

Osteotome-Mediated Sinus Floor Elevation: A Clinical Report

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Purpose: It was the aim of the present study to clinically evaluate the success of osteotome-mediated sinus floor elevation (OMSFE) using autogenous and xenogenic bone and a variety of screw-type implants. **Materials and Methods:** From August 1995 to February 2003, 276 OMSFE procedures with simultaneous implant placement were completed in 167 patients. **Results:** The mean residual bone height (RBH) of the alveolar ridge was 7.1 mm (range 3 to 10 mm). The mean increase in height of the implant sites using osteotome techniques was 3.8 mm (range 2 to 7 mm). Of the 276 implants placed, 240 had been loaded for an average of 27.9 months (range 1 to 84 months). There were a total of 18 failures: Ten implants failed to integrate, 3 implants were lost within the first 18 months of loading, 1 implant fractured after 3 years in function, and 4 implants demonstrated excessive bone loss. The overall survival rate was 93.5%. When only sites with an RBH of 4 mm or less were considered, the survival rate dropped to 73.3%. Small tears in the schneiderian membrane were clinically assessed at 13 sites, for a detectable perforation rate of 4.7%. **Discussion:** The primary determinant in implant survival with OMSFE procedures was the height of the residual alveolar ridge. Implant design, graft material, and the method of sinus floor infraction (direct or bone-cushioned) exerted minimal influence on survival outcome; however, factors such as edentulism, osteoporosis, and an overdenture prosthesis were shown to negatively influence postloading survival of implants placed in areas of limited RBH. **Conclusion:** OMSFE procedures can be used predictably for implant placement at sites with moderate vertical deficiencies in the posterior maxilla. *INT J ORAL MAXILLOFAC IMPLANTS* 2004;19:266–273

Key words: dental implants, infraction, osteotome, perforation, primary stability, sinus floor elevation, sinus membrane

In the posterior maxilla, implant placement is frequently complicated by unfavorable postextraction resorptive patterns, pneumatization of the maxillary sinus, and the often poor quality of the remaining alveolar bone.¹ Implant success and primary stability are greatly affected by localized bone density,² with implants placed in areas of poorer bone quality associated with higher failure rates.^{3–5} However, these published results have been based on implants placed according to the manufacturer's standard drilling recommendations. Conventional surgical protocol, in which drills of increasing diameter are used, calls for the removal of the existing bone and does not enhance cancellous bone quality. Modifications to

traditional placement protocol to increase success rates in areas of reduced bone quality include the use of: (1) undersized osteotomies; (2) self-tapping implants with roughened (ie, bone-conductive) surfaces to enhance primary stability and bone-to-implant contact in poor-quality bone^{6,7}; and (3) osteotome techniques.^{8–14}

As an alternative to standard drilling, end-cutting osteotomes are used to gradually expand the osteotomy, compressing and apically displacing cancellous bone within the confines of the cortical plates and thus improving localized bone density.^{8,9} The improved density of the implant site enhances the implant's primary stability.¹⁵ The results of a recent animal study revealed that the benefit of the osteotome technique was an increased bone-to-implant contact ratio in the early phase after implant treatment.¹⁶ New bone formation was shown to begin earlier than after conventional implant placement.¹⁶ A clinical study by Glauser and associates¹⁷ has shown that the osteotome technique significantly improves the success rate of implants in type

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4 bone. In addition, osteocompression may allow implants placed in the posterior maxilla to be loaded earlier, with success rates comparable to those experienced using a traditional healing protocol.¹⁴

Osteotomes are also used as part of a minimally invasive technique to obtain a small localized elevation of the sinus floor.^{9,10,12,13,18,19} This technique involves a crestal approach, common to standard implant surgery, with little or no contact between the osteotomes and the schneiderian membrane, which reduces the risk of complications.¹⁸ When there is adequate bone for primary stabilization of implants, osteotome sinus floor elevation procedures allow for 2 to 7 mm of localized sinus floor elevation with simultaneous implant placement.^{9,10,12,13,18,19} Modifications have been made to Summers' bone-added osteotome sinus-floor elevation (BAOSFE) protocol¹⁰ to expedite the procedure, minimize malleting force, and simplify sinus floor fracture.^{18,19}

This article reports on the clinical success of osteotome-mediated sinus floor elevation (OMSFE) procedures using autogenous and xenogenic bone and a variety of screw-type implants placed from August 1995 to February 2003 by a single clinician.

MATERIALS AND METHODS

From August 1995 to February 2003, OMSFE with simultaneous implant placement was performed at 276 sites in 167 patients (96 women and 71 men) with a mean age of 56.8 years (range 27 to 82 years). Both partially and completely edentulous patients were included. All patients signed an informed consent form. Patients with systemic diseases exhibiting risk factors for surgical procedures, as well as patients with untreated periodontitis or sinusitis, were excluded. OMSFE was indicated at maxillary premolar and molar implant sites with a residual bone height (RBH) of 10 mm or less. The RBH was determined for each site by the author in a nonstandardized manner. A ruler or periodontal probe was used to ascertain this measurement from the preoperative periapical radiograph, rounding off to the nearest millimeter. After implant placement the sinus floor elevation was calculated as the difference between the length of the implant and the RBH.

For sinus floor augmentation, bovine bone mineral (Bio-Oss; Osteohealth, Shirley, NY, or PepGen P-15; Dentsply/CeraMed, Lakewood, CO) and autogenous bone harvested from the tuberosity or posterior mandible were used in various combinations (10% to 75% autogenous bone).

The distribution of the 276 screw-type implants was as follows:

- 23 machined screws, 3.25 to 5.00 mm in diameter and 10 to 13 mm in length (3i/Implant Innovations, Palm Beach Gardens, FL)
- 170 acid-etched screws, 3.25 to 6.0 mm in diameter and 8.5 to 15 mm in length (Osseotite and Osseotite NT, 3i/Implant Innovations)
- 63 TiO-blasted screws, 4 to 5 mm in diameter and 9 to 13 mm in length (Astra ST; Astra Tech, Lexington, MA)
- 20 stepped, root-form, etched screws, 3.8 to 6.5 mm in diameter and 10 to 13 mm in length (Frialit-2; Dentsply/Friadent).

A variety of system-specific osteotomes (Summers Osteotomes, 3i/Implant Innovations; Frialit-2 Bone Condensers, Dentsply-Friadent; Astra ST Osteotomes, Astra Tech) and site-specific, rapid-expansion limited-bone (RELB) osteotomes (H&H, Ontario, California) were used to prepare the osteotomy and lift the sinus floor.

Surgical Procedure

Treatment of the posterior maxilla was carried out under local anesthesia. Patients were instructed to take 2.0 g of amoxicillin or 600 mg clindamycin 1 to 2 hours prior to surgery. If the patient requested it, nitrous oxide and/or triazolam (0.25 mg) was also used. A beveled crestal incision was made with full-thickness flap reflection. If the decision was made to use a single-stage protocol, minor modification to the marginal tissues allowed for good adaptation around the healing abutment (25 sites). To secure proper alignment of the implants, a surgical template was used when available. The proposed implant site was first clearly marked with a 2.0-mm round drill followed by a 2.0-mm twist drill to a depth of 2.5 to 5 mm. A 2.0-mm guide pin was then placed to verify implant positioning relative to the planned restoration. 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. This position was confirmed radiographically after the osteotomy had been widened to 2 or 3 mm in diameter (Fig 1). Expansion of the osteotomy was carried out with a combination of drills and concave-tipped osteotomes based on residual bone density. Since February 2002 the author has used personally designed RELB osteotomes for localized sinus floor elevation and simultaneous implant placement in areas of limited bone height (4.0 to 8.0 mm). The RELB osteotomes are marked at 4, 5, 6, 8, and 10 mm, unlike system-specific

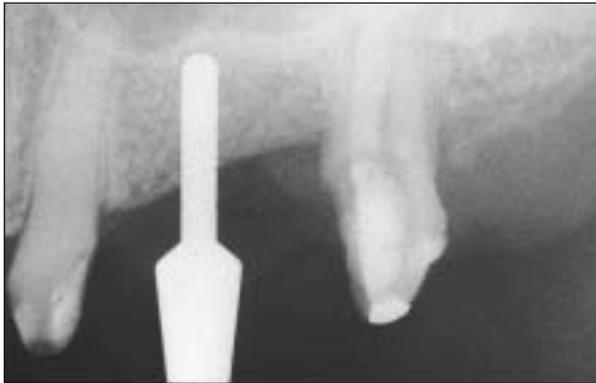


Fig 1 Radiographic confirmation of the working depth 1 to 1.5 mm from the sinus floor, with a 2-mm guide pin inserted at the site of the maxillary left first molar.

Fig 2 (Right) Osteotomy at the site of the maxillary left first molar after expansion with an osteotome and direct infraction of the sinus floor. The site is now ready for insertion of the collagen sponge and grafting.



Fig 3 Periapical radiograph taken immediately after direct sinus floor infraction with a 3-mm RELB osteotome. Note the localized apical displacement of the sinus floor.

osteotomes, which are marked at the corresponding implant lengths. RELB osteotomes with a 30-degree offset were used for first and second molar sites to improve access for ideal implant positioning.

After radiographic verification of ideal subsinus position, the osteotomy was gradually expanded in 0.5-mm increments using RELB 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. If a tapered implant was used, implant site preparation was modified based on intended implant length, degree of taper, and coronal implant diameter. Sinus elevation was delayed until the final apical diameter of the osteotomy had been achieved at the desired working depth. Sinus infraction was then initiated using one of the following methods.

- *Bone-Cushioned Sinus Floor Infraction.* This method was used in 136 sites from August 1995 through February 2001. Utilizing the technique reported by Davarpanah and associates,¹⁹ graft material was added to fill the fully prepared osteotomy, and the final osteotome was once again malletted to the working depth. This action compressed and apically displaced the column of bone, infracturing the sinus floor. If repeated malleting displaced the graft, but infraction had not been achieved, the graft plug was removed, additional apical preparation was performed with a 2.0- or 3.0-mm twist drill, and the grafting procedure was repeated.
- *Direct Sinus Floor Infraction.* This method was used in 140 sites from February 2001 through February 2003. Using the technique reported by Cavicchia and associates,¹⁸ the final osteotome punched out the cortical plate of the sinus floor with the adherent membrane (Figs 2 and 3). Immediately after infraction the implant site was tested for perforation of the sinus membrane by the Valsalva maneuver. A collagen sponge was then added to the osteotomy as “membrane insurance” and compressed apically prior to initiating the grafting procedure. This technique was used exclusively from February 2001 through February 2003.

After sinus floor infraction using one of the aforementioned techniques, columns of the graft mixture were added to the osteotomy and apically displaced to the working depth. Each 4.0- to 5.0-mm column of bone was used to create 1.0 mm of

localized sinus floor elevation. This procedure was repeated until adequate elevation was attained to accommodate the selected implant length. The osteotomy was then half-filled with the graft mixture in advance of implant placement. Periapical radiographs were taken immediately after placement to confirm graft containment (Fig 4).

Postoperative Care

Patients were maintained on preoperative antibiotics for an additional 5 days, and analgesic medications (600 mg ibuprofen or a combination of 7.5 mg hydrocodone and 325 mg acetaminophen) were prescribed. Fixed prostheses were immediately replaced to relieve the pontic area and avoid traumatizing the surgical site. Removable prostheses were relined and replaced 2 to 3 weeks postoperatively. Implants were allowed to heal for a minimum of 5 months prior to second-stage surgery. Healing abutments were placed if this additional surgery was required, and the implants were restored 2 to 4 weeks later. Prostheses included single-tooth restorations, multiple-unit implant-supported restorations, and overdentures. After prosthetic treatment all patients were seen every 3 to 6 months by a hygienist for periodontal and implant maintenance. At each maintenance visit the patients were examined by the author, and all implant sites were evaluated.

The criteria for implant survival were based not only on the implant being in function, but also on the modifications of Albrektsson and coworkers²⁰ success criteria proposed by Rosen and associates¹² in their retrospective analysis of implants placed using the BAOSFE technique. Evaluation was non-standardized, with the following criteria for survival:

1. The individual, unattached implant was immobile when tested clinically after removal of the prosthesis.
2. A nonstandardized radiograph demonstrated no evidence of peri-implant radiolucency.
3. Vertical bone loss, as measured on a nonstandardized radiograph, was less than 2 mm annually following the implant's first year of service.
4. There was no persistent or irreversible pain, infection, neuropathy, or paresthesia/anesthesia.

RESULTS

A total of 276 OMSFEs with simultaneous implant placement were performed in 167 patients. These procedures were accomplished at 13 second molar sites, 101 first molar sites, 117 second premolar sites, and 45 first premolar sites. The mean RBH of the alveolar crest was 7.1 mm (range from 3 to 10



Fig 4 Periapical radiograph taken immediately after placement of a 5 × 10-mm implant to confirm graft containment along with 3 to 5 mm of localized sinus elevation.

mm). The mean increase in height of the implant sites by the osteotome techniques was 3.8 mm (range 2 to 7 mm), regardless of the method used for sinus infraction or the grafting material. Of the 276 implants placed, 240 implants had been restored and in function for an average loading period of 27.9 months (range 1 to 84 months). A variety of implant lengths were used, including 8.5- to 9-mm implants (n = 16), 10-mm implants (n = 62), 11.0- to 11.5-mm implants (n = 145), 13-mm implants (n = 51), and 15-mm implants (n = 2).

Ten implants failed to integrate. Seven were lost because of early postoperative infection, 1 of the implants placed using a single-stage protocol developed mobility 4 weeks after placement, and 2 implants were mobile at uncovering. Of the 7 implants lost early because of infection, 2 implants were immediately placed at the time of extraction of periodontally hopeless teeth with simultaneous crestal augmentation, 1 implant was placed in a delayed approach 6 weeks after extraction of an endodontically involved tooth, 2 implants had simultaneous grafting as a result of dehiscence-type defects with subsequent ePTFE membrane exposure, 1 implant was adversely affected by a periapical infection in an adjacent tooth, and 1 implant was placed at a site with a sinus membrane perforation. Three implants were lost within the first 18 months of loading, and 1 implant fractured after 3 years in function. In addition, progressive bone loss has been noted at 4 implants in 2 edentulous, osteoporotic patients. Considering these 4 implants as failures, there would be a total of 18 failures out of 276 implants placed for an overall survival rate of 93.5%. Two patients had multiple failures of 3 implants each. Both patients were smokers (1 to 1.5 packs per day for 30 to 35 years) who had lost all their maxillary teeth because of advanced periodontal disease

Table 1 Failure Rate by Implant Type

Implant type	Total placed	Failures	
		n	%
Machined screws (3i)	23	3	13.0
Acid-etched screws (Osseotite, 3i)	170	9	5.3
TiO-blasted screws (Astra ST)	63	4	6.3
Stepped screws (Frialit-2)	20	2	10.0



Fig 5 A small tear in the schneiderian membrane (arrow) has occurred during the initial drilling procedures at the site shown.

and had been diagnosed with osteoporosis during the previous 2 years. These patients had been restored with maxillary overdentures. Of the 14 failed implants removed, 6 have been replaced and restored.

A summary of the failure rate for each implant type is seen in Table 1. The highest failure rate was noted with the machined screws (3 out of 23 implants). However, these were the first implants placed in the study and were negatively affected by operator inexperience with the procedure. After June 1997 machined implants were no longer used and were replaced with implants incorporating subtractive surface technology. Table 2 summarizes the failure rate of the implants by RBH. In sites with 4 mm or less, there was a survival rate of 73.3%. At locations with 5 mm or more RBH, the survival rate improved to 94.6%. Poorer survival rates were seen for the shorter (8.5- to 10-mm) implants, as these were placed at sites with the lowest RBH.

Small tears in the schneiderian membrane were clinically assessed in 13 patients, for a detectable perforation rate of 4.7% (Fig 5). The majority of these tears occurred during initial drilling procedures. At these sites a collagen sponge (Collacote;

Table 2 Failure Rate by Residual Bone Height

Residual bone height	Implants placed	Failures	
		n	%
4 mm or less	15	4	26.7
5 to 6 mm	78	4	5.1
7 mm or greater	183	10	5.5

Sulzer Medica, Carlsbad, CA) was placed in the final osteotomy in advance of an implant that was 2 to 3 mm longer than the measured RBH. As of 2002, no particulate graft material had been placed at any site with a confirmed tear. A mild degree of postoperative nasal bleeding occurred in one of the patients with a membrane perforation.

DISCUSSION

The BAOSFE procedure and reported modifications have proven to be efficacious techniques in managing moderate vertical deficiencies in the posterior maxilla.^{10,12,18,19} The technique most often utilized in the present study closely resembles the localized sinus lift reported by Cavicchia and associates.¹⁸ In that modification of the BAOSFE procedure, a combination of drills and osteotomes was used to prepare the osteotomy, followed by direct infracture of the sinus floor with the final osteotome. A resorbable collagen sponge was then introduced into the osteotomy and advanced apically to the level of the sinus floor. Implant placement was preceded by the placement of autogenous bone into the osteotomy. However, in the present study, autogenous bone was used in various combinations with xenogenic bone in amounts proportional to the degree of sinus floor elevation.

Summers¹⁰ and Davarpanah and colleagues¹⁹ achieved sinus floor infracture by using a “bone-cushioned” approach, applying pressure on the grafted material interposed between the tip of the osteotome and the sinus floor. It was hypothesized that hydraulic pressure was created which safely fractured the floor and initiated localized membrane elevation without direct osteotome–sinus floor contact. In the author’s experience, as well as that reported by Cavicchia and colleagues,¹⁸ this approach can often prove to be impractical unless the bone is extremely soft and there is no definite sinus floor. Unless the osteotomy has uniformly been prepared to 1 mm or less from the sinus floor, repeated, forceful malleting is required to apically advance the graft plug and displace the sinus floor.

Frequently the graft mixture needs to be removed and additional apical drill preparation performed. For the less experienced clinician, direct infracture would increase the risk of membrane perforation, but as one becomes more familiar with the tactile and auditory changes associated with sinus floor encroachment, modification of the applied malleting force results in a more controlled infracture. The combination of drills in the initial expansion of the osteotomy in denser bone and direct infracture of the sinus floor has proven to be the most expeditious and “patient-friendly” approach to OMSFE.

Frequently, several sets of osteotomes from different manufacturers are required to perform osteotome sinus floor elevation at sites with a limited RBH of 3 to 7 mm. The rapid-expansion principle employed with a single set of RELB osteotomes simplifies sinus floor elevation at sites with more limited RBH. Stops may be attached to the osteotomes to limit apical preparation and avoid rapid infracture, overinsertion, and concurrent membrane perforation. Access to first and second molar sites is very often limited with straight osteotomes and can result in less-than-ideal axial inclination of the implant. Osteotomes designed with 60- to 90-degree offsets improve access, but the magnitude of apical forces and tactile sensitivity are significantly diminished because of flexing. RELB osteotomes have also been designed with a 30-degree offset to provide adequate access without sacrificing tactile sensitivity or instrument stability (Fig 6). Based on clinical experience, an osteotome with 30-degree offset is recommended at first and second molar sites to improve access, idealize implant positioning, and deliver maximal controlled force.

The results of the present study would indicate that implant type, graft material selection, and method of sinus floor infracture appear to be inconsequential in relation to the height of the remaining subsinus alveolar bone in predicting implant survival with OMSFE procedures. Initial fixation of the implant is derived solely from the residual alveolar ridge; therefore, a minimum of 5 mm of preoperative bone height has been suggested.¹⁰ An RBH of less than 4 mm is associated with reduced primary implant stability.^{21,22} This might explain the low survival rate of 73.3% noted here for implants placed in areas with 4 mm of RBH or less. The survival rate improved to 94.6% in patients with at least 5 mm RBH. In a multicenter study of 147 implants placed with the BAOSFE procedure, an overall survival rate of 95.4% was obtained.¹² When implants placed at sites with less than or equal to 4 mm of RBH were considered, survival declined to 85.7%.¹² Other reports have demonstrated similar



Fig 6 Offset osteotomes (30 to 90 degrees) at the first and second molar sites. The more efficient 30-degree RELB osteotome is in the center position.

findings with an RBH of less than 5 mm.^{18,23} In cases of severely resorbed maxillae, minimally invasive sinus floor elevation with simultaneous implant placement using osteotomes does not seem to be the method of choice.²³ A 2-stage procedure using a lateral window technique^{24,25} or a crestal core approach^{26,27} would be preferred.

In areas of limited RBH, primary stability of the implant is clearly critical to implant success, as the added graft material used to displace the sinus floor does little to improve initial implant fixation. But to what extent does localized “tenting” of the sinus floor (Fig 7) increase implant support and long-term survival? The amount of graft material delivered via OMSFE is generally limited in comparison to the peri-implant graft volume attained with a lateral approach.²⁸ In endoscopically controlled osteotome sinus floor elevation, only 0.5 mL of graft material was required to achieve an average of 3.0 mm sinus elevation.²³ With a lateral window technique, an average graft volume of 3.50 ± 1.33 mL was necessary to place an implant of 13 mm in length in site with an RBH of 5 mm.²⁹

Reiser and associates³⁰ demonstrated in human cadavers that the sinus membrane can be domed predictably without perforation by progressively adding graft material utilizing the BAOSFE procedure. When several implants were placed, a continuous membrane doming could be achieved.³⁰ This argues for the utilization of graft material to vertically and horizontally displace the sinus floor for broader augmentation. Using solely a resorbable collagen sponge to tent the sinus membrane would most likely result in membrane collapse and the formation of a thin peri-implant sheath, which would do little to provide functional implant support. Doming or oblique packing of graft material would

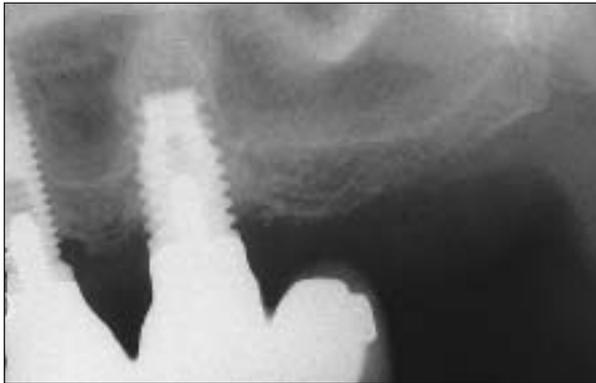


Fig 7 Four-year postloading radiograph at the maxillary left second premolar site reveals a thin peri-implant sheath of graft material alongside the apical third of the implant, with graft tenting at the apex. Support for this implant would be primarily derived from the residual alveolar bone (restorative treatment by Dr Frank Petronella, New York, NY).



Fig 8 Radiographic evidence of migration of graft material into the sinus cavity at a site with small membrane perforation. Note the irregular appearance of the apical graft margin, indicating poor containment.

contribute more to long-term implant stability than membrane tenting.

As a crestal osteotome approach involves a blind elevation of the sinus floor, the incidence of membrane perforation, detectable or nondetectable, is a concern. The extent to which the sinus floor can be safely elevated prior to tearing using an osteotome technique is not clearly defined and is probably a function of localized anatomy, membrane quality, and operator experience. A detectable perforation rate of 4.7% (13 sites) has been reported here, although some small perforations might not have been detected. Membrane integrity is usually verified by having the patient perform a Valsalva maneuver. The validity of this test was recently been questioned by Nkenke and associates²³ in a study on endoscopically controlled osteotome sinus floor elevation. A perforation that was visible by endoscopy was related to a negative Valsalva maneuver, showing the limited effectiveness of this test. This study has prompted the use of a resorbable collagen sponge to initiate sinus membrane elevation and seal any small tears undetected by the Valsalva maneuver test prior to particulate grafting. Displacement of graft material through the sinus membrane (Fig 8) is a great concern, as it can lead to transient or chronic sinusitis in 10% to 20% of sinus elevation cases, prompting the need for additional treatment.³¹⁻³³

Boyne³⁴ reported that implants protruding 2 to 3 mm directly into the antrums of rhesus monkeys had complete spontaneous regeneration of bone over the entire surface. When these implants protruded up to 5 mm into the antrum, only partial growth of bone occurred at the implant apex. Bauermann and Ewers³⁵ reported spontaneous recovery

of slight membrane perforation after implant placement. Based on these 2 studies, Reiser and colleagues³⁰ speculated that it is possible for minor perforations to be obturated in vivo as a result of combined bone graft and blood clot stabilization. Based on these studies as well as clinical experience, the author has established a “perforation protocol.” When a perforation is suspected or has been clinically verified, no particulate grafting material is used, and a collagen sponge is introduced in advance of an implant. In the instance of a small membrane tear, the collagen sponge is not easily displaced and may even act as a barrier between the sinus and the implant site.¹⁸ An implant no more than 2 to 3 mm longer than the original subsinus bone height is then placed. If this does not allow for placement of an implant of adequate length (8.5 mm or more), then the site is abandoned and implant placement is delayed for 3 months.

CONCLUSION

The primary factor in predicting implant survival using OMSFE procedures is the residual height of the alveolar ridge and its ability to stabilize the implant. The implant type or proportion of autogenous grafting materials to xenogenic grafting materials utilized in this study were found to have little influence on implant survival; however, other factors, such as edentulism, osteoporosis, and overdenture prostheses, may negatively influence the postloading success of implants placed in areas of limited RBH in the posterior maxilla.

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