

Mini-invasive Implant Placement in Combination with Maxillary Sinus Membrane Perforation During Transcrestal Sinus Floor Elevation: A Retrospective Study



Paolo Toscano, MD, DMD, OMFS¹
Calogero Toscano, DMD¹
Massimo Del Fabbro, BSc, PhD²

The aim of this retrospective study was to report preliminary outcomes of a modified technique for transcrestal sinus floor elevation with simultaneous implant placement. A total of 165 implants were placed in 110 patients using a modified Summers technique. During implant site preparation, after fracturing the sinus floor, a small perforation of the membrane was made using the first osteotome. After grafting with anorganic bovine bone mixed with venous blood, standard-length implants were inserted. The prosthetic phase occurred after 4 to 5 months. Patients were followed for at least 2 years after loading. During the follow-up, sinus condition was assessed by cone beam computed tomography. Periapical radiographs were taken to assess graft height and peri-implant bone levels. Three implants failed within 2 months of placement, yielding an overall implant survival of 98.2%. The mean follow-up was 38.3 months (range: 28 to 60 months) from placement. All other implants were stable and peri-implant soft tissues were healthy throughout the observation period. Peri-implant bone loss averaged 0.62 ± 0.26 mm after 1 year of function. No biologic or biomechanical complications occurred. No evidence of graft material dispersion into the sinus space was detected, except for two cases that resolved spontaneously. After 1 year of loading the graft height averaged 4.8 ± 1.3 mm above the sinus floor level. In the presence of sinus membrane perforation, the proposed modified osteotome technique may allow a predictable rehabilitation of the atrophic posterior maxilla by means of standard length implants without the occurrence of adverse events. Int J Periodontics Restorative Dent 2016;36:199–211. doi: 10.11607/prd.2280

¹Private Practice, Vicenza, Italy

²Academic Researcher, Università degli Studi di Milano, Department of Biomedical, Surgical and Dental Sciences, Milano, Italy; IRCCS Istituto Ortopedico Galeazzi, Milano, Italy.

Correspondence to: Dr Massimo Del Fabbro, Università degli Studi di Milano Istituto Ortopedico Galeazzi Via Riccardo Galeazzi 4 20161, Milano, Italy. Fax: +39 02 50319960. Email: massimo.delfabbro@unimi.it

©2016 by Quintessence Publishing Co Inc.

Maxillary sinus augmentation is a surgical procedure for increasing the available bone volume to allow the placement of implants in the posterior maxilla of patients whose anatomy does not permit the use of graftless treatment options such as short or tilted implants.^{1–10} In 1994, Summers presented a minimally invasive approach for grafting the maxillary sinus using a series of increasingly wider osteotomes.^{11,12} This technique allows a crestal approach to the maxillary sinus and, if performed in a controlled and atraumatic manner, allows the alveolar ridge to be augmented toward its apical direction while preparing the implant site as well as a simultaneous implant placement. Instead of drilling into the bone tissue with burs, a series of osteotomes are gently malleted toward the sinus floor at the intended implant site of the alveolar ridge until fracture of the cortical plate occurs. Hence, the sinus floor can be pushed up and the ridge height increased by 3 to 4 mm along its antral direction. Furthermore, the compaction and condensation effect of the osteotomes can increase the bone density around the osteotomy site.^{11–13} A graft of autogenous bone or bone substitutes can be introduced and compacted in the osteotomy site to further increase the bone volume around the apical side of the implant. Such added mass

may also act as a hydraulic plug for the existing fluids (blood) inside the drilled cavity, helping to elevate the sinus boundary. It was recommended that as the sinus membrane was raised care should be taken to prevent its tearing and/or perforation.^{11–12}

Clinicians have proposed a number of modifications to this crestal (also called “transcrestal”) technique over the years to improve its predictability or adapt it to different clinical situations.^{14–21} The crestal technique is currently supported by a large amount of clinical evidence, and its outcomes may be compared with those of conventional lateral technique, as testified by recent systematic reviews.^{10,22–24} Implant survival rates well above 90% have been reported, with some of these studies including more than 5 years of follow-up.^{25–27} The crestal approach with simultaneous implant placement is generally reserved for those cases in which the residual bone height at the intended site is at least 4 to 5 mm, though some reports have been published of successful cases in the presence of lower residual ridge height.^{16,27–30} In cases of extremely atrophic posterior maxillae, with residual bone height less than 4 mm, the lateral technique is generally recommended as it allows safer management of the grafting procedure at the sinus floor.^{31–33}

The most frequent intra-operative complication associated with both the lateral and crestal approaches for maxillary sinus augmentation surgery is sinus membrane perforation.³⁴ The

incidence of mucosa perforations, as reported in the literature, ranges from no perforation to over 50% for the lateral technique.^{35–37} The reported perforation incidence using the crestal technique is generally lower.^{24,38–39} However, since the former is considered a blind technique, it is possible that some perforations remain undetected and their true incidence is greater than reported.³⁸ The causes of the large variation have not been explored systematically, though it is believed that the skill of the operator, the characteristics of the mucosa (such as its thickness), the gingival phenotype, and the residual ridge height may have a considerable effect.^{40–42} It has been suggested that following a perforation, the irritated mucosa may become hypertrophic and lead to maxillary sinusitis and blockage of the osteomeatal complex, which could cause severe patient discomfort and ultimately increase the risk of implant failure.³¹ If the perforation is not properly managed, there may be a risk that part of the graft, especially if in granular form, could find a way across the perforation and enter the sinus, leading to further irritation of the mucosa. The perforation size may also have an effect on such graft migration and on the outcome of the procedure. Sinus membrane perforations have been classified according to size and position,^{43–45} and several repair techniques have been proposed.^{37–39,43–47} It has been demonstrated that small perforations (< 2 mm) may self-repair physiologically as elevation continues, when the sinus membrane folds over itself.³⁷

Regarding the effect of perforations on the clinical outcome, a clear and systematic relationship between sinus membrane perforation and implant failure has been suggested but never established.^{48–50} In most cases, in spite of an occasional sinus membrane perforation, the procedure may be continued and succeed without compromising implant survival.^{31,51–53}

The purpose of this study was to report the preliminary outcomes of a modified technique for crestal maxillary sinus floor elevation involving a small perforation of the sinus membrane and simultaneous implant placement, that allows for a safe and consistent augmentation procedure and a predictable rehabilitation of the atrophic posterior maxilla.

Materials and methods

This is a single cohort retrospective analysis of a series of patients treated in a private practice setting. All the patients were treated following the principles embodied in the Helsinki Declaration of 1975 for biomedical research involving human subjects, as revised in 2000.⁵⁴ This retrospective analysis was approved by the Review Board of the Istituto Ortopedico Galeazzi.

Inclusion criteria were those currently adopted in the authors' private practice (Vicenza, Northern Italy) for subjects undergoing maxillary sinus grafting, as follows:

- At least 18 years of age
- Absence of general medical contraindications for oral

surgery procedures (American Society of Anesthesiologists ASA-1 or ASA-2)

- Full-mouth bleeding score and full-mouth plaque score less than 25% at baseline
- Partially edentulous ridge in the posterior maxilla with residual bone height of at least 5 mm at the intended implant site
- Absence of ongoing acute sinus pathologies and of endodontic and endoperiodontal focal pathologies
- Able to sign the informed consent form

Patients were excluded if they presented at least one of the following exclusion criteria:

- Any disease, condition, or medication that might compromise healing or osseointegration
- Previous surgical reconstruction of the maxillary sinus floor
- Inability or unwillingness to return for follow-up visits
- Inability or unwillingness to maintain a good level of oral hygiene throughout the study

The preoperative state of health of the maxillary sinuses was accurately evaluated with cone beam computed tomography (CBCT). In the presence of sinus pathology the patient was given proper treatment and sinus surgery was postponed until maxillary sinus returned healthy. Based on the above criteria, a cohort of 110 patients (accounting for 165 implants) that underwent maxillary sinus augmentation by means of the

crestal approach were selected. Patients were consecutively treated between April 2009 and January 2012. Only patients whose rehabilitation had been in function for at least 24 months were included.

All patients were advised in advance that the sinus membrane was to be perforated during the intervention and signed an informed consent form before surgery. They were also offered the option of lateral approach to the sinus augmentation.

All surgical procedures were performed by a single experienced oral and maxillofacial surgeon (PT).

Step-by-step surgical procedure

One hour before surgery, 2 g of amoxicillin and clavulanic acid (Augmentin, Roche) were administered to patients as a prophylactic regimen.

Local anesthesia was induced with articaine chlorhydrate 4% and adrenaline 1:100,000 (Alfacaina N, Weimer Pharma). After the elevation of a full-thickness flap to expose bone tissue, a distal vertical incision was made in many cases to increase the mobility of the flap. The surgical site was first prepared using a bur with conical tip, which also served to assess bone density. The bur penetrated to a depth of no more than 2 mm, so that 3 to 4 mm of the sinus floor height was left intact. The implant site was then prepared according to the Summers technique by gently malleting the base of the first tapered osteotome of 1.6 mm diameter (Summers Osteotome OST01, Biomet 3i) until a greenstick fracture

of the compact bone of the sinus floor was induced. The osteotome was pushed through the fractured bone wall of the sinus floor, inducing tension on the sinus mucosa that lifted like a tent until a small laceration was produced. A change in the tapping sound confirmed the occurrence of the perforation. Hence, the osteotome was gently moved forward up to 13 to 15 mm from the ridge without encountering resistance. A periapical radiograph was taken before retracting the osteotome (Fig 1). Then, up to 1 mL of anorganic bovine bone (Bio-Oss small granules, 0.25 to 0.50 mm, Geistlich), which was mixed with venous blood to improve graft cohesiveness, was inserted into the site. Using a modified cylindric compactor, the graft was gently pushed through the fractured bone wall and anchored to the borders of the mucosal laceration, further raising and detaching the membrane from the sinus floor, until reaching 13 to 15 mm from the ridge. The second osteotome with a flat head of 2.2 mm (OST02, Biomet 3i) was used with minimal apical pressure and rotation and slight malleting, further pushing the bone wall of the above fracture (and, consequently, the graft) in the apical direction. The tip of the second osteotome reached 10 to 13 mm from the ridge. In this way, the fractured bone wall assumed a conical shape, entering about 2 to 3 mm inside the sinus cavity and increasing the inward apical shift of the sinus membrane caused by the first osteotome. An additional 0.5 mL of anorganic bovine bone was inserted and pushed up using another compactor

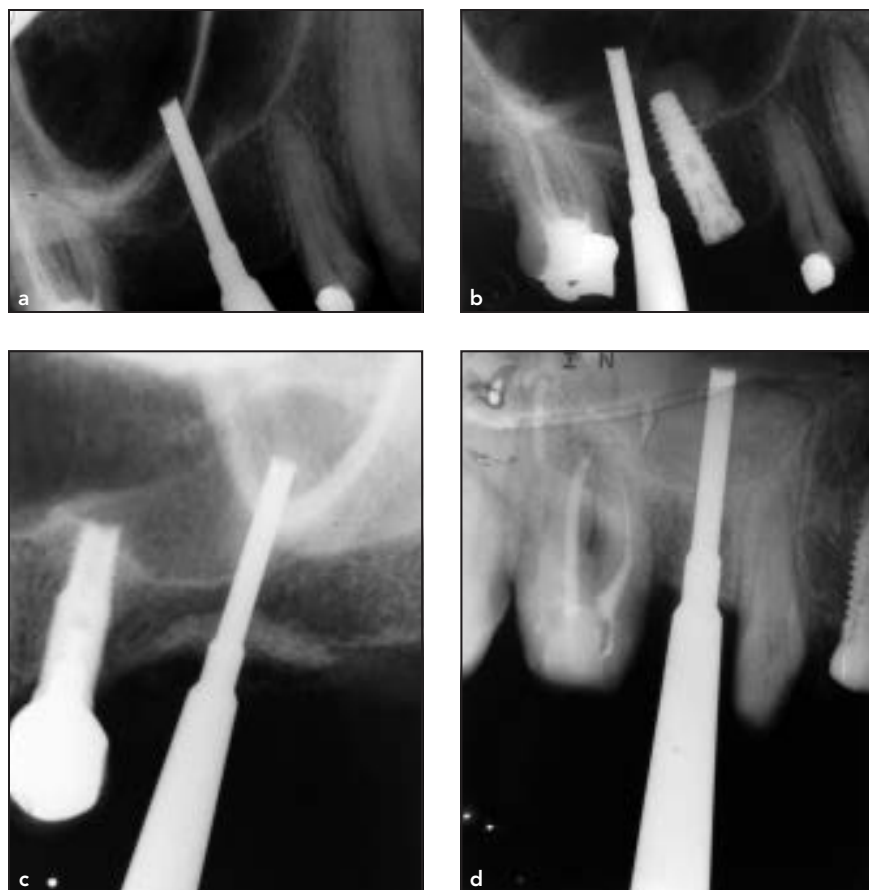


Fig 1 (left) Periapical radiographs showing examples of penetration of the first osteotome into the sinus cavity through sinus membrane perforation. The tip of the osteotome is located well beyond the sinus floor level, to a depth of 10 to 15 mm from the ridge level. (a) Right second premolar. (b) Right second premolar after grafting and placement of a 13-mm-long implant. Another implant site preparation is done at the level of the right first molar. (c) The first osteotome is inserted at the left first molar level. (d) The first osteotome is inserted at the right first molar.

Fig 2 (below) Panoramic radiograph showing the presurgical condition of a patient requiring extraction of the maxillary right first and second molars.

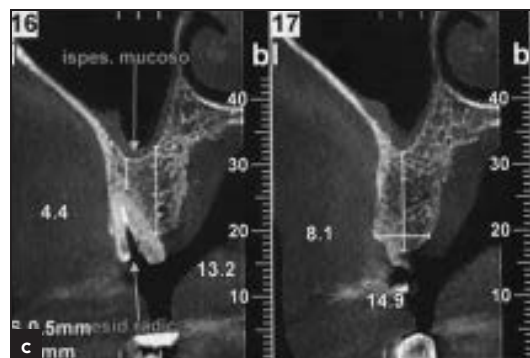
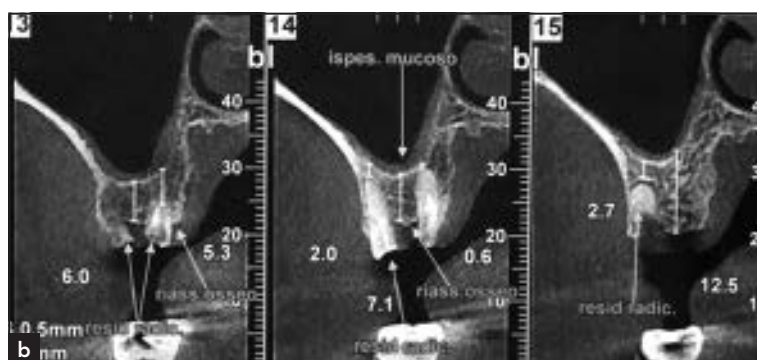
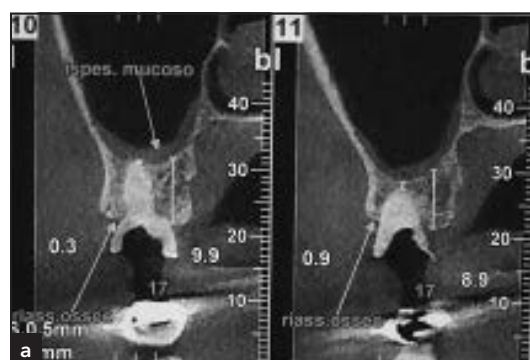


Fig 3 CBCT scans showing local condition of the same patient as Fig 2.

until contact was made with the existing graft. The graft material mixed with blood acted as a lateral plug on the conical fractured part of the sinus wall. Then, a third osteotome (3.2 mm tip size, OST03, Biomet 3i), if necessary, slightly enlarged the site by entering 3 to 4 mm from the ridge to facilitate implant insertion.

Conical and cylindrical implants 4 mm in diameter and 10 to 13 mm long were used (Certain Osseotite, Biomet 3i). The apical diameter of the implants was 0.8 mm larger than the crestal implant site. The choice of conical or cylindrical implants depended on the local anatomical features of the bony ridge at the intended implant site.

Implants were gently inserted and seated with a torque generally ranging between 25 and 40 Ncm, using a manual torque-controlled wrench. During the procedure, periapical radiographs were taken with the osteotome in situ to demonstrate membrane perforation (Fig 1). At the end of the procedure, another periapical radiograph was taken to assess the amount of sinus floor augmentation and the implant position in respect to the sinus floor.

After implant placement, the flap was repositioned and sutured with 5-0 nonresorbable sutures (Ethicon). Sutures were removed after 10 to 14 days.

Figures 2 to 7 show the initial condition, the surgical sequence, and the early postoperative course of a double postextraction case treated with the described technique.

Prosthetic procedures generally started after 4 months of healing. In cases of insertion torque lower than 20 Ncm, 5 months of healing were allowed before uncovering and impression taking. After less than 1 month, a reinforced composite, zirconia, or metal-ceramic prosthesis was placed.

Follow-up

Follow-up visits were scheduled at 4 to 6 and 12 months after loading and then yearly. At each visit, the operator checked implant stability without removing the restoration, using the handles of two opposing metallic instruments. Peri-implant soft tissue condition was clinically verified by probing around the implants. A periapical radiograph was taken with the paralleling technique using a customized holder to assess peri-implant bone level and the absence of peri-implant radiolucency and to evaluate graft stability. A CBCT scan was also taken yearly to evaluate the condition of the maxillary sinus.

The outcome measures evaluated at each follow-up were:

- Prosthesis stability: the prosthesis was in function, without mobility or pain. Prosthesis stability was tested by means of two opposing instruments' pressure.
- Prosthesis failure: the prosthesis had to be removed for any reason.
- Implant survival: the implant was still functioning, with no evidence of peri-implant radiolucency on radiograph, no suppuration or pain at the implant site, and no ongoing pathologic processes.
- Peri-implant bone level change: the peri-implant bone level was measured as the distance between a reference point on the implant (implant neck) and the most coronal bone-



Fig 4 Clinical condition of the teeth to be extracted due to extensive caries and root fracture.

to-implant contact at both the mesial and the distal aspect. The bone level change was the difference between follow-up measurement and baseline (the day of placement).

- Graft height beyond the baseline sinus floor: the linear distance between the floor of the maxillary sinus and the most apical point of the graft surrounding the implant.

The latter two parameters were assessed at the surgical phase and one year after surgery using ImageJ software (National Institute of Health).

Since this is a retrospective analysis of a single cohort of patients, only descriptive statistics have been done.

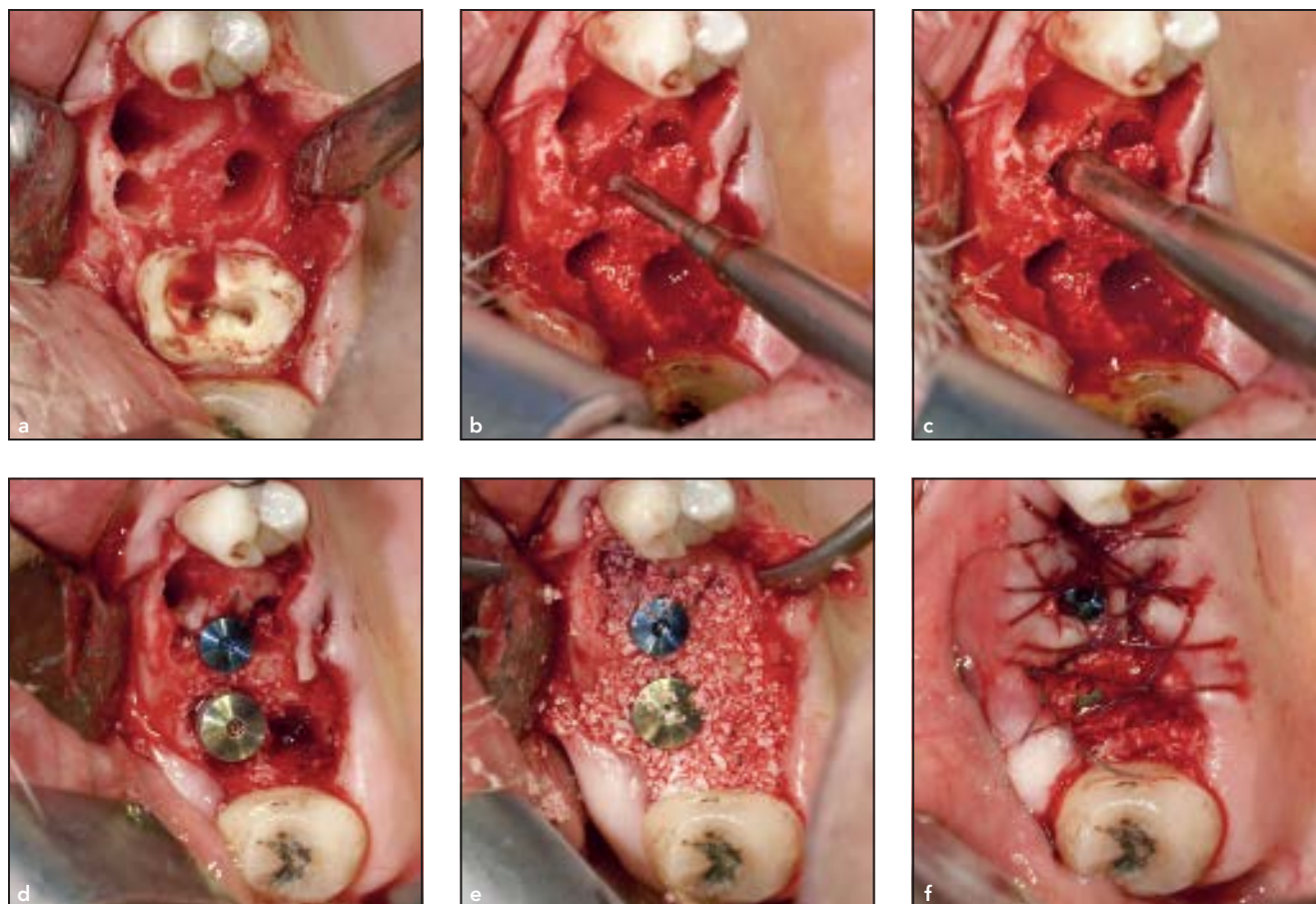


Fig 5 Surgical sequence. (a) The first molar was extracted. (b) After extraction of both teeth, the first osteotome is inserted in the implant site and gently pushed upward until the sinus membrane is perforated. (c) The second osteotome is carefully inserted for graft compaction and further raising of the membrane before implant insertion. After insertion of the first implant the procedure is repeated to prepare the site at the second molar position. (d) Both implants positioned. (e) The gaps left by the roots are filled with anorganic bovine bone before suturing. (f) The sutures are placed.



Fig 6 Periapical radiograph showing the position of the two implants, with both tips shielded by the graft.

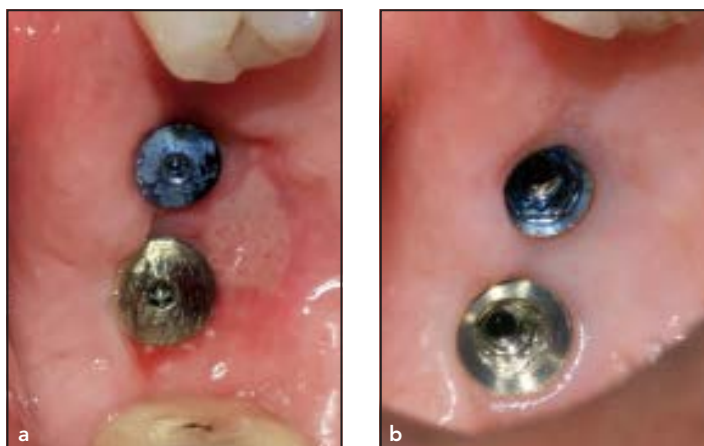


Fig 7 (a) Clinical view of the implants with the cover screw 4 months after surgery. (b) The prosthesis delivery stage, 6 months after surgery.

Results

The study included 65 women and 45 men. Patient characteristics are given in Table 1. Three implant failures were recorded in three patients throughout the observation period. Failures occurred during the healing phase and were detected at the uncovering stage. All failed implants had been placed in healed sites with an insertion torque of 20 Ncm. One of the patients experiencing failure was a smoker. In another case a granuloma was present at the tooth apex close to the implant. In the three failed cases the available native bone at the surgical site was 5.5 to 6 mm. All other implants were stable throughout the study. The overall implant survival after 1 year of function was 98.2%.

No further biologic or mechanical complications occurred throughout the study. No peri-implant radiolucency was observed. No inflammation of the peri-implant mucosa was recorded at any follow-up visit. Postoperative radiographic evaluations did not show traces or consequences of the original sinus mucosa perforation. No graft material dispersion into the sinus space occurred, except for two cases that resolved spontaneously within 2 days without additional complications. One of these patients was Valsava-positive at surgery. The follow-up from implant placement ranged from 28 to 60 months (24 to 55 months of functional loading). The mean follow-up from implant placement was 38.3 months.

The periapical radiographs of 21 implants (12.7%) could not

Table 1 Features of the study sample and main outcomes

No. patients	110
No. males/females (%)	45/65 (40.9/59.1)
Mean age at surgery \pm SD, y (range)	56.4 \pm 18.8 (40–67)
No. smokers (%)	17 (15.45)
No. implants placed	165
No. implants in smokers (%)	29 (17.58)
No. implants in postextraction sites (%)	35 (21.21)
No. failures (%)	3 (1.82)
Mean residual crest height \pm SD, mm (range)	5.82 \pm 1.35 (4.5–8.2)
Mean 1-y graft height above sinus floor \pm SD, mm (range)	4.8 \pm 1.3 (2.8–7.0)
Mean 1-y peri-implant bone loss \pm SD, mm (range)	0.62 \pm 0.26 (0–1.0)
Mean follow-up \pm SD, mo (range) from placement	38.3 (28–60)
Mean follow-up \pm SD, mo (range) from loading	33.5 (24–55)



Fig 8 Periapical radiograph of the presurgical condition, showing an edentulous space at the maxillary right first molar position, with reduced vertical dimension of the ridge.

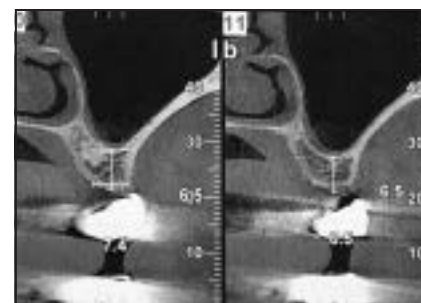


Fig 9 Preoperative CT scan. Residual bone height and width were measured at the edentulous site intended for transcresal sinus augmentation. In two consecutive slices, the ridge height was 7.4 and 6.5 mm, respectively, and the ridge width was 6.5 and 6.5 mm.

be used for marginal bone level change assessment at 1 year due to inadequate quality of the radiograph. In this case peri-implant bone level was evaluated through a panoramic radiograph to make sure that peri-implant bone loss fell within normal ranges. Though the peri-implant bone loss values assessed with panoramic radiographs never exceeded 1 mm, they were not averaged with those measured in periapical radiographs to avoid bias deriving from combining different measurement techniques. None of

the implants evaluated at 1 year of function ($n = 144$) showed a marginal bone loss greater than 1 mm (mean value = 0.62 ± 0.26 mm). After 1 year, the height of the graft beyond baseline sinus floor level averaged 4.8 ± 1.3 mm.

Figure 8 shows the presurgical condition of a patient with a missing maxillary left first molar. Two consecutive slices from a preoperative CT scan were used to measure residual ridge height and width at the edentulous site intended for transcresal sinus augmentation



Fig 10 Periapical radiograph taken soon after sinus floor fracturing. The first osteotome was inserted through the sinus mucosa, penetrating into the sinus up to 13 mm from the residual ridge level.



Fig 11 Periapical radiograph taken soon after grafting, with the second osteotome deepening for 10 mm beyond the ridge level.



Fig 12 After grafting of the site, a 13-mm-long, 4-mm-wide implant was placed. The apical part of the implant is completely surrounded by the graft.

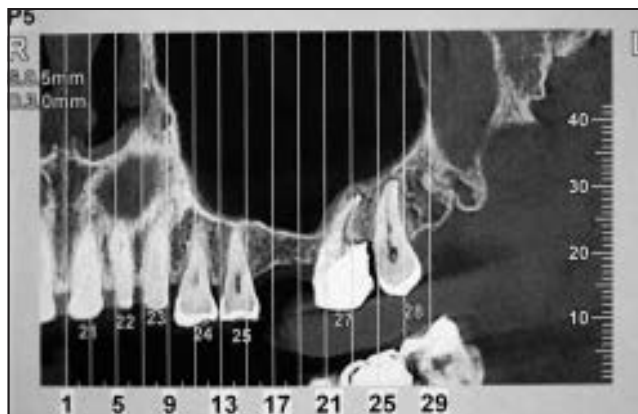


Fig 13 Panoramic radiograph (a) and CBCT (b) showing an edentulous space at the maxillary left first molar position with reduced vertical dimension of the ridge.

(Fig 9). A periapical radiograph taken during the surgical procedure, just after sinus floor fracturing, shows penetration of the first osteotome up to 13 mm from the residual ridge level (Fig 10). Figure 11 shows penetration of the second osteotome up to 10 mm from the ridge level after initial grafting of the site. After placement, the apical part of a 13-mm-long, 4-mm-wide implant could be seen invading the sinus and completely surrounded by the graft (Fig 12).

Another clinical case is shown in Figs 13 to 16. An edentulous

space at the maxillary left first molar position underwent transcresal maxillary sinus augmentation (Fig 13). The height and width of the residual ridge at the intended implant site were measured from CT scan (Fig 14). Figure 15 is a periapical radiograph taken soon after implant placement showing a 13-mm-long implant with the apical side invading the sinus cavity and surrounded by the bone graft. Figure 16 is a periapical radiograph taken at the 4-year follow-up. The peri-implant bone level and the bone graft size appear stable.

Discussion

The present study is one of the largest reports on the clinical outcomes of patients with maxillary sinus membrane perforation. The absence of postoperative complications and the excellent implant survival after an average follow-up of 3 years testify to the predictability of the technique presented. It allows a safe and effective elevation of the maxillary sinus floor through the crestal approach in the presence of a mucosa perforation. The major limitations of

Fig 14 Residual ridge height and width were measured using a preoperative CT scan. In two consecutive slices, the ridge height was 5.5 and 4.8 mm, respectively, and the ridge width was 5.0 mm in both cases.

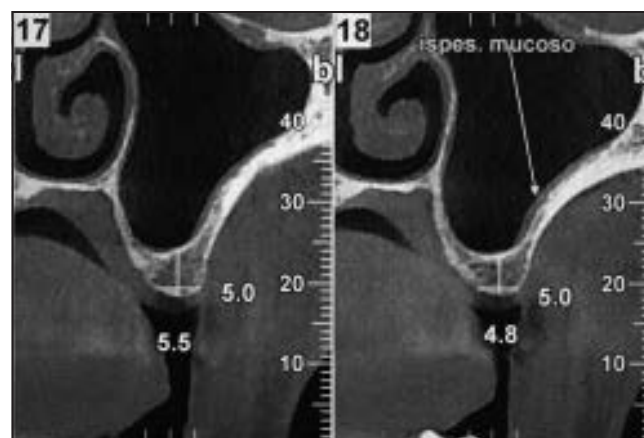


Fig 15 Periapical radiograph taken soon after placement of a 4-mm-wide, 13-mm-long implant, with the apical side invading the sinus cavity and surrounded by the bone graft.



Fig 16 Periapical radiograph taken at the 4-year follow-up. The peri-implant bone level and the bone graft size appear stable.

the present study, however, are its retrospective nature and the absence of a control group, which prevents direct comparison with patients with nonperforated sinus membrane. Clinicians should not systematically think of a perforation as a fastidious complication to be avoided. In some cases, a small membrane laceration or perforation allows pushing of a compact graft a little further into the sinus, allowing greater cushioning of the implant. The elastic properties of the membrane and its tendency to fold over itself after osteotome

penetration might be among the reasons for the negligible risk of graft material dispersion into the sinus space observed in the present study. In addition, if the particulate graft is mixed with autogenous venous blood its consistency and cohesion are supposed to be improved, preventing spreading into the sinus. Furthermore, perforation of the maxillary sinus membrane during implant site preparation allows the formation of an intentional controlled small wound in the sinus membrane to further stimulate a biologic healing reaction, possibly

enhancing the regeneration process. While a few studies found no osteogenic contribution of the sinus membrane to the healing process,^{55,56} several in vitro and in vivo studies demonstrated the osteogenic potential of the membrane and proved the existence of osteoprogenitor cells in the connective stromal portion of the membrane, below the ciliated epithelium.⁵⁷⁻⁶¹ It is therefore suggested that through appropriate stimuli, such progenitor cells could undergo osteogenic differentiation, favoring bone formation at the graft site.

The key steps of the technique are: (1) induction of a direct trauma to separate the elastic portion of the membrane from the periosteum and its subsequent mobilization and (2) building a bone "hat" on the sinus floor beneath the membrane, lifted by means of the gradual insertion of the bone graft in the site. The coagulum derived from bleeding mucosa should act as a glue, sealing any breach to the sinus space. The placement of the graft and, finally, of the fixture, is then supposed to close the gaps with the sinus, securing the perforation like a plug.

The present technique was developed after a long experience in the management of techniques for sinus surgery and successfully adopted by the main author (PT) several years ago. During his early experience with osteotome-mediated sinus floor elevation technique, he realized that small incidental perforations could be easily managed and did not cause post-operative complications or affect implant survival. Subsequently, he noted that small perforations release the tension on the sinus membrane, facilitating its detachment and the placement of the graft. Nevertheless, due to the draping of the membrane, such small perforations tend to self-close, reducing the risk of graft dispersion into the sinus. The author therefore introduced small controlled perforation of the sinus mucosa as a routine during surgical procedures with simultaneous implant placement, achieving a consistent and safe augmentation of the sinus floor. The perforation was demonstrated by the use of

intraoral radiograph taken with the osteotome still inserted in the site: the tip of the osteotome was always located about 5 to 9 mm over the original level of the maxillary sinus floor, strongly suggesting the perforation of the sinus membrane. This technique takes advantage of a sinus membrane laceration, achieving a substantial augmentation of the sinus floor and thereby protecting the apical side of the implant. It is not suggested, however, that a perforation is needed to allow for larger graft volume. Especially in the lateral technique, the intact membrane is actually easier to elevate to the maximum desired graft volume than a perforated membrane. The border between safe management of a sinus membrane perforation and a true complication derived from the perforation itself is very thin. Some critical steps exist that must be undertaken very carefully, such as grafting of the site after perforation. In fact, the risk of graft migration into the sinus may still exist even for small perforations that may tend to become larger, especially in thin membranes, when the pressure of graft placement is applied.

It is recommended that the present technique be performed only in the absence of adjacent and contiguous endodontic and endoperiodontal focal pathologies, as infections could spread through perforation and might compromise healing. Nevertheless, some patients presenting with mild asymptomatic thickening of the sinus mucosa, deriving from a chronic pathology, have been successfully treated under adequate antibiotic coverage.

In summary, the technique presented is a fast and inexpensive procedure that can be adopted in daily practice only after the clinicians are properly trained in the technique and have acquired the skills needed to perform it.

The clinical results of the present study support the concept that a perforation occurring during maxillary sinus augmentation procedure does not invariably lead to negative outcomes. This was suggested in 1980 when Breine and Brånemark demonstrated that moderate penetration of an implant into a non-infected sinus may be tolerated without complications even in the presence of a laceration of the sinus membrane.⁵¹

There is no clear evidence of systematic negative outcomes related to sinus perforations, nor that a perforation compromises sinus mucosa functions more than simple detachment from the sinus walls does.⁶²⁻⁶³ A perforation causes increased local bleeding and, if properly controlled, this may prove useful for achieving improved cohesion of the graft as well as properly triggering the healing process.

An experimental study reported that after an intentional perforation of the membrane the inflammatory process developing in the mucosa does not prevent the integration of the graft and the implants and that following the sinus lifting procedure some changes occur in the sinus membrane that allow adaptation to the new situation and are not detrimental to the success of the procedure.⁶⁴

Another study in dogs evaluated the effects of dental implant penetration to different extents into the maxillary sinus following intentional sinus perforation, in terms of implant osseointegration and sinus health.⁶⁵ Implants were inserted into postextraction sockets after drilling through the sinus floor. No signs of inflammatory reactions were recorded in any sinus. Histologic analysis showed no between-group difference in bone-to-implant contact and bone area in implant threads. Implant stability was also similar between groups. The study concluded that penetration of dental implants into the maxillary sinus associated with membrane perforation does not compromise sinus health and implant osseointegration in the dog.⁶⁵

A recent clinical study provided histologic evidence of a significantly greater percentage of vital bone in augmented sinuses in which a membrane perforation occurred as compared to nonperforated sinuses.⁶⁶ The study concluded that "maxillary sinus membrane perforations, when properly repaired during surgery, do not appear to be an adverse complication in terms of vital bone production or implant survival."⁶⁶

Finally, a recent clinical study evaluated the survival rate of 8- to 10-mm-long implants placed in the posterior maxilla through intentional perforation of the sinus membrane and protruding up to 3 mm beyond the sinus floor.⁶⁷ Residual ridge height ranged from 5 to 8 mm. Sinus floor perforation was caused by a 2-mm twist drill. After a follow-up of 1 year, the study re-

ported one implant failure out of 63 implants (98.4% survival) in 56 patients. Minor manageable complications, ranging from epistaxis to sinusitis, were reported.⁶⁷

Though implant survival rates were similar, perforation of the sinus mucosa was achieved less traumatically in the present study. Osteotomes were used, and a sinus floor augmentation procedure was associated with implant placement so that the implant tip was not actually exposed to the sinus space. Furthermore, in the present study the sample size was wider and the follow-up longer. Following the steps of the present clinical protocol, no intraoperative nor postoperative adverse events were recorded except for the three failed implants. Such failures could be related not to the perforation per se, but to other conditions such as the nonoptimal implant primary stability or the presence of an apical lesion close to the implant.

Conclusions

Within the limitations of the present retrospective study, the implant survival rate in the medium term after transcrestal sinus augmentation procedure in the presence of a small sinus membrane perforation is comparable with that reported in the absence of perforation. The intriguing results obtained with this technique should be confirmed by well-designed comparative prospective studies with a large sample size and a long-term follow-up.

Acknowledgments

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

References

1. Att W, Bernhart J, Strub JR. Fixed rehabilitation of the edentulous maxilla: Possibilities and clinical outcomes. *J Oral Maxillofac Surg* 2009;67:60–73.
2. Rossetti PH, Bonachela WC, Rossetti LM. Relevant anatomic and biomechanical studies for implant possibilities on the atrophic maxilla: Critical appraisal and literature review. *J Prosthodont* 2010;19:449–457.
3. Renouard F, Nisand D. Impact of implant length and diameter on survival rates. *Clin Oral Implants Res* 2006;17(suppl 2):35–51.
4. Felice P, Soardi E, Pellegrino G, et al. Treatment of the atrophic edentulous maxilla: Short implants versus bone augmentation for placing longer implants. Five-month post-loading results of a pilot randomised controlled trial. *Eur J Oral Implantol* 2011;4:191–202.
5. Perelli M, Abundo R, Corrente G, Saccone C. Short (5 and 7 mm long) porous implants in the posterior atrophic maxilla: A 5-year report of a prospective single-cohort study. *Eur J Oral Implantol* 2012;5:265–272.
6. Ridell A, Gröndahl K, Sennerby L. Placement of Brånemark implants in the maxillary tuber region: Anatomical considerations, surgical technique and long-term results. *Clin Oral Implants Res* 2009;20:94–98.
7. Aparicio C, Perales P, Rangert B. Tilted implants as an alternative to maxillary sinus grafting: A clinical, radiological, and periotest study. *Clin Implant Dent Relat Res* 2001;3:39–49.
8. Del Fabbro M, Bellini CM, Romeo D, Francetti L. Tilted implants for the rehabilitation of edentulous jaws: A systematic review. *Clin Implant Dent Relat Res* 2012;14:612–621.
9. Maló P, Nobre Md, Lopes A. Immediate loading of 'All-on-4' maxillary prostheses using trans-sinus tilted implants without sinus bone grafting: A retrospective study reporting the 3-year outcome. *Eur J Oral Implantol* 2013;6:273–283.

10. Corbella S, Taschieri S, Del Fabbro M. Long-term outcomes for the treatment of atrophic posterior maxilla: A systematic review of literature. *Clin Implant Dent Relat Res* 2015;17:120–132.
11. Summers RB. A new concept in maxillary implant surgery: The osteotome technique. *Compendium* 1994;15:152, 154–156.
12. Summers RB. The osteotome technique: Part 3—Less invasive methods of elevating the sinus floor. *Compendium* 1994;15:698–700.
13. Rosen PS, Summers R, Mellado JR, et al. The bone-added osteotome sinus floor elevation technique: Multicenter retrospective report of consecutively treated patients. *Int J Oral Maxillofac Implants* 1999;14:853–858.
14. Bruschi GB, Scipioni A, Calesini G, Bruschi E. Localized management of sinus floor with simultaneous implant placement: A clinical report. *Int J Oral Maxillofac Implants* 1998;13:219–226.
15. Cosci F, Luccioli M. A new sinus lift technique in conjunction with placement of 265 implants: A 6-year retrospective study. *Implant Dent* 2000;9:363–368.
16. Deporter D, Todescan R, Caudry S. Simplifying management of the posterior maxilla using short, porous surfaced dental implants and simultaneous indirect sinus elevation. *Int J Periodontics Restorative Dent* 2000;20:476–485.
17. Nedir R, Bischof M, Vazquez L, Smuzkler-Moncler S, Bernard JP. Osteotome sinus floor elevation without grafting material: A 1-year prospective pilot study with ITI implants. *Clin Oral Implants Res* 2006;17:679–686.
18. Taschieri S, Corbella S, Del Fabbro M. Mini-invasive osteotome sinus floor elevation in partially edentulous atrophic maxilla using reduced length dental implants: Interim results of a prospective study. *Clin Implant Dent Relat Res* 2014;16:185–193.
19. Pozzi A, Moy PK. Minimally invasive transcrestal guided sinus lift (TGSL): A clinical prospective proof-of-concept cohort study up to 52 months. *Clin Implant Dent Relat Res* 2014;16:582–593.
20. Better H, Slavescu D, Barbu H, Cochran DL, Chaushu G. Minimally invasive sinus lift implant device: A multicenter safety and efficacy trial preliminary results. *Clin Implant Dent Relat Res* 2014;16:520–526.
21. Lundgren S, Cricchio G, Palma VC, Salata LA, Sennerby L. Sinus membrane elevation and simultaneous insertion of dental implants: A new surgical technique in maxillary sinus floor augmentation. *Periodontol* 2000 2008;47:193–205.
22. Emmerich D, Att W, Stappert C. Sinus floor elevation using osteotomes: A systematic review and meta-analysis. *J Periodontol* 2005;76:1237–1251.
23. Del Fabbro M, Corbella S, Weinstein T, Ceresoli V, Taschieri S. Implant survival rates after osteotome-mediated maxillary sinus augmentation: A systematic review. *Clin Implant Dent Relat Res* 2012;14 (suppl 1):e159–e168.
24. Călin C, Petre A, Drafta S. Osteotome-mediated sinus floor elevation: A systematic review and meta-analysis. *Int J Oral Maxillofac Implants* 2014;29: 558–576.
25. Pjetursson BE, Rast C, Brägger U, Schmidlin K, Zwahlen M, Lang NP. Maxillary sinus floor elevation using the (transalveolar) osteotome technique with or without grafting material. Part I: Implant survival and patients' perception. *Clin Oral Implants Res* 2009;20:667–676.
26. Tetsch J, Tetsch P, Lysek DA. Long-term results after lateral and osteotome technique sinus floor elevation: A retrospective analysis of 2190 implants over a time period of 15 years. *Clin Oral Implants Res* 2010;21:497–503.
27. Bruschi GB, Crespi R, Capparè P, Gherlone E. Transcrestal sinus floor elevation: A retrospective study of 46 patients up to 16 years. *Clin Implant Dent Relat Res* 2012;14:759–767.
28. Cavicchia F, Bravi F, Petrelli G. Localized augmentation of the maxillary sinus floor through a coronal approach for the placement of implants. *Int J Periodontics Restorative Dent* 2001;21:475–485.
29. Schmidlin PR, Müller J, Bindl A, Imfeld H. Sinus floor elevation using an osteotome technique without grafting materials or membranes. *Int J Periodontics Restorative Dent* 2008;28:401–409.
30. Nedir R, Nurdin N, Szmukler-Moncler S, Bischof M. Placement of tapered implants using an osteotome sinus floor elevation technique without bone grafting: 1-year results. *Int J Oral Maxillofac Implants* 2009;24:727–733.
31. Khoury F. Augmentation of the sinus floor with mandibular bone block and simultaneous implantation: A 6-year clinical investigation. *Int J Oral Maxillofac Implants* 1999;14:557–564.
32. Peleg M, Garg AK, Mazor Z. Predictability of simultaneous implant placement in the severely atrophic posterior maxilla: A 9-year longitudinal experience study of 2132 implants placed into 731 human sinus grafts. *Int J Oral Maxillofac Implants* 2006;21:94–102.
33. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part I: Lateral approach. *J Clin Periodontol* 2008;35 (suppl 8):216–240.
34. Katranji A, Fotek P, Wang HL. Sinus augmentation complications: Etiology and treatment. *Implant Dent* 2008;17: 339–349.
35. Schwartz-Arad D, Herzberg R, Dolev E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. *J Periodontol* 2004;75:511–516.
36. Wallace SS, Mazor Z, Froum SJ, Cho SC, Tarnow DP. Schneiderian membrane perforation rate during sinus elevation using piezosurgery: Clinical results of 100 consecutive cases. *Int J Periodontics Restorative Dent* 2007;27:413–419.
37. Testori T, Wallace SS, Del Fabbro M, et al. Repair of large sinus membrane perforations using stabilized collagen barrier membranes: Surgical techniques with histological and radiographic evidence of success. *Int J Periodontics Restorative Dent* 2008;28:9–17.
38. Tan WC, Lang NP, Zwahlen M, Pjetursson BE. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: Transalveolar technique. *J Clin Periodontol* 2008;35: 241–254.
39. Garbacea A, Lozada JL, Church CA, et al. The incidence of maxillary sinus membrane perforation during endoscopically assessed crestal sinus floor elevation: A pilot study. *J Oral Implantol* 2012;38: 345–359.

40. Aimetti M, Massei G, Morra M, Carde-
si E, Romano F. Correlation between
gingival phenotype and Schneiderian
membrane thickness. *Int J Oral Maxil-
lofac Implants* 2008;23:1128–1132.
41. Pommer B, Unger E, Sütö D, Hack N,
Watzek G. Mechanical properties of the
Schneiderian membrane in vitro. *Clin
Oral Implants Res* 2009;20:633–637.
42. Yilmaz HG, Tözüm TF. Are gingival phe-
notype, residual ridge height, and mem-
brane thickness critical for the perforation
of maxillary sinus? *J Periodontol* 2012;
83:420–425.
43. Vlassis JM, Fugazzotto PA. A classi-
fication system for sinus membrane
perforations during augmentation pro-
cedures with option for repair. *J Peri-
odontol* 1999;70:692–699.
44. Fugazzotto PA, Vlassis J. A simplified
classification and repair system for sinus
membrane perforations. *J Periodontol*
2003;74:1534–1541.
45. Chen L, Cha J, Chen H-C, Liang Lin H.
Sinus perforation: Treatment and clas-
sifications. *J Implant Advan Clin Dent*
2011;3:19–30.
46. Pikos MA. Maxillary sinus membrane re-
pair: Update on technique for large and
complete perforations. *Implant Dent*
2008;17:24–31.
47. Shlomi B, Horowitz I, Kahn A, Dobriyan
A, Chaushu G. The effect of sinus mem-
brane perforation and repair with Lam-
bone on the outcome of maxillary sinus
floor augmentation: A radiographic as-
sessment. *Int J Oral Maxillofac Implants*
2004;19:559–562.
48. Karabuda C, Arisan V, Özyuvaci H.
Effects of sinus membrane perfora-
tions on the success of dental implants
placed in the augmented sinus. *J Peri-
odontol* 2006;77:1991–1997.
49. Hernández-Alfaro F, Torradeflot MM,
Marti C. Prevalence and management
of Schneiderian membrane perforations
during sinus-lift procedures. *Clin Oral
Implants Res* 2008;19:91–98.
50. Testori T, Weinstein RL, Taschieri S, Del
Fabbro M. Risk factor analysis following
maxillary sinus augmentation: A retro-
spective multicenter study. *Int J Oral
Maxillofac Implants* 2012;27:1170–1176.
51. Breine U, Brånemark PI. Reconstruction
of alveolar jaw bone. *Scand J Plast Re-
constr Surg* 1980;14:43–48.
52. Ardekian L, Oved-Peleg E, Mactei EE,
Peled M. The clinical significance of si-
nus membrane perforation during aug-
mentation of the maxillary sinus. *J Oral
Maxillofac Surg* 2006;64:277–282.
53. Oh E, Kraut RA. Effect of sinus mem-
brane perforation on dental implant in-
tegration: A retrospective study on 128
patients. *Implant Dent* 2011;20:13–16.
54. World Medical Association Declaration
of Helsinki: Ethical principles for medi-
cal research involving human subjects.
JAMA 2000;284:3043–3045.
55. Scala A, Botticelli D, Rangel IG Jr, et
al. Early healing after elevation of the
maxillary sinus floor applying a lateral
access: A histological study in mon-
keys. *Clin Oral Implants Res* 2010;21:
1320–1326.
56. Jungner M, Cricchio G, Salata LA, et al.
On the early mechanisms of bone for-
mation after maxillary sinus membrane
elevation: An experimental histologi-
cal and immunohistochemical study.
Clin Implant Dent Relat Res 2015;17:
1092–1102.
57. Gruber R, Kandler B, Fuerst G, Fischer
MB, Watzek G. Porcine sinus mucosa
holds cells that respond to bone mor-
phogenetic protein (BMP)-6 and BMP-7
with increased osteogenic differentiation
in vitro. *Clin Oral Implants Res* 2004;15:
575–580.
58. Palma VC, Magro-Filho O, De Oliveria
JA, Lundgren S, Salata LA, Sannerby
LO. Bone reformation and implant in-
tegration following maxillary sinus mem-
brane elevation: An experimental study
in primates. *Clin Implant Dent Relat Res*
2006;8:11–24.
59. Kim SW, Lee IK, Yun KI, Kim CH, Park JU.
Adult stem cells derived from human
maxillary sinus membrane and their os-
teogenic differentiation. *Int J Oral Max-
illofac Implants* 2009;24:991–998.
60. Srouji S, Kizhner T, Ben David D,
Riminucci M, Bianco P, Livne E. The
Schneiderian membrane contains os-
teoprogenitor cells: In vivo and in
vitro study. *Calcif Tissue Int* 2009;
84:138–145.
61. Srouji S, Ben-David D, Lotan R, Rimi-
nucci M, Livne E, Bianco P. The innate
osteogenic potential of the maxillary
sinus (Schneiderian) membrane: An ec-
topic tissue transplant model simulating
sinus lifting. *Int J Oral Maxillofac Surg*
2010;39:793–801.
62. Timmenga NM, Raghoobar GM, Liem
RS, et al. Effects of maxillary sinus floor
elevation surgery on maxillary sinus
physiology. *Eur J Oral Sci* 2003;111:
189–197.
63. Griffo A, Berrone M, Boffano P, Viterbo
S, Berrone S. Mucociliary function dur-
ing maxillary sinus floor elevation. *J Cra-
niofac Surg* 2010;21:1500–1502.
64. Onişor-Gligor F, Lucaci O, Câmpian
R, Oană L, Gheban D, Florea A. Exper-
imental study on histological changes in
the sinus membrane following sinus lift.
Rom J Morphol Embryol 2011;52:1293–
1297.
65. Zhong W, Chen B, Liang X, Ma G. Ex-
perimental study on penetration of
dental implants into the maxillary si-
nus in different depths. *J Appl Oral Sci*
2013;21:560–566.
66. Froum SJ, Khoully I, Favero G, Cho SC.
Effect of maxillary sinus membrane per-
foration on vital bone formation and
implant survival: A retrospective study.
J Periodontol 2013;84:1094–1099.
67. Nooh N. Effect of schneiderian mem-
brane perforation on posterior maxillary
implant survival. *J Int Oral Health* 2013;
5:28–34.