Sinus Grafts: Science and Techniques—Then and Now

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Abstract

Introduction Sinus lifts have been around for more than four decades now, and the amount of changes that we have seen in techniques and armamentarium coupled with the advent of newer materials is worth taking note of.

Materials and Methods A complete review of the literature was done since the advent of ways and means to augment the posterior maxilla with a run through of various advantages and disadvantages of the same.

Conclusion In conclusion, we can say that this procedure is today very predictable and offers clinicians a possibility to rehabilitate the posterior maxilla with implant-based solutions.

Keywords Maxillary sinus · Sinus grafting · Maxillary implants

Introduction

Maxillary sinus lift is a procedure commonly used nowadays to augment the hard tissue volume prior to implant placement in the maxillary posterior region.

This is a result of pneumatisation of the sinus which reduces the vertical component of bone.

The conventional method for maxillary sinus elevation requires surgical access through the lateral wall of maxilla, followed by elevation of the sinus membrane and insertion of bone graft under direct vision. Thus the name ‘Direct sinus lift.’

A modified less invasive method utilizes an approach via the crestal region without direct vision of the membrane thus the name ‘Indirect sinus lift.’

With evolution through the ages, this procedure has mutated into a relatively simple and predictable one with the advent of newer techniques, biomaterials and armamentarium.

History

1. Tatum (1970) augmented the posterior maxilla with autogenous rib.
2. Tatum (1974) developed a modified Caldwell–Luc procedure by infracturing the crest of the alveolus.
3. Tatum modified his own procedure to lift the membrane via a lateral approach.
4. Summers (1994) gave an internal approach to lift the membrane via the osteotomy.
5. Chen (1996) gave the hydraulic sinus condensing technique. This technique uses an osteotomy on the lateral aspect of the ridge of the maxilla.

Although sinus grafting is considered to be a relatively invasive surgical procedure, the incidence of reported surgical and postsurgical complications is relatively low. In fact, reported perforation rates vary from as low as 7% to as high as 58%.

In 1994, Summers introduced a less invasive procedure for sinus membrane elevation along with dental implant placement. The ‘Summers technique,’ often referred to as ‘osteotome/crestal sinus membrane elevation,’ or OCSME, is recommended for patients with at least 5.0–6.0 mm of adequate residual alveolar bone below the sinus floor.

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Investigations

Radiological investigations prior to sinus lift procedures have evolved from analog X-rays to digital X-rays to medical grade CT to cone beam CT scans.

Today cone beam CT (CBCT) is considered the standard of care when assessing a case for a possible sinus graft.

Scans should be assessed in all possible sections coronal, cross-sectional and axial to get a clear picture of the sinus anatomy and possible septae.

Radiological investigations need to be assessed for any opacity in the sinus, and a differential diagnosis needs to be ascertained whether the opacity in question is mucosal hypertrophy or fluid retention or a mucosal cyst/polyp.

If a radiological diagnosis of reactive mucositis is confirmed clinically to arise from a tooth in the vicinity, this should be attended to prior to the sinus graft procedure.

Patency of the ostia should be assessed along with any hypertrophy of the uncinate process, as these could hamper spontaneous drainage of a grafted sinus, thereby causing detrimental turgor pressure on the particulate graft.

Patient Evaluation

Patients need to be evaluated from the medical and dental point of view prior to being taken up for a sinus graft.

In particular the nasal symptoms if any need to be evaluated thoroughly as we are dealing with a part of the sinonasal complex.

It may be prudent to ask for an ENT clearance in patients with chronic recurrent paranasal sinusitis [2–4].

Some patients may even require functional endoscopic sinus surgery (FESS) to aid spontaneous drainage of the sinuses.

Clinicians can use components of the sinonasal outcome test (SNOT-22) to predict likelihood of symptom improvement after surgical intervention in subjects with Chronic rhinosinusitis (CRS) [2]. Here patients are given a self-assessment questionnaire to rate their symptoms on a scale of 0–5 following which they can be assessed for prior ENT consultation for potential CRS postoperatively which could affect the integration of the graft.

Nasal obstruction symptom evaluation (NOSE) test may be used by clinicians to assess possible areas of concern that may pose a threat to postoperative development of acute or chronic maxillary sinusitis.

Both these are relatively simple methods of evaluation and may be used on an outpatient basis [5]. This gives a reliable insight into the level of nasal obstruction if any that would impair postoperative drainage and potentially lead to acute or Chronic rhinosinusitis.

Methods

Lateral Window/Direct Technique

Boyne and James published this technique in 1980, and it is reported that Tatum described this surgical method first during a 1977 lecture and later in a publication [6, 7].

The lateral bone window can be prepared utilizing many methods described in the literature, ranging from carbide/diamond burs to piezoelectric devices to hand-held bone scrapers to hard tissue lasers.

All these have their inherent advantages and disadvantages ranging from time taken to safety to costs to learning curves involved.

For the not so experienced surgeon piezoelectric devices hold a significant advantage from the safety angle compared to other armamentarium.

The bone window separated maybe trap doored or removed and milled with the particulate graft as the autogenous component or kept in suitable media and replaced at the original site.

Again the simplest for a beginner is lifting the window as a trap door, wherein the Schneiderian membrane is dissected from the inferior, anterior and posterior aspects and hinged inwards and upwards on the superior osteotomy line.

Till date, the lateral window technique is the most followed in cases where there is sinus pathology such as a polyp or where there are numerous septa to be addressed and even in cases with previous surgical attempts on the sinus, because any perforations that occur can be easily identified and sealed.

Gentle dissection of the membrane may be carried out utilizing hand instruments (of varying sizes and shapes as per operator convenience and also accessibility of the surgical site) or the ‘Elephant foot’ tip in the piezosurgical unit.

It is imperative that the clinician be familiar with perforations and handling them, because at any given time during the procedure if the perforation is too large the clinician may need to defer the grafting to a later date.

Transcrestal/Indirect Technique

This technique has undergone the maximum modifications over time mostly due to the minimally invasive nature and better patient compliance.

The thin Schneiderian membrane [8] and complicated sinus structure pose a risk to the membrane while manipulation via the lateral window; thus, many modifications of the original Summer’s technique have been studied and reported, including safe-ended drills, trephine burs or piezoelectric bone device techniques.

Even the ‘Von Ebner’ bone scraper has been described in the literature as a means of exposing the membrane for manipulation.

Sclar et al. have presented guidelines for flapless surgery that requires approximately 3 mm width and depth of keratinized attached gingiva, and this should be kept in mind while attempting flapless surgical approach [9].

The flapless approach without soft tissue flap reflection includes less alveolar crestal resorption and better blood supply to graft material, which results in minimal postoperative pain and bleeding. It also allows the maintenance of normal oral hygiene procedures immediately postoperatively.

Overview and Recent Developments in Crestal Sinus Floor Elevation

- (a) In the first three articles, Summers [1] described the use of osteotome hand instruments with gentle incremental malleting to break the cortical floor and lift the sinus membrane. The osteotomes compressed soft maxillary bone, widened narrow ridge segments (ridge expansion osteotomy REO technique) and elevated the sinus floor for immediate implant insertion (osteotome sinus floor elevation OSFE and bone-added osteotome sinus floor elevation BAOSFE surgery).

Thereafter, Summers combined the original OSFE procedure with the addition of a bone graft material, called the BAOSFE, as he considered it to be more conservative and less invasive than the lateral approach. It should be noted that in this technique, the bone substitutes are blindly introduced inferior to the sinus membrane.

Furthermore, Summers [1] introduced a novel method of intruding the ridge crest with large diameter osteotomes to create broader areas of sinus floor elevation, known as the future site development (FSD procedure).

In all three techniques, he relied on the use of osteotomes and mallet to break the cortical floor, the difference between the three lying in the way the membrane was elevated.

Pressure on the graft material and trapped fluids exerts hydraulic pressure on the sinus membrane, creating a blunt force over an expanded area that is larger than the osteotome tip Chen and Cha [10]. This was the evolution of the hydraulic sinus condensation method.

- (b) Modified osteotome technique utilizing drills

In the presence of dense bone quality, with no need to improve it further, the use of the osteotomes following Summers technique would not be recommended.

In which case safe-ended drills are used till 1 mm of the sinus floor following which grafting material is introduced into the surgical site to partly absorb the shock from osteotomes.

This ‘modified technique’ eliminated unnecessary malleting in the presence of a dense residual bone and therefore proved to be more tolerable to patients.

Fugazzotto [11] presented a technique in which a trephine with a 3.0 mm external diameter is utilized as a first step, followed by an osteotome to implode a core of residual alveolar bone prior to simultaneous implant placement.

- (c) Cosci technique—this crestal approach technique by Cosci and Luccioli [12] is a one-stage crestal SFE approach using a specific sequence of atraumatic drills of varying lengths.

The shape of the drill tip prevents perforation of the sinus membrane and permits gentle abrasive removal of the cortical bone of the sinus floor without fracture.

After using the first atraumatic lifting drill, the site is probed with a blunt instrument to feel the presence of the Schneiderian membrane. If the presence of bone is felt, a 1-mm-longer atraumatic lifting drill is used, and so on, until the sinus lining is felt.

- (d) Minimally invasive antral membrane balloon elevation (MIAMBE)

The presence of septa in maxillary sinus requires modification of surgical technique and carries a higher complication rate. Minimally invasive antral membrane balloon elevation (MIAMBE) is one of many modifications of the BAOSFE method, originally described by Soltan and Smiler [13], in which antral membrane elevation is executed via the osteotomy site using a dedicated balloon.

The predetermined depth is reached by way of pilot drills and osteotomes, the sinus membrane integrity is checked, and then the balloon device is inserted and inflated slowly with the barometric inflator up to 2 atm. Once the balloon emerged from the metal sleeve underneath the sinus membrane, the pressure dropped down to 0.5 atm. Contrast fluid is utilized in the balloon which could be visualized on radiological investigations.

- (e) Hydraulic pressure technique

The same year Soltan and Smiler [13] published their ‘MIAMBE’ technique, Sotirakis and Gonshor [14] developed a new modification of the original Summers technique. After the use of osteotomes, saline is injected beneath the membrane under hydraulic pressure with a suitably fitted syringe.

- (f) Another innovative crestal technique based on high hydraulic pressure, considered as a minimally

invasive sinus floor augmentation (MISFA), has also been studied recently by Jesch et al. [15]. This method consists of a drill, a pump and a connecting tube set. After drilling into the RBH and staying 1–2 mm away from the sinus floor, a hydraulic pressure is created by the pump (1.5 bar); it pushes back the sinus membrane from the drill using physiological saline (NaCl).

- (g) In recent times, even putty bone substitute materials extruded from a cartridge have been used to elevate the membrane via hydraulic pressure after osteotomes or safe-ended drills have removed all bone from under the sinus membrane.
- (h) Based on the same principle, another system has been developed using a piezoelectric device with specially designed tips, considered to be safe and atraumatic during site preparation when compared to osteotomes and hammering.
- (i) Eitan Mijiritsky et al. [16] tested an implant-derived minimally invasive sinus floor elevation technique. The dental implant used in this trial was a self-tapping endosseous dental implant that contains an internal channel to allow the introduction of liquids

through the implant body into the maxillary sinus; those liquids include saline and a flowable bone grafting material.

In a survey by Young-Kyun Kim, Yong-Seok Cho and Pil-Young Yun, it was revealed that the satisfaction levels of dentists using a crestal approach sinus elevation kit was around 92.9% to approach the sinus floor but 25% did not use the hydraulic lifter provided thus indicating a mix of techniques employed in practice [17].

Review of Biomaterials Used

Biomaterials used have evolved since the time of Boyne and Tatum.

During 1974–1979, most grafts were autogenous bone.

Thereafter, deproteinized bovine bone mineral (DBBM) was in vogue after which came synthetic grafts such as beta-tri-calcium phosphate (β -TCP) and calcium phospho-silicate (CPS) morsels/putty [18, 19].

Initially, more surgeons were attempting to use autogenous inlay block grafts in the sinus, but this used to

Fig. 1 **a** Pneumatized sinus, **b** 5 months post-op shows the repositioned sinus floor, **c** 7 years post-op the CBCT scan shows the graft volume maintained

increase the turnover and integration time thus the shift to particulate grafts happened.

With the turn of the century, more literature has emerged with the use of autologous fibrin and platelet concentrates as grafting material.

There is little evidence in the literature to prove their osteogenic or osteoinductive potential in humans, and it is understood that they serve more as a space-maintaining material. However, their role in soft tissue healing and maturation is proven beyond doubt.

Lundgren et al. first reported radiographic new bone formation in the human sinus with membrane elevation alone. However, the study did not demonstrate histological evidence to verify new bone formation in the sinus [20].

Palma et al. demonstrated histological evidence to verify new bone formation in the monkey's sinus. According to this study, no differences on new bone formation, implant stability and bone-implant contacts were demonstrated between two groups with and without adjunctive autogenous bone graft [21].

Fig. 2 **a** Assessing the volume attained with an indirect sinus lift using the hydraulic pressure technique with calcium phosphosilicate graft, **b** immediate implants placed, **c** 3 months post-op the graft and

the repositioned floor are not well delineated. Volume loss is evident, **d** the crystalline graft particles are seen through a thin distended membrane post the indirect lift (Endoscopic view)

Fig. 3 **a** Good volume maintenance of the graft 5 months post-op after an indirect lift. A mix of DBBM and autograft was used, **b** a distended but thick membrane is visualized (Endoscopic view)

Sohn et al. first demonstrated histological evidence of new bone formation in human maxillary sinuses with sinus membrane elevation alone and simultaneous implant placement [22].

Platelet aggregates, such as platelet-rich plasma (PRP), platelet rich in growth factors (PRGF), platelet-rich fibrin (PRF) and fibrin-rich gel with concentrated growth factors alone (CGF) have been used to accelerate new bone formation associated with guided bone regeneration and sinus graft.

Review of Local Anesthetic Techniques

The posterior superior alveolar, middle superior alveolar and the anterior superior alveolar nerve subdivisions innervate the maxillary sinus.

If the procedure involves an indirect lift for a single implant placement, then one could rely on buccal infiltration and greater palatine nerve block, but if a larger area is to be augmented via the direct approach, then it is better to go for a combination of posterior superior alveolar and greater palatine nerve blocks with some amount of infiltration.

Some operators also use infraorbital nerve blocks, but these are optional and generally relied upon if the scans show an anteriorly pneumatized sinus that requires augmentation.

General anesthesia is seldom recommended unlike the past where the maxillary sinus was augmented using bone blocks from the anterior iliac crest and implants placed either at the same or a second stage [23].

Complications

The most commonly reported surgical complication being perforation of the sinus membrane [24].

Janner et al. [8] have studied the dimensions and characteristics of the Schneiderian membrane and reported that the thickness exhibited a wide range, with a minimum value of 0.16 mm.

Maxillary sinus membrane perforations, as described in the literature, also are strongly linked to the development of postoperative complications such as acute or chronic sinus infection, edema, bleeding, wound dehiscence, loss of the bone graft material and a disruption of normal sinus physiologic function. Conversely, some authors have

Fig. 4 **a** Bruising evident in the distended membrane, **b** sunburst appearance of graft in the sinus (taken after 15 min of indirect lift) suggests membrane rupture, **c** membrane rupture confirmed with escape of phosphosilicate particles into the sinus (Endoscopic view)

Fig. 5 **a** Lateral part of the sinus grafted with the entire medial part *left* vacant, **b** implant placed into an incompletely grafted sinus with no bone medial to the implant

reported no association between sinus membrane perforations and implant survival, while others have attributed implant failure directly to the sinus membrane perforation [24–27].

In the Summers technique if after several mallet strikes the osteotome does not progress, the surgeon has to go back to a smaller-sized osteotome or use a drill.

The osteotome technique is superior to drilling when working with soft (D4) maxillary bone.

Disadvantages to the technique include psychological trauma to the patient from frequent malleting, benign paroxysmal positional vertigo (BPPV) among others like membrane perforation in inexperienced hands [28].

Consequently, OCSME is a visually indirect procedure and is considered to be more technique sensitive with inherent limitations.

In a 2008 systematic review, Tan et al. reported transcrestal membrane perforation varied widely between 0 and 21.4%.

In reality, the incidence of potential postoperative complications in the indirect lift technique may be greater than in the lateral approach technique, which possibly goes

undiagnosed in the immediate intraoperative period due to limited visualization of the membrane.

In 2000, Wiltfang et al. reported that endoscope-controlled sinus floor augmentation may actually have a lower postoperative complication rate for the transcrestal procedure in patients with 4.0–8.0 mm of vertical bone height below the sinus floor. The intraoperative use of sinuscopy as described by Grunenberg and Gerlach in 1990 for maxillary sinus elevation procedures allows for exclusion of sinus pathology intraoperatively, control of the bone graft position, a reduced risk of sinus membrane perforations and fewer postoperative complications [29] (Figs. 1, 2, 3, 4).

Conclusion

In conclusion of the techniques and biomaterials enumerated following are the salient points.

1. Lateral window method offers the best visualization of the sinus membrane.
2. Membrane perforations reported are more often in lateral window techniques than indirect lift methods.

Fig. 6 **a** Multiple septae seen in the CBCT scan, **b** direct approach with membrane dissected off all the septae

3. The most common mistake in a lateral window is not to elevate the membrane all the way from the lateral to medial aspect. The result as seen in a sagittal scan is the lateral half grafted and the medial half left as is. If an implant is inserted into such an area, the medial wall will be devoid of bone and may be perforating the membrane (Fig. 5a, b).
4. If sinus septae are seen, the case should be meticulously planned either to work around them or to exclude them from the area of lift (Fig. 6a, b).
5. Lesser number of perforations have been reported with the indirect lift due to difficulty in confirmation of a perforation.
6. In relatively inexperienced hands, the piezosurgery option is better than other devices to prepare the lateral window.
7. Indirect lifts are much more technique sensitive than they seem and clinicians should be careful while

attempting it. These days rather than rely on one technique or kit alone, clinicians would get better results utilizing a carefully planned mix of techniques and devices (Fig. 7).

8. Clinicians attempting an indirect lift with whichever modified method should be adept in a lateral window exposure, should there be a need to address an inadvertent intraoperative perforation.
9. Lifting the membrane more than 5–6 mm via the indirect approach can prove risky if the membrane is of a thin variant [30].
10. The recommended protocol for residual alveolar height 4 mm or more is to plan for an indirect lift attempting to achieve about 5 mm of vertical augmentation.
11. In cases with residual alveolar height of 3 mm or less, the direct sinus lift would be a more reliable option attempting to achieve almost 10 mm of vertical augmentation.
12. Endoscopic visualization of the membrane while and after manipulation offers the best confirmation of integrity of the same (Figs. 2d, 3b, 4c).
13. Be it lateral window or indirect lifts, the amount of elevation should be just sufficient to accommodate an implant of adequate length.
14. Particulate grafts used should possess osteoinductive or osteoconductive properties and help in long-term volume maintenance. Thus the concept of mixing different biomaterials to achieve better osteoinductive potential and volume maintenance. If possible a mix of either autografts or allografts with either DBBM or synthetic grafts yields an optimal particulate biomaterial.
15. A tear in the membrane while attempting a lateral window approach must be sealed prior to progressing, and collagen fleece has been reported to be a good material to seal the perforation followed by application of a delayed resorption collagen membrane [26].
16. In the event of a tear while attempting an indirect lift, it is imperative that the perforation be detected prior to insertion of bone substitutes else it becomes very difficult to proceed with the procedure. Bone substitute particles inadvertently introduced into the sinus cavity may cause acute or chronic inflammatory reactions.
17. Forceful valsalva maneuvers are no longer indicated to detect membrane integrity as a thin membrane may get perforated by the pressure change. Gentle respiratory movements are sufficient to elicit membrane integrity.
18. Failure to detect movement in the membrane on inhalation or exhalation may not always indicate

Fig. 7 Diagrammatic representation of safe-ended drills to remove the cortical floor, insertion of fluid for a hydraulic lift, thereafter insertion of particulate graft and the implant

membrane perforation, this may also indicate fluid collection or a polyp in the sinus (turgor pressure from the fluid or polyp restricts movement).

19. It may be prudent to protect a thin membrane by way of collagen fleece application prior to insertion of particulate bone substitute, lest the sharp graft particles perforate the membrane.
20. The lateral window always needs to be covered with a delayed resorption collagen membrane to prevent fibrous tissue incorporation into the graft.

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