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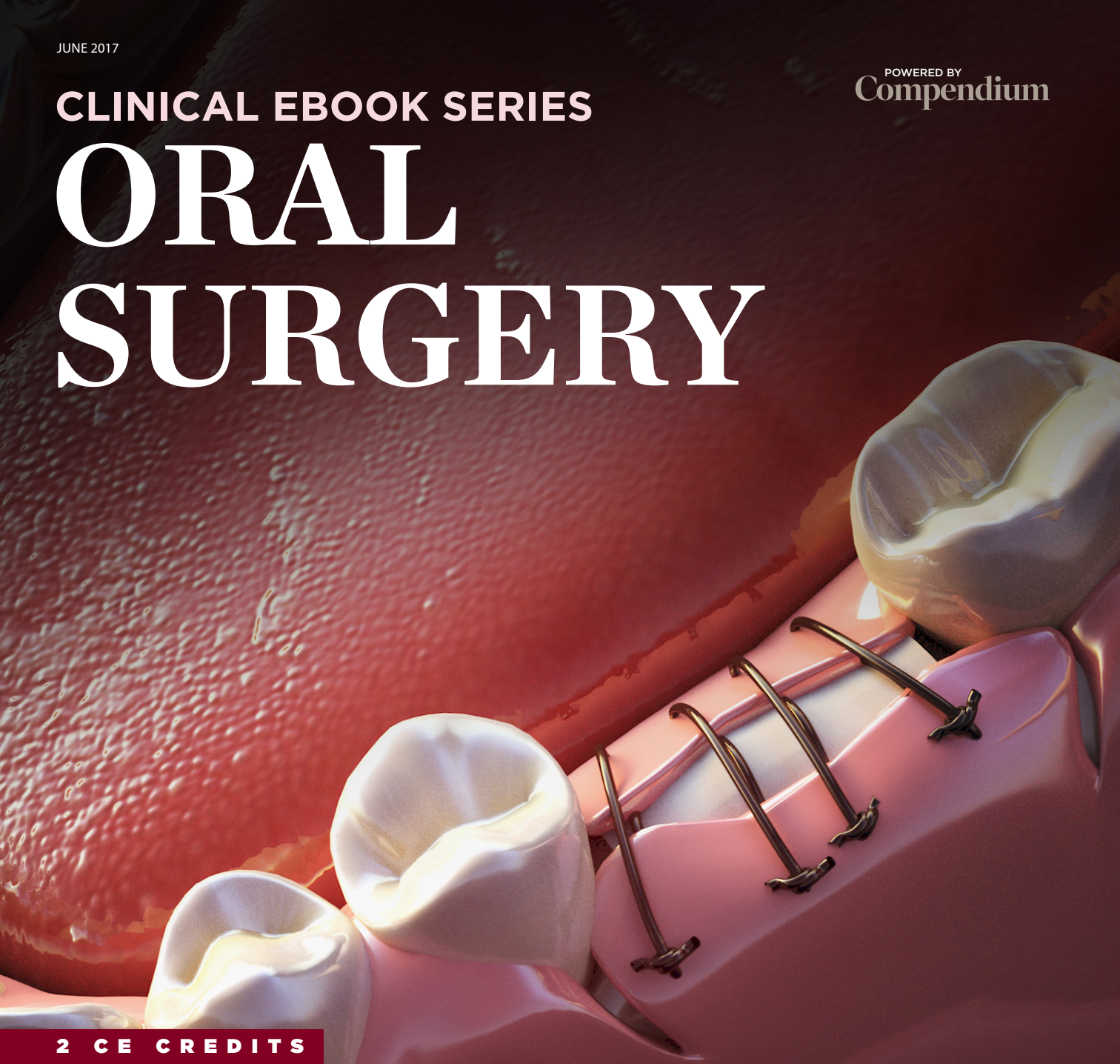

2 CE CREDITS

PERIODONTAL SURGERY

Gummy Smile and Short Tooth Syndrome

Simone Verardi, DDS, MSD; Marjan Ghassemian, BDS, DDS; Andrea Bazzucchi, DDS, MSD; and Antonello F. Pavone, DDS

2 CE CREDITS

SINUS LIFT

From Maximally to Minimally Invasive Surgery for Sinus Floor Augmentation

David Polak, DMD, PhD; and Lior Shapira, DMD, PhD

Approaches to Cases in Oral Surgery

Oral surgery is highlighted in this *Compendium* eBook, which features two continuing education articles and activities. The first article describes periodontal surgical approaches in interdisciplinary treatment of patients with a gummy smile and short tooth syndrome. The second article discusses the progression in dental techniques over time for sinus floor augmentation procedures, from maximally to minimally invasive surgery.

As Drs. Simone Verardi, Marjan Ghassemian, Andrea Bazzucchi, and Antonello F. Pavone explain in the first article, high smile lines are not uncommon in the adult population. Gummy smile and short tooth syndrome can be treated with different surgical approaches, depending largely on the case of each patient, such as the type of eruption that may be responsible for the problem. The authors describe different interdisciplinary approaches, including biological, restorative, and others. They stress that before undertaking any of these procedures, diagnostic protocol and treatment planning are crucial to avoid esthetic and periodontal failures.

The second continuing education article covers sinus floor augmentation, also known as sinus lift. Drs. David Polak and Lior Shapira discuss the biological and surgical concepts of sinus floor augmentation, which may be needed to enlarge bone volume for implants in the posterior maxillary region. They go on to explain the advantages and disadvantages of various procedures that have evolved for sinus floor augmentation, from maximally to minimally invasive surgery. Although minimally invasive procedures have become more prevalent, they require microsurgical skills and the right type of equipment. The authors emphasize the importance of knowledge and experience in performing any type of surgery.

further continuing education and more resources on oral surgery and other branches of dentistry.

Sincerely,
Louis F. Rose, DDS, MD
Editor-in-Chief

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Gummy Smile and Short Tooth Syndrome: Periodontal Surgical Approaches in Interdisciplinary Treatment

Simone Verardi, DDS, MSD; Marjan Ghassemian, BDS, DDS; Andrea Bazzucchi, DDS, MSD; and Antonello F. Pavone, DDS

ABSTRACT: One of the most frequent causes of gummy smile is an altered eruption, ie, the gingival margins are located at a more coronal position than normal. These cases can be successfully treated with a periodontal surgical approach. Several techniques may be used, depending on the different anatomic variations. The surgery must be carefully planned so as to avoid discrepancies between the soft tissues and the teeth. Clinical examination and radiographic evaluation will allow clinicians to determine the position of the gingival margin, bone crest, and cemento-enamel junction and thus elicit a correct diagnosis of the subtype of altered eruption. The periodontist will need to consider these factors in order to obtain a satisfactory outcome, especially in multidisciplinary cases.

LEARNING OBJECTIVES

- Explain the differences between two types of altered eruption: altered passive eruption and altered active eruption.
- Describe the biological and restorative approaches used in treating gummy smile and short tooth syndrome.
- Discuss the importance of exposing the cemento-enamel junction surgically when treating gummy smile cases.

Past and recent studies suggest that high smile lines (Figure 1) are present in a considerable amount of the adult population,[1] possibly affecting up to about 29% of patients.[2] In a previous article, the authors proposed a revised classification of the possible causes of gummy smile (GS) and short tooth syndrome (STS) and suggested a diagnostic process aimed at defining the etiological causes and correlating them to the responsible anatomical area(s).

When this condition is confined to the dental and/or periodontal structures, it is important to identify if the pink/white disproportion

recently, two types of altered eruption have been described: altered active eruption (AAE) and APE.[4]

APE is determined by the failure of passive dental eruption, giving rise to excessive gingival overlap on the anatomical crown of the tooth while the distance from the bone crest to the cemento-enamel junction (CEJ) remains normal. With AAE, there is primary failure of the active dental eruption phase, which results

DISCLOSURES: The authors had no disclosures to report.

Fig 1. Example of a patient with a gummy smile.

in the tooth failing to emerge sufficiently from the alveolar bone, thereby leaving the CEJ extremely close to the bone crest. This situation, in turn, would prevent apical migration of the gingiva during the passive eruption phase.[4]

The clinical analysis of the incisal margins, the localization of the CEJ, and radiographs can be used for diagnosing the intraoral causes of the disproportion. The presence of dental wear, however, does not necessarily exclude the simultaneous presence of an AAE or APE.

Once a precise diagnosis has been made, the goal of interdisciplinary treatment is to obtain the ideal coincidence of anatomical crown and clinical crown, the correct crown width/height proportion, and the ideal 3-dimensional positioning of incisal margin within the "smile stage."[5]

In treating GS and STS patients, the periodontist may adopt two different approaches that could be defined as biological or restorative. In the biological approach, the key objective is to reestablish the physiologic distance between the CEJ and gingival margin and, thus, between the CEJ and bone crest. Therefore, this kind of treatment is indicated for patients with gingival hyperplasia,[6] as well as AAE or APE. The therapeutic goal of the restorative approach is to improve smile esthetics only by obtaining a harmonious line of the gingival zeniths and by restoring correct proportions of the clinical crowns using crowns and bridges. When using this type of therapeutic approach, a series of compromises may have to be accepted, because final restorations recreate the restorative margin mimicking the CEJ in positions that may differ from their original anatomical positions. This approach is mainly indicated with fixed prostheses.

Surgical Indications and Technique

1. Biological Approach in Gingival Enlargement

The presence of a pseudopocket may confirm the presence of gingival hyperplasia.[7] Bone sounding with a periodontal probe under local anesthesia may help to measure the biologic width. The scope of the surgery entails reducing the amount of gingiva and placing the gingival margins at close proximity to the CEJ.[8] The most commonly used techniques are gingivec-[9] pically

2. Biological Approach in Altered Eruption

Sounding under local anesthesia will allow the clinician to differentiate between an active and a passive altered eruption, because these two conditions may coexist in the same area. The surgical guide is not absolutely necessary, because the amount of gingival scalloping is dictated by the position of the CEJ; this could be determined by extrapolating the dimension clinically and radiographically.

A paramarginal incision should be used if a wide band of gingiva is present and at least 2 mm of it would remain after scalloping; if a narrower band of gingiva is present, an intrasulcular incision should be used. The papilla will be incised at the base and be left in place. A full-thickness flap will be raised in cases in which an abundant quantity of gingiva exists; otherwise, a mixed flap will be preferred: full-thickness flap in the more coronal area and partial-thickness flap in the interdental and apical portions. After flap elevation, osteoplasty and

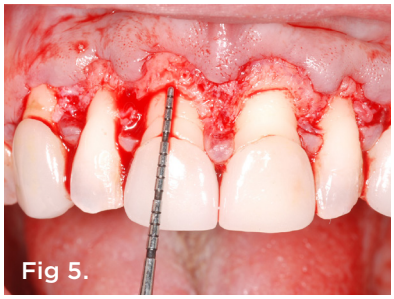


Fig 2. Orthodontic treatment with invisible appliances. **Fig 3.** Initial parasulcular scalloped incisions. **Fig 4.** Flap elevation pre-osseous resection. **Fig 5.** Surgical field after osteoplasty and ostectomy. **Fig 6.** Repositioning of the flap and interrupted suture. **Fig 7.** Healing after 3 months.

ostectomy can be performed. The ostectomy is carried out only in cases of AAE. This phase can be executed with surgical burs mounted on rotatory instruments, or piezoelectric surgical handpieces, which allow a more precise and less traumatic resective surgery.[11]

During the procedure, the surgical guide is repositioned in the mouth to assess if there is a constant and adequate distance between the osseous margins and the planned outline. After repositioning the flaps, an interdental 5.0 or 6.0 suture is placed. In cases in which a mixed flap is used, the flap is kept in place by suturing it to the underlying periosteum.

3. Surgical Technique in the Esthetic Restorative Approach

This approach is indicated in cases that require anterior crown lengthening surgery, where the CEJ can no longer be the reference point. In patients with anterior wear due to bruxism and parafunction, subsequent compensatory eruption can, in fact, result in irregular CEJ positions and a gingival zenith line instead of a regular parabolic or "W" line,[12] or when patients choose not to have orthodontic treatment.

Because the CEJ cannot be used as a reference, the surgical guide, which is fabricated according to the esthetic guidelines, has an important role during the surgery. The incision can be intrasulcular or paramarginal, depending on the amount of keratinized tissue present. In cases in which a paramarginal incision is used, it is important to leave at least 2 mm of gingiva.[13]

Flap elevation follows the same guidelines as the previous approach, leaving a distance of approximately 3 mm between bone margin and the surgical guide. The bone should have an ideal physiologic form, and the flaps are closed with vertical mattress sutures.

Biological Approach (Case 1)

In case 1 (Figure 2 through Figure 10), the main contributing factor to the gummy smile was AAE. After a thorough clinical and radiographic examination, the therapeutic approach was aimed at resolving the intraoral cause to offset the esthetic problem.

Invisalign® arch alignment (Figure 2) was used to resolve the Bolton discrepancy by


Fig 8.


Fig 9.


Fig 10.

Fig 8. Removal of the old veneer; note the aggressive preparation. **Fig 9.** Final veneer preparations after masking with flowable composite. **Fig 10.** Final smile.

expanding the upper and lower arches. This would result in upper incisor diastemas, which initially would emphasize the incisive lateral microdontia but would subsequently be restored with porcelain veneers.

A laboratory-made wax-up was used as the basis of the mock-up, which was carried out to define and study the final esthetics of the patient's smile. After making changes to the mock-up in consultation with the patient, a surgical guide was produced to indicate the surgical incisions to be made by the periodontist during the surgery.

Following anesthesia, a scalloped incision was made on the keratinized tissue (Figure 3). In the interproximal area, a papilla-sparing incision was made. A full-thickness flap was raised to give access to the underlying bone (Figure 4). Both osteoplasty and ostectomy were performed to position the bone crest approximately 2 mm to 3 mm from the CEJ (Figure 5). The gingival tissue was repositioned, coinciding with the initial labial incision and the interproximal papilla. Interrupted sutures were placed (Figure 6), which were removed 7 days following the surgery.

After healing (Figure 7), previous restorations were removed (Figure 8) and the existing preparations were modified; the laterals and canines were also prepared for veneers to the ideal biological position. Pigmented dentin (resulting from tetracycline use) was exposed once the previous restorations were removed, and the new preparations were finalized.

"Masking buildup" was performed (Figure 9), according to the concepts of immediate dentin sealing.[14] A slightly opaque veneer composite cement was used for cementation and to enhance the masking effect (Figure 10).

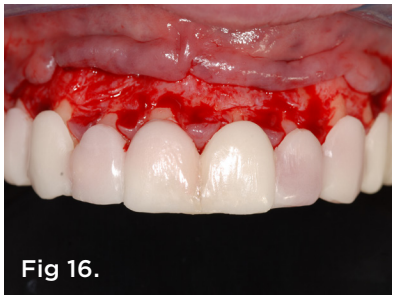
Restorative Approach (Case 2)

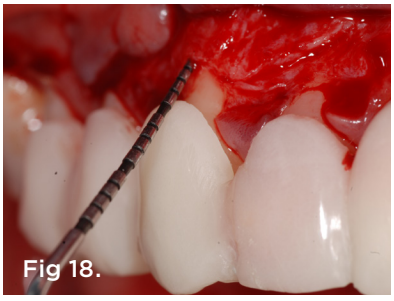
The patient who presented in this case (Figure 11 through Figure 20) had a history of bulimia nervosa. She had previously commenced treatment with another dentist but was dissatisfied with her dental esthetics (Figure 11).

The two central incisor crowns were replaced with new provisionals, and composite was used to restore her canines. Following this, fixed orthodontic therapy was started. The intention was to lingually displace and intrude the anterior teeth and reduce their torque (Figure 12).

The laboratory-made wax-up was used to produce the mock-up (Figure 13), which was aimed at creating the ideal form and proportions of the final restorations and reproducing the gingival zeniths.

A surgical guide was used for the anterior crown-lengthening procedure. It was intended to balance the width-to-height ratios of the teeth and to give an adequate biologic width for the two central incisors (Figure 14). The band of gingiva was preserved, and an intrasulcular incision was made (Figure 15). The flap was elevated, leaving an intact periosteum on the bone of the interdental spaces (Figure 16). The surgical guide was necessary during the bone resection (Figure 17), because there was no reference point. Ostectomy was per-





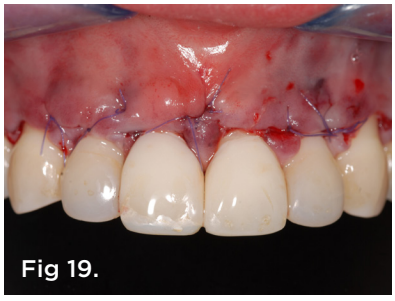


Fig 11. Patient's initial smile. **Fig 12.** Fixed orthodontic treatment after placement of provisional crowns on teeth Nos. 8 and 9. **Fig 13.** Indirect mock-up used to evaluate possible final results. **Fig 14.** Surgical guide fabrication based on the information obtained by clinical examination, mock-up, and radiographs. **Fig 15.** Intrasulcular incision. **Fig 16.** Flap elevation with full-thickness flap mixed with split-thickness flap. **Fig 17.** The surgical area after osseous resection. **Fig 18.** Surgical guide was used to check the appropriate amount of ostectomy. **Fig 19.** Sutures to stabilize flap repositioning.

formed to leave a distance of about 3 mm from the bone crest to the margin of the surgical guide (Figure 18). The flap was repositioned, and periosteal interrupted sutures were used to stabilize it (Figure 19).

The temporary crowns were replaced with single crowns, and porcelain veneers were used on the upper laterals and canines (Figure 20). Knife-edge preparations were used for the final restorations as they were situated on radicular surfaces of the teeth, though this would affect the adhesion of the restorations.[15]

Fig 20. Extraoral view of final result; note the marked reduction of the gummy smile.

Discussion

In GS cases in which the problem may be treated or compensated for with routine periodontal treatment, it is important to first diagnose the presence of an altered passive or active eruption.[3,4,16] The aim of the surgery is to restore the dimensions of the anatomical crown with respect to the gingival and osseous tissues, by exposing the portion of enamel surface covered by the gingiva. This is what the authors define as the "biological approach."

Distinction between active or passive altered eruptions is necessary, because as in the first case the surgery required both osteoplasty and ostectomy, whereas in the second case a gingivectomy may be sufficient.[17] Performing only a gingivectomy in areas of AAE would lead to failure of the treatment caused by reestablishment of the biologic width at the same position.[17]

Some authors suggest that esthetic and prosthetic reference points should be used to outline the surgical incision and also guide the quantity of ostectomy through a surgical guide.[18] Often though, asymmetrical wear of incisal margins, consequent asynchronous and asymmetrical compensatory eruption, and frequent possibility of altered eruption are observed. Surgically exposing the CEJ position is important. Orthodontic treatment aligns the teeth in their ideal positions, and, finally, the restorative phase is completed.

Therefore, when performing surgery with a biological approach, the correct reference point is not determined by the surgical guide but by the CEJ. The surgical guide may be used for the soft-tissue incision to transfer the information extracted from clinical and radiographic examinations and not from an esthetically or prosthetically guided stent.

Traditionally, the vertical parameters considered in orthodontic treatment—in relation to the lip line—were the posterior occlusal plane, gingival margins, crown lengths, and incisal plane.[19] Teeth were aligned in relation to their incisal margin, but this applies when no incisal wear has occurred. The gingival margin position was also considered[20]; vertical discrepancies were corrected without taking into consideration if altered eruption was present. This is why the authors propose the necessity of revealing the correct CEJ location with the biological approach.

Maintaining the preparations to within undercut-free areas, which conversely occurs when the preparations are made apical to the CEJ,[21] minimizes useless removal of tooth structure. The biological approach is favorable for prosthodontists because final adhesive restorations are placed on the enamel surface, improving the longevity on the restoration margin[22] and providing ideal profile and contour of the restoration and long-term periodontal health.

The restorative approach includes cases with previous crowns in which the CEJ can no longer be located, there are malaligned teeth, and teeth with loss of periodontal attachment. In these situations the goal of the surgery is to lengthen the crown using esthetic and structural parameters such as the crown-root ratio, the periodontal status, and the incisal margin position.[23] With this approach, where full-crown restorations are already present with margins apical to the CEJ, the emergence profiles are often over-contoured to promote biologically acceptable gingival contours, although this can lead to an esthetic compromise.[23]

Conclusion

Periodontists may adopt two different approaches when treating GS and STS patients: biological or restorative. Regardless of the planned therapeutic approach, misdiagnosis of an altered eruption due to the absence of a valid and repeatable diagnostic protocol can create esthetic and periodontal failures, such as misproportioned teeth and unnatural lengthening of incisal margins, which may jeopardize the smile and facial esthetics and cause longer anterior guides.[24] Furthermore,

restorative margins placed too far coronally from the CEJ may be at risk of subsequent and progressive resolution and compensation of the altered eruption with time and, ultimately, esthetic failure.

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Gummy Smile and Short Tooth Syndrome:
Periodontal Surgical Approaches in Interdisciplinary Treatment

Simone Verardi, DDS, MSD; Marjan Ghassemian, BDS, DDS; Andrea Bazzucchi, DDS, MSD; and Antonello F. Pavone, DDS

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1. **When gummy smile/short tooth syndrome (GS/STS) is confined to dental structures, what is due to either incisal wear or an altered eruption?**
   A. black/white disproportion
   B. pink/white disproportion
   C. crown width/height disproportion
   D. cemento-enamel junction (CEJ)/bone crest disproportion

2. **With what is there primary failure of the active dental eruption phase, which results in the tooth failing to emerge sufficiently from the alveolar bone?**
   A. altered active eruption (AAE)
   B. altered passive eruption (APE)
   C. short tooth syndrome (STS)
   D. immediate dentin sealing (IDS)

3. **In the biological approach to treating GS and STS, the key objective is to reestablish the physiologic distance between the CEJ and:**
   A. periodontal ligament.
   B. cementum.
   C. incisal margin.
   D. gingival margin.

4. **The presence of what may confirm the presence of gingival hyperplasia?**
   A. gingival scalloping
   B. a pseudopocket
   C. incisal wear
   D. pigmented dentin

5. **Because an active and a passive altered eruption may coexist in the same area, what will allow the clinician to differentiate between these two conditions?**
   A. a gingivectomy with an external bevel
   B. a flap elevation
   C. an ostectomy
   D. bone sounding under local anesthesia

6. **The surgical technique in the esthetic restorative approach is indicated in cases that require anterior crown lengthening surgery, where the CEJ:**
   A. must be used as the reference point.
   B. should be used as the reference point.
   C. can no longer be the reference point.
   D. none of the above

7. **In Case 1, masking buildup was performed according to the concepts of:**
   A. immediate dentin sealing.
   B. altered passive eruption.
   C. gingivectomy treatment.
   D. resective surgery.

8. **In Case 2, use of a surgical guide for anterior crown lengthening was intended to:**
   A. balance the width-to-height ratios of the teeth.
   B. expose the portion of enamel surface covered by gingiva.
   C. give an adequate biologic width for the two canines.
   D. reproduce the gingival zeniths.

9. **In the biological approach, the aim is to restore the dimensions of the anatomical crown with respect to the gingival and osseous tissues by:**
   A. lengthening the crown using esthetic and structural parameters.
   B. over-contouring the emergence profiles.
   C. placing final adhesive restorations directly on the dentin surface.
   D. exposing the portion of enamel surface covered by the gingiva.

10. **The authors propose the necessity of revealing the correct CEJ location with the:**
    A. biological approach.
    B. restorative approach.
    C. surgical technique in the esthetic restorative approach.
    D. B and C

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From Maximally to Minimally Invasive Surgery for Sinus Floor Augmentation

David Polak, DMD, PhD; and Lior Shapira, DMD, PhD

ABSTRACT: **Placing implants in the posterior region of the maxilla may require expanding the floor of the maxillary sinus. A major surgical procedure developed 30 years ago used lateral window access to the sinus cavity to achieve this. In the intervening years, less invasive techniques using a crestal approach were introduced; while they have reduced the complication and morbidity risks, they require micro-surgical skills. This review of the progression of maxillary sinus augmentation from major surgery to a minimally invasive procedure explores the various surgical approaches, discussing the advantages and disadvantages of each.**

LEARNING OBJECTIVES

- Explain the surgical principle of sinus floor augmentation.
- Describe the biologic concept of sinus floor augmentation.
- Discuss two approaches to sinus floor augmentation.

Due to the anatomy of the maxillary sinus, particularly after the loss of maxillary molars and premolars, the posterior maxillary region often lacks the amount of bone volume needed for dental implant placement. As a result, various techniques have been developed to enlarge the bone volume in this area. These types of techniques are referred to as "sinus floor augmentation" or "sinus lifts."

Boyne and James[1] were the first to publish a report on maxillary sinus floor augmentation in 1980. They described how sinus augmentation was performed using particulate autogenous bone harvested from the iliac crest; 3 months later, blade implants were placed to support removable or fixed reconstructions. Six years later, in 1986, Tatum[2] reported a lateral window technique for raising the sinus membrane, a method that also involved raising the membrane using an inferior crestal approach through the implant preparation site. Thus, the concept of sinus floor augmentation was established and confirmed in many retrospective and prospective controlled studies reviewed by Pjetursson et al[3] in 2008 in an article that also suggested various surgical techniques for sinus floor elevation.

This review traces the progression of sinus floor elevation techniques from their beginnings as a major surgical treatment to a modern minimally invasive procedure.

The Biological Concept of Sinus Floor Augmentation

Sinus floor augmentation involves the relocation of the inferior border of the maxillary

DISCLOSURES: The authors report no conflicts of interest associated with this work.

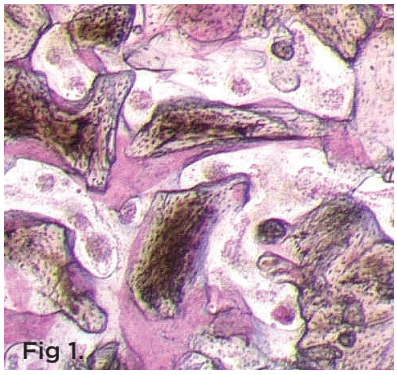


Fig 1.

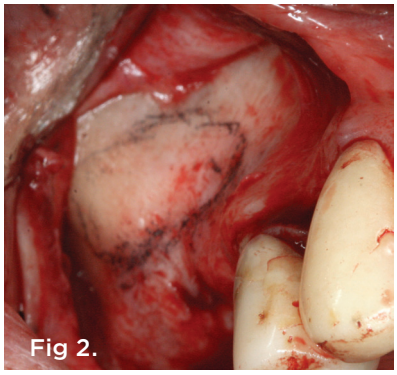
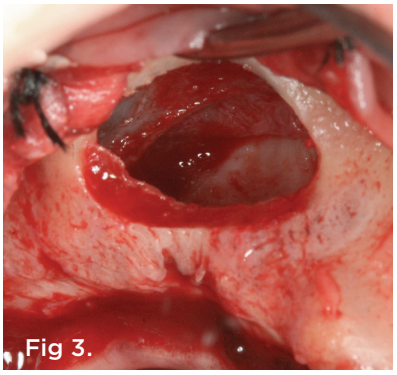


Fig 2.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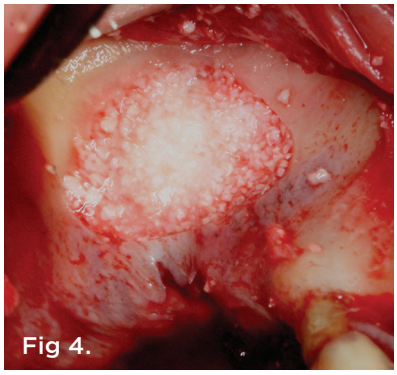
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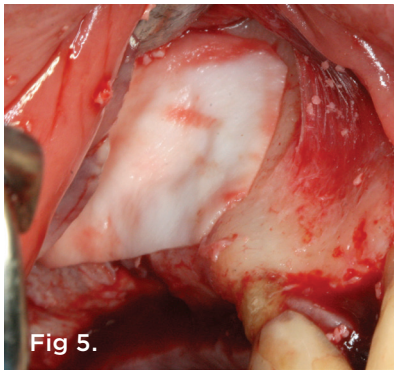
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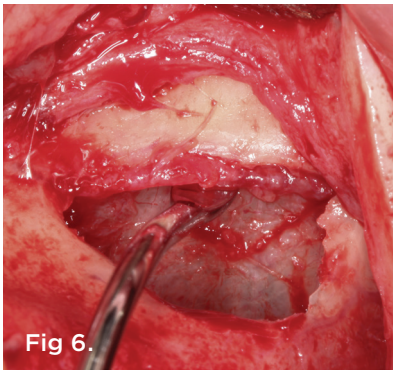


Fig 6.

Fig 1. Histologic analysis of bone core taken from augmented maxillary sinus with bone biopsies from an augmented maxillary sinus (stained with acid fuchsin and toluidine blue). Viable de-novo bone (pink staining) and bone marrow (white spaces) are formed around the filler (gray staining). (Histology by A. Piattelli, Chieti, Italy) **Fig 2.** Lateral approach to sinus floor augmentation steps. Full-thickness flap elevated and the outline of the lateral window is marked. **Fig 3.** Schneiderian membrane from the sinus walls is elevated. **Fig 4.** Space is created between the Schneiderian membrane and the sinus walls filled with particulate xenograft. **Fig 5.** Window is covered with a collagen membrane, and the flap is sutured back into place. **Fig 6.** Dissection and isolation of a major blood vessel from the sinus wall during surgery.

sinus and creation of sufficient osseous volume for implant placement. This is accomplished by separating the maxillary sinus membrane—ie, the Schneiderian membrane—from the osseous walls at the inferior potion of the maxillary sinus, and creating adequate space for bone regeneration. This new space is filled by new viable osseous tissue that is able to support dental implants. The first histologic description of this special bone formation was published in 1994 by Nishibori et al,[4] who reported on the placement of autogenous bone or allogeneic demineralized freeze-dried bone grafts in the sinuses of two patients. The study noted the presence of viable osseous tissue in both treatments, thus demonstrating the bone-forming capacity of the space beneath the periosteum of the Schneiderian mucous membrane.

Sinus floor augmentation space may be maintained by using various autogenic, allogeneic, xenogenic, or alloplastic materials, which are utilized for guided bone regeneration procedures. The regenerative bone typically forms around the bone-filling materials (Figure 1).[5] Several recent studies suggest that a blood clot alone (without filler) may also promote sufficient bone formation,[6] as long as the space can be maintained during healing.

The discussion below covers the different surgical approaches to sinus floor augmentation, without addressing the different materials used.

Surgical Principle of Sinus Floor Augmentation

The basic surgical principle and technique have remained essentially the same throughout the years. After achieving intraoral access to the maxillary sinus wall through the oral mucosa, a bony window is prepared. Next, the Schneiderian membrane is dissected and raised from the sinus floor to enable insertion of a graft to facilitate bone formation in the secluded space created.

Modifications to reduce surgical complications and morbidity—both during and after the procedure—have been made in the site of access to the maxillary sinus and the extensiveness of the surgical procedure.

The two approaches used for sinus floor augmentation—the lateral approach and the crestal approach—are described below.

Lateral Approach for Sinus Floor Augmentation

The original maxillary sinus floor augmentation technique described by Boyne and James[1] in 1980 was performed by osteotomy of the lateral wall of the maxillary sinus, followed by Schneiderian membrane elevation and autogenous particulate bone graft—ie, the "modified Caldwell-Luc approach." The area was left undisturbed for 3 months to allow for sufficient healing before placement of blade implants.

Although different techniques for lateral approach sinus floor elevation have been presented since then, their differences have been minor.

The technique described below is based on a deep buccal full-thickness flap with vertical release in the canine area, followed by creation of a "window" at the lateral wall of the sinus (Figure 2). The bony window is either removed or rotated medially with the sinus membrane and pushed inward. The Schneiderian membrane is then separated from the bone anteriorly, posteriorly, and medially until clinically sufficient space is established (Figure 3). The created space, which occupies the lower third of the sinus, is filled with a bone graft (Figure 4), and the lateral access window is covered with a collagen membrane (Figure 5).

The cumulative survival rate of implants placed in augmented sinuses is 92.8%,[3] and is comparable to that among implants placed in pristine maxillary bone. However, as with any surgical procedure, complications may occur during or after surgery. Perforation of the sinus membrane is the main complication associated with a maxillary sinus lift. The presence of a septum may increase the possibility of perforations. Ulm et al[7] observed the presence of a septum in approximately 30% of sinuses located close to the premolar-molar region. Sinus shape, too, influences the chance of perforations. Cho et al,[8] who examined different angles within the maxillary sinus, found that when the angle between the buccal alveolar wall and palatal alveolar wall was narrow, it was associated with more instances of perforations. Reporting on a simplified classification and repair system for sinus membrane perforations, Vlassis and Fugazzotto[9] proposed five different classes associated with lateral window sinus lift based on their location and extent of perforation. They wrote that—depending on their extent and location—perforations that can be isolated can be repaired by folding the sinus membrane over itself and placing a collagen membrane. However, they added, when perforation continues to increase in size and cannot be isolated, the procedure should be aborted and attempted again after waiting 4 months.

Other possible complications associated with maxillary sinus augmentation may include infra-orbital nerve injury, bruising, and soft-tissue dehiscence. The risk for post-operative infections, which occur in up to 10% of sinus floor augmentation procedures, may be reduced by the use of preoperative antibiotics.[10,11] Occasionally, complications such as excessive bleeding from major blood vessels near the bone of the lateral wall or the sinus membrane (Figure 6), hematomas, wound de-

hiscence, and implant migration into the sinus cavity are also reported to occur.[12]

Crestal Approach for Sinus Floor Augmentation

In 1994, Summers introduced the osteotome technique, a minimally invasive modification to sinus lift that can be used to place implants at the time of sinus surgery or to prepare a future implant placement site. Osteotome-root analog instruments are used to prepare the crestal osteotomy site (Figure 7). The osteotome is inserted through the edentulous alveolar crest at the inferior border of the maxillary sinus floor and produces a fracture at the cortical bone of the sinus floor, leaving the Schneiderian membrane intact. Then, the condensing of the bone graft material applies lateral and apical pressure, resulting in separation of the Schneiderian membrane from the floor of the sinus, creating new space for the graft between the membrane and the sinus floor.[13]

The osteotome technique is, by nature, a less invasive surgery with smaller flap design and a less extensive osteotomy, compared with the lateral approach for sinus floor augmentation. As a consequence, post-operative complications and morbidity are less likely to occur. In 1996, the Report of the Sinus Consensus Conference attributed 48% of failed sinus grafts to preoperative complications; among them, 38% were related to sinus-membrane perforation.[14] Ferrigno et al[15] reported that the rate of sinus-membrane perforation using the osteotome technique was 2.2% to 4.7%, demonstrating a significant reduction in post-surgical complications and infection associated with membrane perforation. Also with the osteotome technique, the bone volume used to augment the sinus typically averages 1 cc to 1.5 cc as opposed to 4 cc to 6 cc of bone in the lateral-window procedure. This may be particularly advantageous when the patient has a clear contraindication to lateral sinus grafting due to space-occupying masses such as polyps, retention cysts, or mucosal thickening. Also, because there is less penetration in the sinus cavity, the crestal approach lessens the chance of osteomeatal complex obstruction, compared with the lateral window approach.

Despite its numerous advantages, the osteotome sinus lift technique is not devoid of complications. Because Summers' osteotome technique is based on a green stick fracture of the sinus floor, damage may occur to the Schneiderian membrane. Following the osteotome technique, Krennmair et al[16] reported an increased incidence of suspected membrane perforation, and Sammartino et al[17] observed the occurrence of benign paroxysmal positional vertigo among approximately 3% of patients. The suspected reason for this side effect is the detachment of the otoliths from their normal location due to percussive and vibratory forces stemming from the preparation of implant bed using a surgical hammer.[17] Recently, it was reported by Jensen at al[18] that after the osteotome technique, a case of severe bleeding was likely due to damage to the posterior superior alveolar artery, which runs intra-sinusally in 29% of cases[19] and may, therefore, readily be damaged by the osteotome.

Due to the above side effects of the osteotome technique and the patient discomfort related to the use of a surgical hammer, various modifications to the Summers technique were introduced. Cosci and Luccioli[20] presented a crestal approach to sinus lift using a specific sequence of specially designed drills (Cosci technique). Each drill has a built-in ledge, and the consecutive drills were designed with stoppers in 1-mm increments to gently grind the bone of the sinus floor. The shape of the drill tip was designed to prevent perforation of the sinus membrane and permit gentle abrasive removal of the cortical bone of the sinus floor without fracture. A recent multicenter study showed that the Cosci technique results in a more than 6-mm bone gain, with a 96.3%

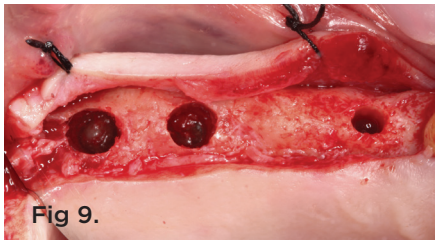


Fig 7. Summers' osteotome original set. **Fig 8.** A drill system with depth gauge for atraumatic osteotomy of the sinus floor. **Fig 9.** Crestal approach to sinus floor augmentation using special drill system. Osteotomy was carried out with drills in 1-mm-depth increments using depth gauge stoppers, until the intact Schneiderian membrane is visible. **Fig 10.** The Schneiderian membrane is separated and elevated from the sinus floor using bone-filling material.

implant survival rate.[21]

Since 2000, several modifications of the Cosci technique were introduced. These modifications can be divided into two aspects: modifications of the crestal osteotomy and modifications of the Schneiderian membrane elevation.

Crestal Osteotomy Techniques

Crestal osteotomy techniques focus primarily on drill design, cutting ability, and drill depth gauge.

Drill design and cutting ability—By the same token as the Cosci technique, different osteotomy tools were developed to diminish destructive force during creation of an access hole to the Schneiderian membrane. The Cosci technique and similar kits are based on non-cutting edge drills that gently grind bone in 1-mm step increments. This offers improved depth control of the working drills and reduced chances of damage to the Schneiderian membrane.

Other drills with characteristics similar to the Cosci drills have been suggested for crestal osteotomy. Chen and Cha[22] proposed using a rounded diamond drill to create a smaller access hole to the Schneiderian membrane. Although this drill is more aggressive than those in the Cosci system, prudent preparation prevents damage to the sinus membrane. In an 8-year retrospective study, Chen and Cha[22] reported more than 99% success with their technique with few side effects.

Drill depth gauge—A common complication of the crestal drill osteotomy is unintended perforation of the Schneiderian membrane.

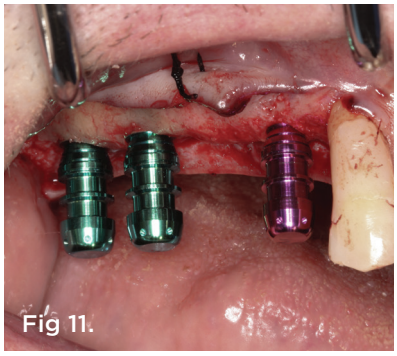
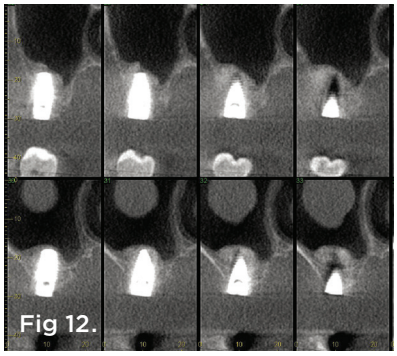


Fig 11.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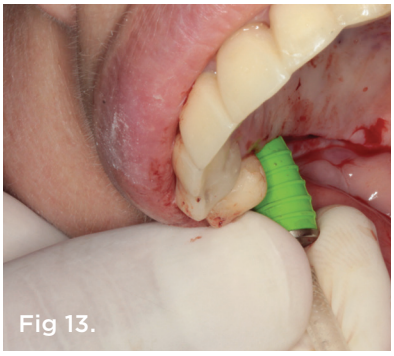
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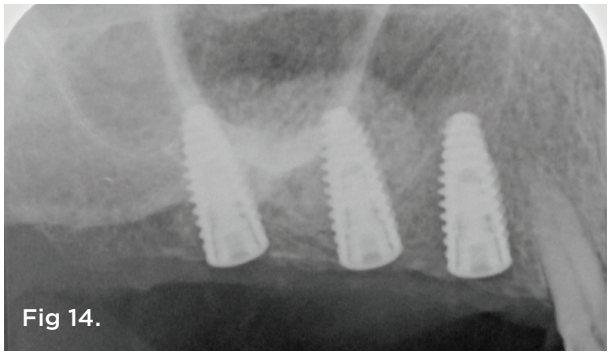
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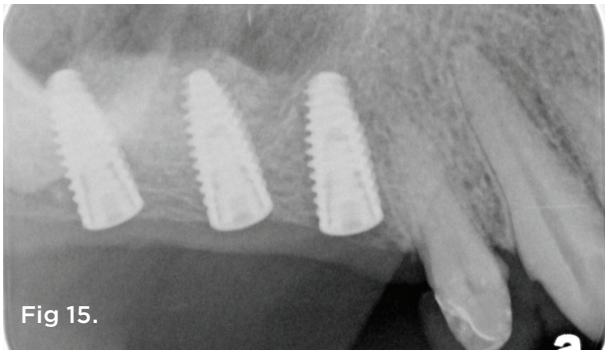
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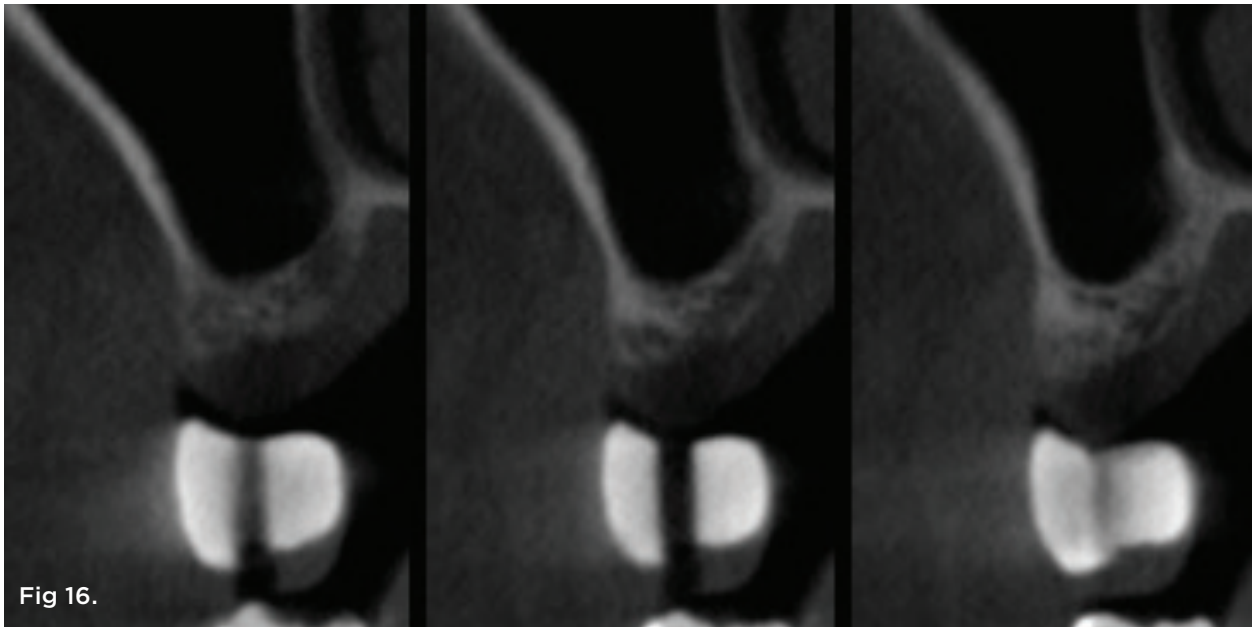
Fig 16.

Fig 11. Dental implants are inserted through the crestal osteotomy preparation. **Fig 12.** Cone-beam computed tomography 6 months after the procedure reveals the bony mantle covering the inserted implants. **Fig 13.** Crestal sinus floor augmentation using saline. Following crestal osteotomy preparation, hydraulic condensing pressure is carried out using a designated devise for saline delivery. The devise has a silicone end that enables sealing of the crestal preparation, preventing leakage of saline. **Fig 14.** Peri-apical X-ray of the site immediately following sinus floor elevation and implant insertion. **Fig 15.** Peri-apical X-ray 5 months following the procedure. Notice bone mantle over the implants. **Fig 16.** Sinus floor augmentation using the balloon technique. Cone-beam computed tomography of a missing upper first molar prior to sinus floor augmentation.

As a consequence, specific sleeves in different lengths were developed (Figure 8). These sleeves, which are placed on the drills, serve as gauge stoppers that prevent drill overextension. While the Cosci system uses only 3-mm-diameter drills, the newer systems include wider-diameter drills, which offer better visibility and control of the osteotomy and the integrity of the Schneiderian membrane. Figure 9 shows an implant insertion case using one of the newer systems to perform this crestal osteotomy technique. Osteotomy was performed with a non-cutting drill in 1-mm depth increments using depth gauge stoppers until the bone tissue is removed and the intact Schneiderian membrane is visible. The Schneiderian membrane is then elevated using bone-filling material, as described by Summers' original technique (Figure 10). Following sufficient augmentation, the implants are inserted (Figure 11). Cone-beam computed tomography after 6 months reveals the bony mantle covering the inserted implants (Figure 12).

Schneiderian Membrane Elevation Techniques

Once access to the Schneiderian membrane is established, the membrane must be separated from the inferior border of the maxillary floor. For this, there are special tools and techniques including micro-curettes and Schneiderian membrane condensing techniques using filler or saline.

Micro-curettes— The limited access through the crestal osteotomy has led to development of various specific tools for this task. Elevation of the Schneiderian membrane in the lateral approach for sinus floor augmentation is done with special curettes, which are designed with a gentle rounded cutting edge and a non-cutting back surface. Similarly, micro-curettes were developed for the crestal approach. These mushroom-like curettes are shaped like a dome with different diameters; they enable a gentle separation of the Schneiderian membrane with minimal possibility for damage to the membrane, particularly when one of the following is used: micro-surgical suction tips, high-powered magnification loops, and direct light. These curettes, however, offer limited access to the Schneiderian membrane and are restricted in their ability to elevate the membrane. As a result, other methods to further elevate the sinus membrane must be used after these curettes.

Schneiderian Membrane Condensing Techniques

Using bone fillers—As originally described by Summers, most crestal sinus floor augmentation techniques use bone-filling materials to push gently the Schneiderian membrane from the sinus floor through the osteotomy site. It is believed to cause even pressure, which leads to symmetrical and homogenized elevation of the membrane. However, the Schneiderian membrane has elastic properties and the tissue may have inconsistent thickness. These properties may affect the uneven pressure distribution. Furthermore, the anatomy of the sinus floor may also play a role, and concaved floor anatomy may react differently than a convex floor anatomy. The use of bone fillers diverts from the basic principle of Pascal's law (see below), and may produce uneven pressure. Furthermore, the bone-filling particles may induce micro-tears of the membrane. A recent retrospective long-term study from the authors' department showed that implant survival following crestal sinus floor augmentation was high and was not affected by the bone-filling material that was used, implant type, or implant diameter (unpublished results).

Using saline—The use of saline to push the Schneiderian membrane in a coronal position is based on Pascal's law (which is also known as the principle of transmission of fluid pressure). According to this law, the pressure exerted in a confined incompressible fluid is transmitted

equally in all directions throughout the fluid. Compared to bone-filling materials, the force caused by saline on the sinus membrane is distributed equally, and therefore probably results in less chance for membrane tears. Secondly, unlike particulate materials, saline might leak into the oral cavity during the injection and will lead to reduced pressure on the Schneiderian membrane. Therefore, when using saline to elevate the sinus membrane, it is essential to properly seal the osteotomy opening. Another advantage of using saline is that if membrane tear occurs, the leak of saline to the sinus cavity is less problematic than bone-grafting material. Figure 13 presents a case of crestal sinus lift using saline. A special injection tool with a silicon sealer is placed on the osteotomy opening with light pressure to provide sufficient seal of the osteotomy area, and saline is gently injected, followed by appropriate filler (Figure 14 and Figure 15). Kao and DeHaven[23] presented a controlled hydrostatic sinus elevation technique with saline and the use of pressure gauge. In their article, membrane elevation was carried out in a controlled manner in order to reduce chances for membrane perforation.


Fig 17.

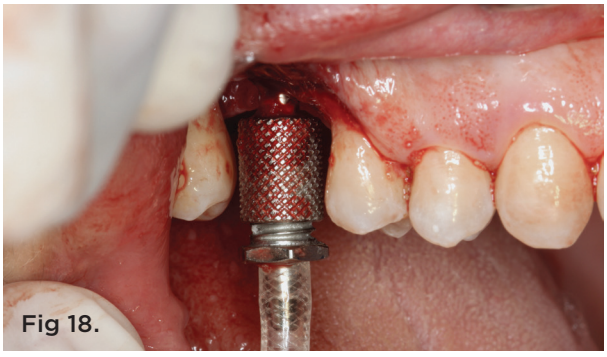
Fig 18.


Fig 19.

Fig 17. The balloon device – the balloon is located at the end of a metal sleeve that fits to the crestal osteotomy preparation (MIAMBE system). **Fig 18.** The balloon devise is inserted into the crestal osteotomy preparation and saline is then injected through a tube until sufficient elevation of the Schneiderian membrane is reached. (not used in original) **Fig 19.** Peri-apical X-ray 13 months after sinus floor elevation and implant insertion.

Using a balloon—In 2006, Kfir et al[24] presented a new method to elevate the Schneiderian membrane. The idea is based on the same principle as catheterization of the coronary vessels, using liquid pressure inside a balloon to detach the Schneiderian membrane from the sinus floor (Figure 16 through Figure 19). The equipment includes a small balloon attached to an insertion tube, which is placed inside the osteotomy preparation (Figure 17). The balloon is then inflated with saline until sufficient volume is created. Following deflation and removal of the balloon, bone-filling material is inserted into the created space, and implants may be placed if anatomic conditions allow. A pressure gauge may be added to this technique and allows better control of the force inflicted on the Schneiderian membrane. In a cadaver study,[25] the Summers condensation technique was compared with the

reduced risk for side effects using the balloon. Recently, Mazor et al[26] presented a case series using a flapless approach to the balloon technique and found 100% implant survival over 18 months follow-up.

Conclusions

The posterior region in the maxilla sometimes lacks sufficient bone volume for implant insertion due to the proximity to the maxillary sinus. As a consequence, various techniques were developed in order to augment the osseous volume in these areas. Initially, major surgical approaches were designed, such as the lateral window approach, which was based on the Caldwell-Luc approach. These methods however, had relatively high incidence of complications and morbidity. Over time, less invasive methodologies were developed. The crestal approaches for sinus floor augmentation lead to reduced morbidity and complications, with success rates similar to the lateral approach. These techniques require microsurgical skills and equipment, due to the limited access and visibility. Various techniques for crestal approach are available, and most of them show predictable results. Guidelines for choosing the right approach for this procedure are based mostly on personal experience and the skills of the surgeon.

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From Maxillary to Minimally Invasive Surgery for Sinus Floor Augmentation

David Polak, DMD, PhD; and Lior Shapira, DMD, PhD

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1. **The posterior maxillary region often lacks the amount of bone volume needed for dental implant placement due to what?**
   A. poor bone quality
   B. proximity to blood vessels
   C. limited keratinized tissue
   D. the anatomy of the maxillary sinus

2. **Sinus floor augmentation involves the relocation of the inferior border of the maxillary sinus and what else?**
   A. presence of nonresorbable bone substitute material
   B. creation of sufficient osseous volume for implant placement
   C. presence of resorbable collagen membrane
   D. special bone remodeling proteins

3. **The original maxillary sinus floor augmentation technique described by Boyne and James in 1990 was performed by osteotomy of the lateral wall of the maxillary sinus, followed by Schneiderian membrane elevation and autogenous particulate bone graft, known as what?**
   A. modified Caldwell-Luc approach
   B. Summers approach
   C. Cosci approach
   D. minimally invasive dentistry

4. **The cumulative survival rate of implants placed in augmented sinuses is 92.8% and is:**
   A. reduced compared with pristine bone.
   B. comparable to that among implants placed in pristine maxillary bone.
   C. increased compared with pristine bone.
   D. not known.

5. **Which is the most common complication during maxillary sinus lift?**
   A. infection
   B. perforation of the sinus membrane
   C. uncontrolled bleeding
   D. pain

6. **In the Summers technique, what is used to prepare the crestal osteotomy site?**
   A. atraumatic bone drills
   B. osteotome-root analogy instruments
   C. diamond burs
   D. Piezo-electrics

7. **When using the Summers technique, Sammartino et al observed the occurrence of which side effect among approximately 3% of patients?**
   A. pain
   B. bleeding
   C. benign paroxysmal positional vertigo
   D. sinus membrane tears

8. **What is a common complication of the crestal drill osteotomy?**
   A. unintended perforation of the Schniederian membrane
   B. implant failure
   C. tooth damage
   D. none of the above

9. **Newer systems include the use of wider-diameter drills than the Cosci system, which uses drills of what diameter?**
   A. 1 mm
   B. 3 mm
   C. 4 mm
   D. 2 mm

10. **Elevation of the Schneiderian membrane in the lateral approach for sinus floor augmentation is done with which of the following?**
    A. gas pressure
    B. condensing techniques with saline
    C. balloon technique
    D. micro-currettes

Course is valid from 6/1/17 to 6/30/20. Participants must attain a score of 70% on each quiz to receive credit. Participants receiving a failing grade on any exam will be notified and permitted to take one re-examination. Participants will receive an annual report documenting their accumulated credits, and are urged to contact their own state registry boards for special CE requirements.

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