

Continuing Education 1

The Maxillary Sinus: Challenges and Treatments for Implant Placement

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LEARNING OBJECTIVES

- describe sinus lift techniques.
- discuss the clinical situations in which to apply sinus lift techniques.
- describe complications of sinus lift techniques.

ABSTRACT

Standard implant placement in the posterior maxilla is often limited by the lack of vertical bone height due to the pneumatization of the sinus cavity. Several techniques have been developed to enter this cavity and elevate the membrane to enable implant placement. These methods may involve the use of bone grafts and membranes, as well as concurrent implant placement. This article reviews the clinical situations in which to apply these sinus lift techniques, complications, and success rates.

In the 1960s, in a lecture cycle of the US Navy postgraduate dental course, Philip Boyne suggested bone grafting of maxillary sinus in order to increase the interarch distance, which is complicated in long-standing edentulous cases due to the atrophic sinus pneumatization. He recommended the lateral window (LW) approach: Caldwell-Luc technique, elevation of Schneiderian membrane, and use of particulate autogenous bone graft.¹ Tatum in 1986 and Boyne in 1995 introduced these cases. With more research and experience, their techniques remain pertinent today.^{2,3}

The osteotome technique, which is less invasive for sinus floor elevation, was introduced by Robert Summers at the 1993 meeting of Academy of Osseointegration, followed by the publication of four articles describing its applications.⁴⁻⁷ Throughout the years, many clinicians have modified this procedure.

Various treatments for implant placement in the compromised posterior maxilla are available (Table 1).⁸ Among these are the placement of shorter implants, placement of tilted implants mesially or distally to the sinus cavity, elongated zygomatic implants in the lateral part of the zygomatic bone, and sinus floor elevation with a one-stage technique using a transalveolar approach (osteotome method), two-stage approach using osteotomes, a one-stage technique using a LW approach, or a two-stage technique with a LW approach, followed by implant placement after a healing period.

ANATOMY OF THE MAXILLARY SINUS

The maxillary sinus is the largest paranasal sinus. It is pyramidal, with the base lying vertically on the medial surface of the lateral nasal wall. The sinus floor is 5 mm to 12.5 mm below the floor of the nose. The dimensions are 15 cc to 20 cc for volume, 32 mm to 34 mm for length, 28 mm to 37 mm for height, and 23 mm to 25 mm for width. The maxillary sinus is surrounded by six bony walls,⁹ and its enlargement is termed *sinus pneumatization*. The sinus floor expands with age and is often in close relationship with the apices of the maxillary molars and premolars. With tooth loss, the antrum further expands and the sinus may join the crest of the residual alveolar ridge.¹⁰

The septa may divide the sinus. A variable number of septa, referred to as Underwood's septa, has been reported with a prevalence of 32% in the atrophic/edentulous maxillary segment and 23% in the non-atrophic/dentate maxillary segment with a mean height of 7.9 mm. Commonly, the septum is between second premolar and first molar.^{11,12}

OSTEOTOME TECHNIQUE

The osteotome technique can help clinicians avoid employing an extensive surgical procedure (atraumatic vs LW or drilling),

and this approach can be performed simultaneously with implant placement. The disadvantages are the uncertainty of possible perforation of the sinus membrane, ridge fracture (extremely narrow ridge), and patient discomfort (tapping). This approach is indicated for a flat sinus floor, when residual bone height is at least 5 mm, and when crestal bone width is adequate for implant installation. The osteotome technique is contraindicated in patients with a history of inner ear complications and vertigo and for an oblique sinus floor ($> 45^\circ$ inclination). There is no drilling, and approximately 3 mm to 5 mm of additional bone height can be achieved. The osteotome is pushed apically, laterally displacing the buccal and palatal bones, while the concave tip with a sharpened end of the osteotome pushes bone apically. The instrument is tapered to allow successive osteotome placement.⁸

Summers describes the ridge expansion osteotomy technique. Each subsequent osteotome fits into the site prepared by the previous osteotome until lateral ridge expansion is achieved. A minimum ridge width of 3 mm is required for the osteotome technique. The technique allows more implants to be placed in a narrower ridge in anterior and posterior sites. The approach is less invasive and has fewer risks compared to split crest and bone spreading.^{9,11} Summers describes the less invasive methods of elevating sinus floor in which bone is added to the original osteotomy sinus floor elevation (OSFE).¹⁰ The osteotomy is prepared to within 1 mm to 2 mm of the sinus floor, then widened with the Nos. 2 and 3 osteotomes. Bone is placed into the osteotomy, and the osteotome is advanced with light malleting (no more than 2 mm). More bone is added, and the procedure is repeated at least three times. When the sinus floor is displaced and the graft is freely moving, the implant is tapped into place and acts as the final osteotomy.¹⁰ The future site development technique is used when less than 6 mm of bone is between the crest and floor and for augmentation in wider sites. The osteotomes *never* enter the sinus. A trephine may be used to create a cut in the bone, short of the sinus floor. The tapping of the "bone plug" inward follows. After the bone plug is slightly moveable, the site is "backfilled" with bone graft material and lightly malletted.¹¹

BONE GRAFT—IS IT NECESSARY?

In an animal study by Boyne,¹³ implants protruding into the maxillary sinus following elevation of the sinus membrane without grafting material exhibited spontaneous bone formation over more than half of the implant's height. The implant design and extent of protrusion influenced the amount of bone formation. Implants with open apices or deep threads had small amounts of new bone growth. Those with rounded apices showed spontaneous bone formation extending around the implants if they only penetrated 2 mm to 3 mm into the maxillary sinus. However, when the same implants penetrated 5 mm into the maxillary

sinus, only a partial (50%) growth of new bone was seen toward the implant apex. This is still pertinent today with different implant surfaces and designs available that will continue to evolve.

WHAT TYPE OF GRAFT?

Researchers of a multicenter retrospective study with 174 implants in 101 patients examined the influence of the grafting material used and found that the type of the grafting material did not affect implant survival. When residual bone height was > 5 mm, the survival rate was 96%. However, when residual bone height was 4 mm or less, the rate decreased to 85.7%.¹⁴ Using the osteotome technique, Brägger and coworkers¹⁵ investigated the patterns of tissue remodeling after the placement of 25 implants in 19 patients. Composite xenografts and autografts were employed. They concluded that the grafted area apical to the implants underwent shrinkage and remodeling and the original outline of the sinus was eventually consolidated and replaced by a new cortical plate. In another study by Leblebicioglu et al,¹⁶ implants were installed into the sinuses of 40 patients using an osteotome technique with no graft or cushion materials; a mean gain of alveolar bone height in scanned panoramic radiographs of $3.9 \text{ mm} \pm 1.9 \text{ mm}$ was found. Pjetursson et al¹⁷ and Tan et al¹⁸ found that when no grafting material was used, some dense structure was often visible apical to the implant, immediately after implant placement. However, after at least 1 year of remodeling, this structure may no longer be detectable and only a moderate amount of bone gain mesially and distally may persist. The researchers also determined that when grafting material is used, a cloudy dome-shaped structure with a hazy demarcation may be visible after implant placement. This size is usually reduced after remodeling but still provides a definite increase in bone volume compared to the preoperative situation.

COMPLICATIONS

Perforation of the Schneiderian membrane is the most common complication of sinus elevation. However, a perforation is not

a contraindication to the augmentation. The best treatment is avoidance of a perforation, but perforations do occur and must be corrected.¹⁹ Rosen et al¹⁴ found that a minimum preoperative ridge height of 5 mm is necessary to achieve adequate elevation of sinus without undue risk of perforation (OSFE with bone). After examining 588 patients, Ferrigno et al²⁰ observed three perforations of the sinus membrane (perforation rate of 2.2%). Tan et al¹⁸ concluded that this was the most frequently reported complication, occurring in 3.8% of the procedures.

SUCCESS AND IMPLANT SURVIVAL

Several authors have examined the success and implant survival after insertion using the OSFE technique. They do not compare survival/success rates of implants placed in sites requiring the osteotome technique versus not requiring the site preparation. Ferrigno et al studied the survival and success rates of 588 implants placed in 323 consecutive patients, with a residual bone height from 6 mm to 9 mm.²⁰ After a mean observation period of 5 years, they found rates of 94.8% and 90.8%, respectively. They concluded that the installation of short implants in conjunction with OSFE is predictable and may reduce the indications for more invasive and complex procedures, such as the sinus floor elevation by the lateral approach. The systematic review by Tan et al¹⁸ yielded 19 studies on implants placed in transalveolar sinus floor augmented sites. The inclusion criteria for each study included a mean follow-up of at least 1 year of functional loading and a minimum of 10 patients. Of the 4388 implants placed, 103 were lost, of which 55 implants were lost before loading and 28 implants were lost after at least 1 year of function. This resulted in a survival rate of 92.8% after 3 years of function. If residual bone height was less than 8 mm, the survival rate decreased to 91.8%. The postoperative complications outlined in this review were graft infection (most common with a mean of 0.8%) hemorrhage, nasal bleeding, blocked nose, hematomas, and loosening of cover screws resulting in supuration.

SINUS FLOOR ELEVATION WITH LATERAL APPROACH

The lateral approach is also used for sinus floor elevation. It is indicated when there is reduced residual bone height, which does not allow standard implant placement or placement of implants in combination with minor sinus floor elevation using the osteotome technique (Figure 1 through Figure 3). Contraindications are

TABLE 1

General Guidelines for Sinus Floor Elevation

Vertical Bone Height	Surgical Procedure	Implant Placement
≥ 10 mm	None needed	Immediate
7 mm to 10 mm	Sinus floor elevation via osteotome technique	Immediate
5 mm to 7 mm	Sinus floor elevation via lateral window approach	Immediate
1 mm to 4 mm		Delayed



Fig 1.

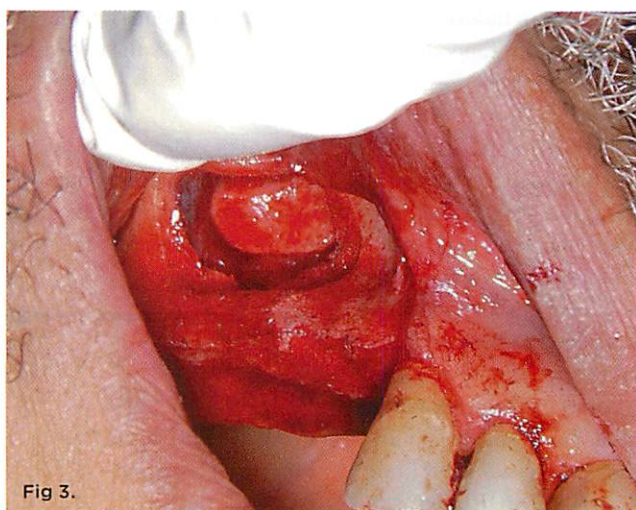


Fig 3.

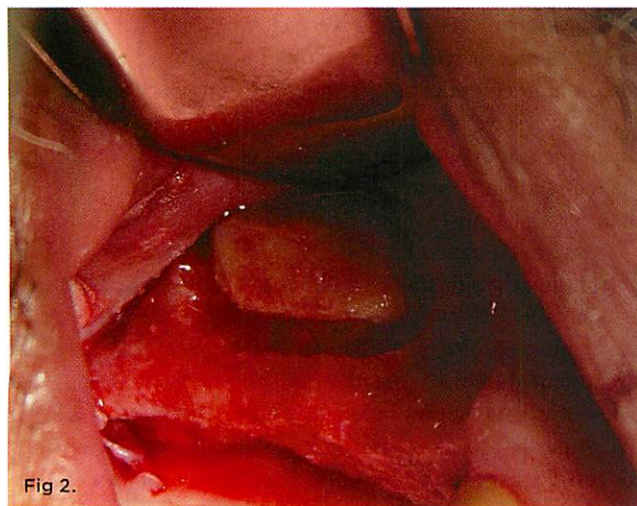


Fig 2.



Fig 4.

Fig 1. Elevation of the flap. Fig 2. Outline of the lateral window.

Fig 3. Elevation of the bony window. Fig 4. Placement of the graft.

excessive interarch distance due to unfavorable crown-to-root ratio, acute or chronic unresolved sinusitis, current sinus pathology (eg, cysts or tumors), lodged root tips in the sinus, history of heavy smoking, a systemic compromise, and psychological problems.

Premedication

The use of many drug combinations has been reported. Among these are amoxicillin 1 g or in the case of allergies, clindamycin 300 mg, both used 1 hour before surgery. If there is a history of chronic or periodic sinus infections, the use of Augmentin® (GlaxoSmithKline, www.gsk.com) 3 days before surgery and up to 7 to 10 days after surgery is recommended. Glucocorticoids (dexamethasone 8 mg) can be prescribed 1 hour beforehand.

One Stage or Two Stage?

The decision to use the one- or the two-stage technique is mainly based on the amount of residual bone available and the possibility of achieving primary stability for the inserted implants: one-stage sinus floor elevation with simultaneous implant placement and two-stage sinus elevation (delayed installation of the implant). The grafted site matures in approximately 6 to 10 months, according to Wallace et al²¹ (Figure 4 and Figure 5).

Fugazzotto and Vlassis²² reported a 97.7% success rate of sinus augmentations when they used the LW, LW with simultaneous implant placement, and the crestal approach. They reported a 97% success rate of implants placed in those sites. Also, the survival rate of implants in LW cases was increased when the crestal ridge height was > 3 mm. Jensen et al²³ found no significant

difference in failure rate when they compared sinus augmentation and simultaneous implant placement verses the two-stage delayed method.

What Kind of Graft?

The type of graft material and its effect on the success of the implants has been examined by many authors. In early studies, the autogenous bone graft was considered the gold standard.^{5,6} Froum et al²⁴ found that when as little as 20% of autogenous bone was added to the bone substitutes, xenografts alone or in combination with autogenous bone and/or demineralized freeze-dried bone allografts (DFDBA) had statistically significant increases in vital bone formation. The mean vital bone formation was 27.1% after healing for 6 to 9 months. Many authors have reported higher survival rates for implants placed into sinuses grafted with 100% xenograft as compared to those placed in sinuses grafted with 100% autogenous bone or composite graft xenograft and autogenous bone.²⁵⁻²⁷ Every bone grafting material has been used for sinus augmentation: DFDBA particulate,²⁸ anorganic bovine bone particulate,²⁴ nonresorbable hydroxyapatite,²⁹ autogenous block grafts,³⁰ rhBMP-2 collagen sponge,³¹ and tricalcium phosphate⁶ (Figure 6).

With or Without a Membrane?

The graft can remain exposed, be covered with a barrier membrane, or be covered with the preserved bone window. Tarnow et al³² performed a split-mouth design study with bilateral sinus grafts for 12 patients with or without covering the LW with a membrane. After 12 months, histologic samples were taken through the LW. The mean percentage of vital bone formation was 25.5% with and 19.9% without covering the barrier. Froum et al²⁴ examined 113 sinuses grafted with either xenograft alone or a composite of xenograft and autograft. The mean vital bone formation was 27.6% with a membrane and 16% without a membrane. Avera et al³³ and Wallace et al²¹ found that the use of resorbable and nonresorbable barrier membranes over LW and graft material aided in graft containment, prevented soft-tissue enucleation, and improved success rates. However, using a 100% autogenous bone versus autogenous bone as a component of a composite bone graft did not affect implant survival.

"The decision to use the one- or the two-stage technique is mainly based on the amount of residual bone available and the possibility of achieving primary stability for the inserted implants."

Is Smoking a Contraindication?

Mayfield et al³⁴ found an implant survival rate of 100% for non-smokers compared to 43% for smokers after 4 years to 6.5 years of loading for implants placed in combination with bone augmentations (horizontal, vertical, and sinus elevations). Similar reduced survival rates have been corroborated by several other authors.^{23,35}

Peleg et al³⁶ examined 2,132 implants after sinus floor elevation with simultaneous implant placement and found conflicting results. Of the 226 patients, floor elevations (627 implants) were performed for smokers and 505 sinus floor elevations (1,505 implants) for nonsmokers. The survival rate of the implants with up to 9 years' follow-up was 97.9%, with no statistically significant differences between smokers and nonsmokers.

Postsurgical

Drugs that are often prescribed are amoxicillin 500 mg tid or clindamycin 300 mg tid for 10 days, glucocorticoids (dexamethasone 4 mg for 2 days), ibuprofen 600 mg every 4 to 6 hours for pain if needed, and 0.12% chlorhexidine twice daily for 10 days (Figure 7).

Common complications are perforation of the sinus membrane, excessive bleeding from the bony window or the sinus membrane, injury of the infraorbital neurovascular bundle, implant migration, hematoma, adjacent tooth sensitivity, infection of the grafted sinuses, sinusitis, and sinus perforation.

Vlassis and Fugazzotto in 1999 described the following sinus perforation classification. *Class I:* Perforation is adjacent to the osteotomy site. This type of perforation will usually self repair when the membrane folds on itself following completion of elevation. Treatment should be considered when the perforation is still evident after membrane reflection. *Class II:* Perforation is in the mid-superior aspect of the osteotomy, extending mesiodistally for two thirds of the dimension of total osteotomy site. It usually occurs with the infracture design of the osteotomy. Repair and treatment are similar to Class I. *Class III:* Located at the inferior border of the osteotomy at its mesial or distal extent, a Class III perforation is the most common and usually caused by inadequacy of the osteotomy or improper execution of membrane reflection. Treatment is needed to repair the perforation, using a lamellar bone sheet to cover it. *Class IV:* A Class IV perforation is in the central two thirds of the inferior border of the osteotomy site. It is almost always caused by lack of care when preparing the osteotomy site and results in the perforation with the rotary instrument. Repair is similar to a Class III. *Class V:* A Class V perforation is a preexisting area of exposure of the sinus membrane caused by a combination of extensive pneumatization and severe ridge resorption. This is obvious only after flap reflection.³⁷

The infection of the grafted sinuses is rare, and the risk increases when a membrane is perforated. Sinus grafting and simultaneous implant placement should be avoided in situations of membrane perforation.²³

Sinusitis

Timmenga et al³⁸ evaluated the function of the maxillary sinus after LW sinus floor elevation. Out of 45 patients who had received 85 sinus grafts and underwent endoscopic examination, 5 patients received a diagnosis of sinusitis. The incidence of sinusitis was low and mainly found in patients with an anatomic or functional disorder prior to the sinus grafting. Tidwell et al³⁹ reported preoperative sinusitis was predictive of postoperative acute sinusitis.

SUCCESS OF THE LW TECHNIQUE

In the consensus Conference of the Academy of Osseointegration, retrospective data were collected from 38 clinicians. There were 1,007 sinus elevations were performed with 2,997 implants placed within 10 years. Most implants were followed for 3 years or more. There were 229 implants lost, resulting in an overall average survival rate of 90%. However, data amongst clinicians were variable depending on the implant type, length, grafting material, and timing of placement.²³ Wallace and Froum⁴⁰ published a systematic review for the effect of maxillary sinus augmentation on the survival of endosseous dental implants. The survival rate of implants placed using sinus lift with a lateral approach was 61.7% to 100% with an average of 91.8%. Rough-surfaced implants had better survival rates than machined-surface implants placed in grafted sinuses. In a systematic review by Pjetursson et al¹⁷ of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation, 48 studies were evaluated. Of these, 26 were prospective and 22 were retrospective and included approximately 4,000 patients between 15 and 86 years of age. The follow-up had to be at least 1 year after functional loading. The mean residual bone height at the site of implant placement was as much as 6 mm. The implants were placed simultaneously (one-stage) and delayed (two-stage) installation at 3 to 12 months after sinus grafting. The implant-based analysis showed that annual implant failure rate was 3.5%, resulting in a 3-year implant survival rate of 90.1%. The annual failure rate of machined-surface implants (6.9%) was significantly higher than that for rough-surface implants (1.2%). Perforation of the sinus membrane, the most frequently reported complication of the LW technique, occurred in 19.5% of the procedures. The mean incidence of postoperative graft infection was 2.9%. Graft loss resulting in the inability for implant placement was reported in 1.9% of cases.

SHORTER IMPLANTS

Recent clinical studies⁴¹⁻⁴³ on short implants (< or = 9 mm) with rough surfaces designed for high initial stability show survival rates of approximately 95%, which correlate with the survival rate reported for implants after 5 years in a systematic review

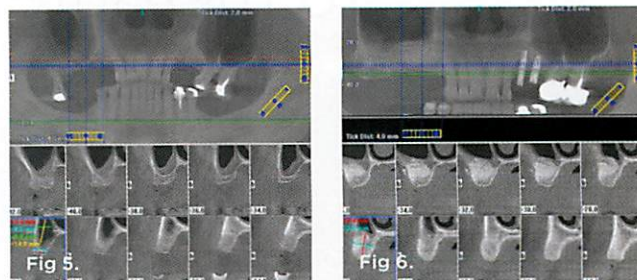


Fig 5. A cone-beam scan was performed prior to the lateral window sinus lift. **Fig 6.** A cone-beam scan was performed after the lateral window sinus lift. **Fig 7.** The graft after suturing.

by Berglundh et al.⁴⁴ However, there is no difference in survival rate of implants placed in maxilla versus mandible. Splinting and cross-arch stabilization are appropriate treatments. There is a 99% implant survival with 7-mm and 9-mm implants in posterior regions with splinting, as well with other biomechanical methods to decrease stress in implant-to-bone interface. For shorter implants, immediate loading in the maxilla can be successful with cross-arch stabilization.⁴⁵⁻⁴⁸

RECENT REVIEWS

More recent reviews have since been published commenting on the LW sinus lift procedure. Nkenke and Stelzle⁴⁹ found no clear reasons for a clinician to choose between autogenous bone and a bone substitute; their findings agree with those of Wallace and Froum in 2003.⁴⁰ Some believe that with an alveolar bone height of 3 mm to 6 mm, there would be fewer complications to sinus lift to 8 mm as opposed to performing a LW to 10 mm. Also, platelet-rich plasma does not improve the clinical outcome of the autogenous or bone substitute grafts.^{50,51}

CONCLUSION

The choice of a method (ie, short implants, osteotome technique, or lateral approach) should be based on the observed residual bone height of the alveolar crest and clinician's preference. Selecting less-invasive therapy (eg, the use of shorter implants) has been the trend; however, sinus elevation is the most predictable for vertical augmentation. With sinus elevation, there is no clinical difference with the type of graft material; however, the use of a membrane is recommended. Smoking is not an absolute contraindication to performing the sinus lift procedure. Based on the alveolar bone height of approximately 7 mm, the guideline for sinus elevation is < 7 mm for the LW and > 7 mm for the osteotome technique.

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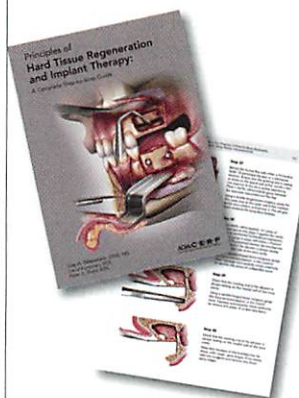
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The Maxillary Sinus: Challenges and Treatments for Implant Placement

By Georgios Tasoulis, DMD; Suellan Go Yao, DMD; and James Burke Fine, DMD

This article provides 2 hours of CE credit from AE GIS Publications, LLC. Record your answers on the enclosed answer sheet or submit them on a separate sheet of paper. You may also phone your answers in to (215) 504-1275 x 207 or fax them to (215) 504-1502 or log on to www.dentalaegis.com and click on "Continuing Education." Be sure to include your name, address, telephone number, and last 4 digits of your Social Security number.

- The maxillary sinus is surrounded by how many bony walls?
 - three
 - four
 - five
 - six
- The osteotome technique is contraindicated in patients with:
 - a history of inner ear complications.
 - vertigo.
 - an oblique sinus floor ($> 45^\circ$ inclination).
 - all of the above
- A minimum ridge width of how much is required for the osteotome technique?
 - 3 mm
 - 4 mm
 - 7 mm
 - 8 mm
- When the same implants penetrated how far into the maxillary sinus, only a partial (50%) growth of new bone was seen toward the implant apex?
 - 3 mm
 - 5 mm
 - 7 mm
 - 9 mm
- Rosen et al found that a minimum preoperative ridge height of how much is necessary to achieve adequate elevation of sinus without undue risk of perforation (OSFE with bone)?
 - 3 mm
 - 5 mm
 - 7 mm
 - 9 mm
- In early studies, which bone graft was considered the gold standard?
 - xenograft
 - freeze-dried bone grafts
 - alloplastic
 - autogenous
- Located at the inferior border of the osteotomy at its mesial or distal extent, which Class perforation is the most common and usually caused by inadequacy of the osteotomy or improper execution of membrane reflection?
 - II
 - III
 - IV
 - V
- Perforation of the sinus membrane, the most frequently reported complication of the LW technique, occurred in what percentage of the procedures?
 - 9.5
 - 19.5
 - 29.5
 - 39.5
- For shorter implants, immediate loading in the maxilla can be successful with:
 - implants placed in cancellous bone.
 - angled abutments to decrease stress.
 - cross-arch stabilization.
 - maximum loading of 57 newtons/mm implant length subgingivally.
- Platelet-rich plasma does how much to improve the clinical outcome of the autogenous or bone substitute grafts?
 - none
 - 10% increase in bone density
 - 20% increase in bone density
 - 30% increase in bone density

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