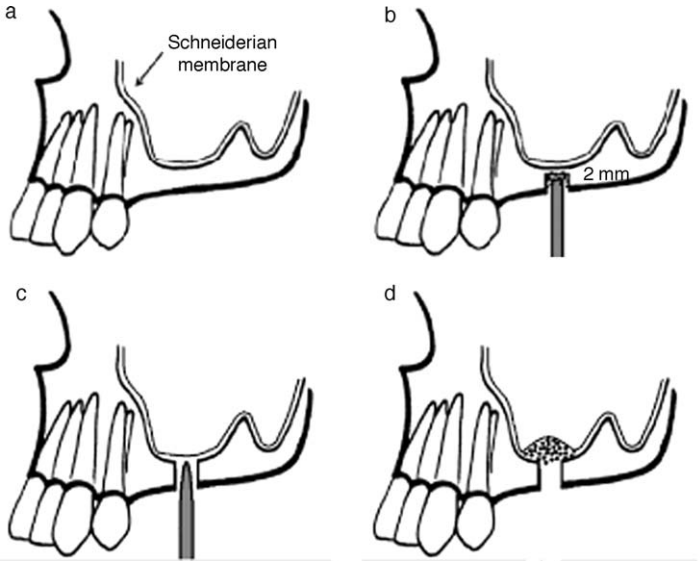

Fig. 2. The two surgical techniques. (a) Initial situation. (b) Osteotome group: the osteotomy was prepared using burs up to 2 mm from the maxillary sinus, then the osteotomes were used to obtain infraction of the sinus cortical plate. (c) Piezosurgery devices can contact the Schneiderian membrane without damaging it. (d) Schneiderian membrane elevation as obtained by both techniques.

interface. An implant-supported prosthesis was classified as surviving if it was functioning, had no fractures and provided the patient with adequate masticatory, aesthetic and phonetic function.

Statistical analysis

For statistical analysis of the data, the SPSS program (15.0 Version, SPSS Twc, Chicago, IL, USA) was used, based on the evaluation of the amount of bone level at 1-year post-implant installation. The null hypotheses, stating that no differences existed between the two different implant shapes (cylindrical vs tapered) nor between the two techniques adopted (osteotomes and burs vs piezosurgery), were tested by the bilateral method. The alpha risk of error was maintained under 5% and the beta was maintained under 20%.

Results

In the present investigation, the mean height of the alveolar process in the intended implant sites was 5.61 mm (range 3–7.5 mm; 5.79 mm for the osteotomes group; 5.48 mm for the piezosurgery group). 11 of the 36 implants analyzed were installed in sites with an initial subantral bone height <5 mm and five implants were placed in sites with an initial subantral bone height equal to 5 mm.

The mean elevation of the sinus membrane was 6.78 mm (range 3.5–10 mm; 6.507 mm for the osteotomes group; 6.989 mm for the piezosurgery group) at 1 year after implant placement (Fig. 3). The relationship between residual bone and grade of sinus floor elevation at 1 year is illustrated in Fig. 4.

Sinus membrane perforation was an intraoperative complication in one of 36 cases (3%) but this did not lead to any unfavourable consequences. In this clinical case osteotomes were used. At the 1-year follow-up two patients had dropped out (one from the osteotome group and one from the piezosurgery group). All the other patients had an uneventful healing and no signs or symptoms of maxillary sinus disease were observed after the augmentation surgical procedures.

All the implants were followed for a mean of 19.29 months (at least 1 year, range 12–57 months). At the time of the last follow-up, only one implant had been lost. In this case piezosurgery was applied, an NT4x11.5 implant was installed and the initial crestal bone height was 7 mm. This failed implant was removed 2 months after surgery and substituted with a larger one (NT5x11.5) but not considered in the statistical analysis. All the other implants followed were successfully integrated and in function, representing a cumulative survival rate (CSR) of 97%, excluding the two patients who had dropped out. The prosthesis CSR was 100%.

There were no significant differences in the bone augmentation level between the two different surgical techniques (osteotomes vs. piezosurgery). A statistically significant difference was found amongst implants of different shapes (cylindrical vs. tapered implants, $P = 0.0102$), with greater bone increase at 1 year using tapered implants (Table 2).

Discussion

A technique for sinus floor augmentation with a 1-step crestal approach when the residual bone is $\leq$7.5 mm was evaluated. If implants are to be installed at the time of sinus grafting, many investigators agree that there should be a minimum of 5 mm or more of initial subantral bone height and bone of sufficient density to provide good initial dental implant stability[15,28].

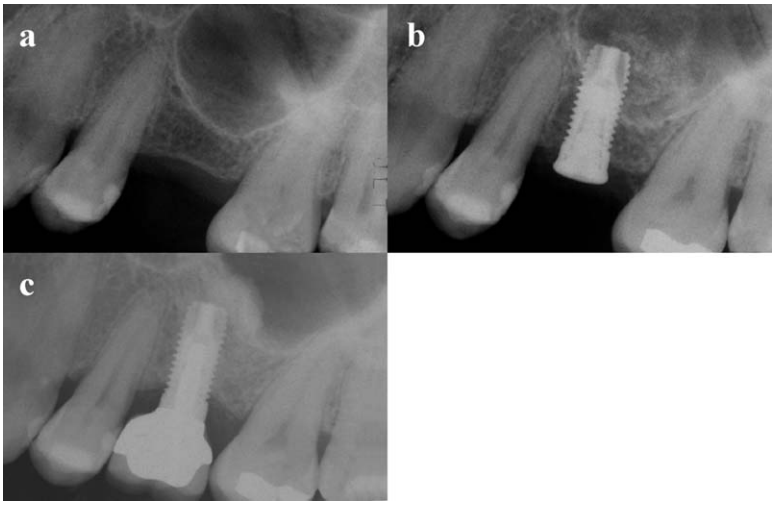

Fig. 3. Intraoral radiographs before sinus lift elevation (a), after implant installation (b) and at 1-year post surgery (c).

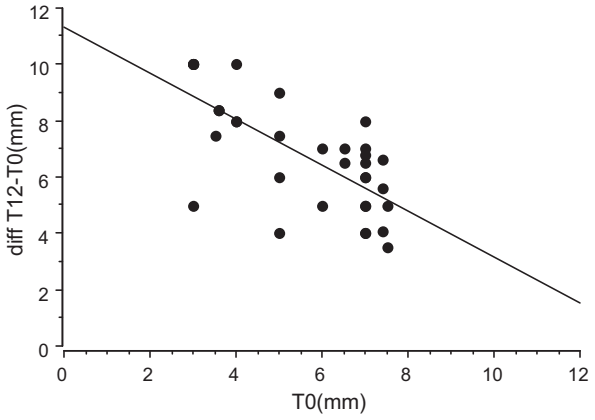

Fig. 4. The abscissa represents the subantral bone height before surgery. The ordinate represents bone increment at 1-year post surgery.

Patients presenting <5 mm of residual subsinus bone are usually treated using the lateral antrostomy technique and 2-stage surgery, with sinus grafting being performed in one stage and implant placement later[13]. In the present investigation, a 1-step crestal approach was used with favourable results. Advantages of the presented procedure are: it is more conservative; the morbidity is reduced; operative time is reduced; implants can be placed at the same surgical visit; and it enables placement of implants measuring 10 mm or longer. Other authors suggest the use of a crestal approach and short implants (8 mm) in atrophic maxillary sinuses with a residual bone height of 3–6 mm[8].

The CSR (97%) was similar to, or higher than, that found in other studies on sinus floor elevation using osteotomes[12,30]. According to Toffler[35], the primary determinant in implant survival with osteotome-mediated sinus floor elevation procedures was the height of the residual alveolar ridge. Although piezosurgery was used and not the osteotome technique, insufficient height of the residual alveolar ridge is not considered a sufficient reason for the implant failure observed in the present investigation, as the residual bone height was equal to 7 mm. Some other factors (trauma, contamination during surgery) may have determined this undesirable event.

The mean elevation of the sinus floor (6.78 mm) was equal to or greater than the sinus floor augmentation found in previous studies in which osteotome-mediated sinus floor elevation was performed[35]. Greater bone gain is reported for patients treated by lateral antrostomy with a 1- or 2-stage approach[13,40].

The present results show significant differences in bone level between tapered and cylindrical implants, with higher bone increase when tapered implants were inserted ($P < 0.05$), even though tapered implants were inserted in the cases with worst bone quality (as subjectively perceived by the surgeon) and quantity.

In case of low supportive capacity of the jawbone, such as in the atrophic posterior maxilla, the diameter of the implant site preparation is usually reduced compared with standard protocols in order to optimize primary stability. In this situation, a conical design facilitates implant insertion and produces a progressive compression during insertion, minimizing bone trauma. When using conical implants, the tapered design of the implant condenses the bone during implant insertion[3,25], further increasing primary stability.

Various factors may have contributed to the success of the surgical procedures described, including implant surface topography and the graft material chosen. The Osseotite implants used in the present investigation are treated with a dual acid-etching (DAE) protocol. As reported in the literature[1,18,36], DAE surfaces promote osseointegration.

Table 2. Bone level comparison at 1-year post-implant installation.

Source of variation	Mean (mm)	Standard deviation	Standard error
Implant type			
Cylindrical	5.827	1.764	0.455
NT	7.526	1.830	0.420
Surgical technique			
Osteotomes	6.507	1.949	0.503
Piezosurgery	6.989	2.013	0.462

The necessity to use grafting material after elevating the sinus membrane utilizing the transalveolar osteotome technique is controversial. Fermergård and Astrand[14] reported favourable outcomes (1-year CSR 96%; mean elevation of the sinus floor 4.4 ± 0.2 mm) with implants placed in the posterior maxilla with osteotome sinus floor elevation without grafting when the mean height of the alveolar process in the intended implant sites was 6.3 ± 0.3 mm. Other authors maintain that if grafting is not performed the procedure becomes less predictable and the augmentation volume is limited[27].

Regarding the graft material, autogenous bone is the material of choice for bone reconstructive procedures[9,23]. A limited amount of bone is available at intraoral donor sites, however, and the use of an extraoral site usually requires general anaesthesia, increasing the time and the cost of treatment and increasing morbidity. To avoid the use of autogenous bone and donor site morbidity, bone substitutes are commonly used. In the present study, BiOss®, a commercially available particulate graft of deproteinized, bovine hydroxyapatite, was used[10]. BiOss® has been widely studied in animals and humans and was found to be very useful in sinus elevation procedures[17,26]. In a study in rabbits by Rahmani et al.[29], the addition of Bio-Oss® graft particles did not result in a statistically significant increase in bone contact with, or bone ingrowth into, the implant surface compared with implants installed without the use of a bone graft material. These authors also suggest that a possible disadvantage of using the relatively sharp-edged Bio-Oss® particles would be that it might damage the Schneiderian membrane. This contrasts with data reported by Berengo et al.,[4] and with the findings of the present study, although this parameter was not investigated specifically. Berengo et al.[4] state that small sinus membrane perforations during the bone-added osteotome procedure are likely to be clinically inconsequential postoperatively. In the present study, only one membrane perforation was detected in a clinical case treated with osteotomes, but this did not lead to any unfavourable consequences.

Autogenous bone in combination with Bio-Oss® was used in the present investigation to increase success and predictability with Bio-Oss®, as reported in the literature[6,16,22].

The technique described uses either osteotomes and traditional burs or piezosurgery devices to perform osteotomies for implant site preparation and sinus membrane elevation.

The method of using Piezosurgery® and the insert sequence is similar to that of traditional burs, but instead of reaching a 2 mm distance from the sinus cortical floor and then continuing with the osteotomes, it is possible to finish the osteotomy with the OT4 insert to achieve delicate contact with the Schneiderian membrane.

No significant differences in bone resorption were found at 1-year post-implant installation using the two different surgical techniques (Table 2) and both procedures led to satisfactory results, particularly when tapered implants were installed.

One of the advantages of the osteotome technique is that it improves bone density, which allows greater initial stability of implants. Bone is compacted laterally around the implant site by use of osteotomes of progressively increasing diameter. Piezosurgery is reported to be more time-consuming than traditional techniques but Beziat et al.[5] reported that in craniofacial surgery piezosurgery increases the time of bone cutting but not the overall operative time, because of the absence of soft tissue protection.

The findings of the present study suggest that piezosurgery is an acceptable method for sinus floor augmentation with a crestal approach in cases in which the residual bone in the posterior maxilla is $\leq$7.5 mm. Use of piezosurgery as part of the surgical approach allowed the authors to achieve results comparable with those of traditional surgical techniques. Although these aspects have not been specifically investigated in the present study, identified advantages were found to be: cut precision; greater intra-operative control; clear surgical site; and selective cut of mineralized tissues with preservation of soft tissues[31,37]. In particular, piezosurgery allowed the surgeon to work directly in contact with the Schneiderian membrane. The ultrasonic insert permitted gentle sectioning of bone without damage to the sinus membrane. Anecdotal reports from patients suggested that implant site preparation was more comfortable when performed with piezosurgery than with continuous malleting of the osteotomes.

The surgical procedure described was found to produce satisfactory results in sinus floor augmentation with a crestal approach and immediate implant installation in cases in which the residual bone is $\leq$7.5 mm. The most satisfactory results in terms of bone level were found using tapered rather than cylindrical implants.

In conclusion, the study found that piezosurgery for sinus floor augmentation using a 1-step crestal approach, where the residual bone is $\leq$7.5 mm and installation of tapered implants yielded the best result. The piezosurgery technique was found to allow precise and selective cutting of mineralized tissues (i.e. bone), thus limiting the risk of Schneiderian membrane perforation. Piezosurgery was also considered to provide a less traumatic intervention with less discomfort for the patient and greater convenience for the surgeon.

Funding

None.

Competing interests

The authors have no conflict of interest to declare.

Ethical approval

This research was approved by the Scientific Ethical Committee of the University of Genoa.

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