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Maxillary sinus floor augmentation with and without graft materials: a literature view

Annotation. The publications in the electronic databases PubMed, Google Scholar and other reliable resources (Embase, Web of Science, and Cochrane Library), were studied during a systematic review of the literature. The author has selected articles whose content concerns the study of maxillary sinus floor augmentation with and without graft materials. Total of 116 articles we reviewed during the review. After analyzing the literature for inclusion criteria, the total number of publications has become 52. **Conclusions.** Within the limits of this study, maxillary sinus elevation and augmentation provides predictable outcome of regenerating lost osseous structure in the posterior maxilla. This offers the patient many advantages for long-term success at implant sites. There are mainly two approaches for maxillary sinus floor elevation: direct and indirect approach. Direct (lateral window technique) and indirect (osteotome sinus floor elevation, minimally invasive transalveolar sinus approach, and antral membrane balloon elevation), as well as a modified graftless sinus lift technique. Indications for the use of any technique for carrying out this operation, such as topography and defect volume, should be taken into account.

Key words: Schneiderian membrane, maxillary sinus lift surgery, direct/lateral window technique, indirect/osteotome technique

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Восстановление объема костной ткани в области верхнечелюстного синуса с и без использования костнопланопластического материала: обзор литературы

Аннотация. Были изучены публикации в электронных базах данных (Embase, Web of Science, и Cochrane Library) в ходе систематического обзора литературы. Авторами были отобраны статьи, касающиеся аугментации в области дна верхнечелюстной пазухи, с использованием и без использования костнозамещающих материалов. В ходе обзора были изучены 116 статей. После анализа литературы по критериям включения общее количество публикаций составило 52. **Заключение.** В рамках данного исследования определено, что поднятие высоты дна верхнечелюстной пазухи и аугментация обеспечивают предсказуемый результат восстановления объема утраченной костной ткани в дистальном отделе верхней челюсти. Это обеспечивает долгосрочный положительный результат для пациента. Существуют два основных подхода: прямой и непрямой. Прямой подразумевает технику латерального окна, к непрямым можно отнести использование остеотомов, минимльно инвазивный крестальный, балонную технику, а также модифицированную методику без использования костнозамещающих материалов. Показания к применению той или иной методики (такие как топография и объем дефекта) должны быть основополагающими в выборе.

Ключевые слова: шнайдерова мембрана, операция синус-лифтинг, прямой метод, метод латерального окна, непрямой метод, использование остеотомов

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INTODUCTION

For several decades, various bone grafts have been widely used for sinus augmentation. The new compartment created between the floor of the maxillary sinus and the elevated sinus membrane is typically filled with autografts, allografts, xenografts, alloplasts, or combinations of different graft materials to maintain space for new bone formation and sinus augmentation with bone grafting. All are considered to be highly predictable surgical procedures for vertical augmentation of bone next to a pneumatized maxillary sinus. Treatment of the highly atrophic alveolar ridge is still challenging [1—5].

To increase local bone volume, lateral and vertical bone augmentation procedures are performed. An important factor that influences the possibility of immediate implantation is the severity of the atrophy of the posterior maxilla. If the maxilla is completely edentulous, the extension of the maxillary sinus can result in severe three-dimensional atrophy with an osteoporotic-like bone structure. After complete tooth loss in the upper jaw and high maxillary atrophy, the space created by the tenting technique can be much larger than in patients with only partial tooth loss. When only a limited number of teeth are missing, a sinus cavity of limited volume bordered by bony walls needs to be filled with new bone. In cases of high atrophy and complete tooth loss, it can be much more difficult to create a stable blood clot as a prerequisite for new bone formation. Periodontal disease and dental caries are the main causes of tooth loss and the incidence of edentulous patients varies worldwide between 7% and 69%; The loss of posterior teeth and subsequent maxillary sinus pneumatization results in atrophy of the alveolar bone and can affect the proper rehabilitation of patients with osseointegrated implants [6—13].

Complete or partial tooth loss is often associated with nutritional deficiencies, oral pain, and poor psychosocial functioning. During the last 40 years, osseointegrated dental implants have become one of the most used biomaterial to replace missing or lost teeth and the treatment has been characterised by a highly successful outcome of complete, partial or single edentulism. Oral rehabilitation with implant-supported prosthesis have shown improved masticatory function and oral specific health-related quality of life compared to removable dentures; However, placement of implants in the posterior part of the maxilla is frequently compromised or impossible due to atrophy of the alveolar process, poor bone quality and maxillary sinus pneumatization. In this context, maxillary sinus lift surgery (also known as maxillary sinus floor augmentation surgery) has been considered a safe treatment modality with a low complication rate. Various surgical approaches comprising elevation of the Schneiderian membrane have been proposed in order to achieve the necessary vertical height of the alveolar process for the installation of implants with a sufficient length including maxillary sinus floor augmentation with the lateral window technique, osteotome-mediated sinus floor elevation and sinus membrane elevation without the use of a graft material. Sinus elevation with bone grafting has become a widely used method for overcoming bone insufficiency and the difficulties of endosseous implant placement in this region [14—18].

Although the clinical efficacy of bone grafting and maxillary sinus augmentation has been confirmed, issues such as the source of the bone used for grafting, the influence of the surrounding tissues on graft outcomes, or the surgical technique used remain under investigation. Different publications have reported the efficacy of different osteoplastic materials; Recently, other investigations have indicated that new bone formation and osseointegration are possible by maintaining the sinus membrane using a blood clot or peripheral blood only [19—23].

MATERIALS AND METHODS

The identification and selection of publications were carried out in several stages. First, the literature seafch was limited to publications dated from 2000 anwards. Second, the titles and abstracts of the retrieved articles were screened. Finally, the full texts of the selected articles were assessed. To assess the risk of bias in the included publications, the Cochrane risk-of-bias tool was used. The risk-of-bias levels were defined as follows:

- Low: If all criteria were met.
- Moderate: If one criterion was not met.
- High: If two or more criteria were not met.
- Unclear: If insufficient detail was reported to permit a judgment.

RESULTS

A total of 116 articles were reviewed using a systematic approach: 68 were identified in PubMed database, 34 in Google Scholar and 14 in other resources (Embase, Web of Science, and Cochrane Library). After applying the exclusion criteria, 52 publications remained for analysis. The selected articles analyzed maxillary sinus floor augmentation techniques,

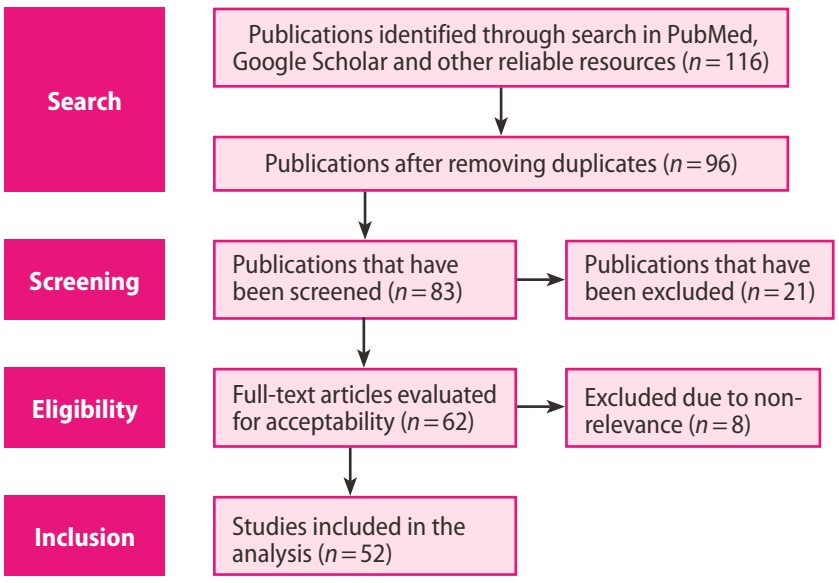

Fig. 1. Article selection process

both with and without graft materials (fig. 1). The figures 2-10 show various methods of sinus lift surgery.

DISCUSSION

The choice of maxillary sinus elevation and augmentation technique far a given patient depends on the surgeon's preference as well as the patient's anatomy. Patient anatomical factors include the residual bone height and amount of lift desired. There are two main approaches for maxillary sinus floor elevation: the direct approach and the indirect approach. Direct: lateral window technique; indirect: osteotome sinus floor elevation, bone added sinus floor elevation, minimally invasive transalveolar sinus approach, and antral membrane balloon elevation [24].

Direct/lateral window technique

In this technique, sinus membrane is directly visualized and elevated through the window created in the lateral wall of the maxillary sinus. The direct (lateral window) technique involves the following steps [25]:

1) **Anesthesia.** Infraorbital, posterior superior alveolar, greater palatine nerve block; subperiosteal anesthesia through slow infiltration (speed 1 ml/min).
2) **Incision.** Soft-tissue incisions must provide adequate room for creation of the lateral window. Anterior vertical incision should be at least 10—15 mm anterior to the wall of sinus to ensure soft tissue over the bone. Next, a mid-crestal ridge/palatal incision with 15C blade is made connecting the vertical incision. It is desirable to make the horizontal incision in keratinized tissue to facilitate suturing. Full-thickness flap is reflected to access canine fossa just below the infraorbital foramen, buttress of the zygomatic arch, and posterior

Fig. 2. Metzenbaum scissors are inserted under the split thickness incision and opened to stretch the nerve branches without cutting them [51]

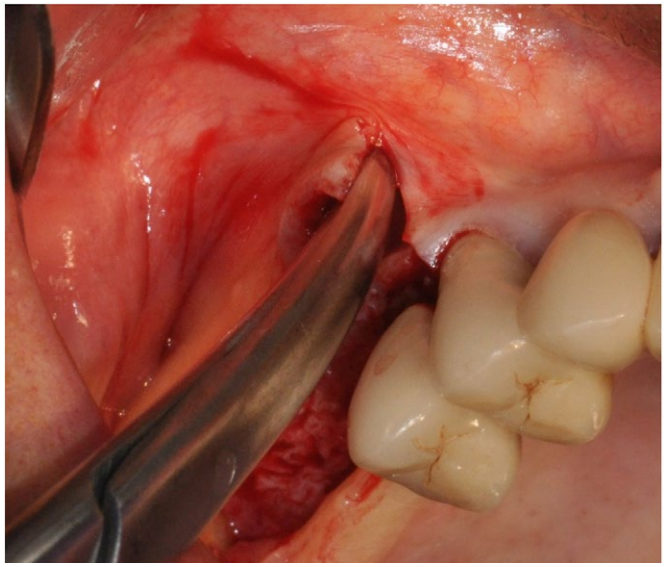

Fig. 3. The anterior alveolor artery has been isolated using piezo surgery [51]

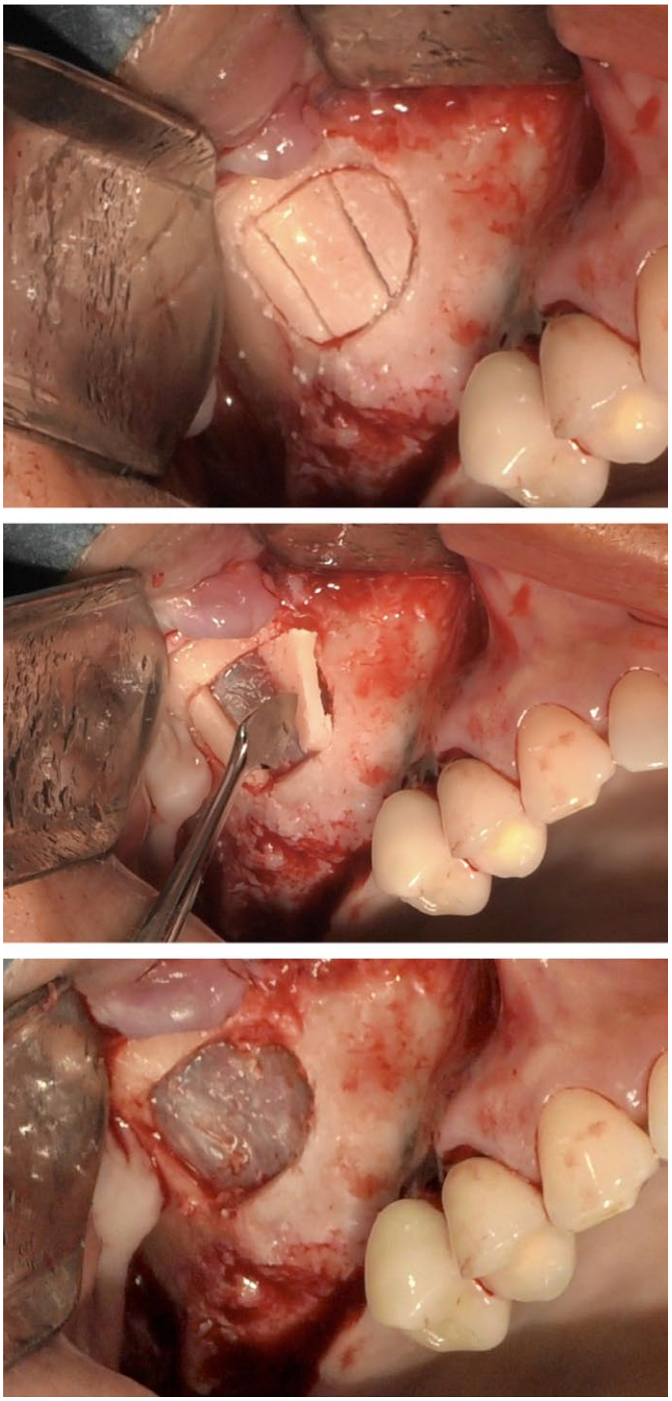

Fig. 4. A — the window is divided in 3 small pieces; B — all pieces are removed successively; C — the sinus membrane is intact [51]

lateral maxillary wall. While elevating full-thickness flap, the elevator must be adherent to the bone surface, so that the periosteum remains unchanged.

3) **Lateral window/antrostomy.** After flap elevation, a sterile number 2 pencil is used to demarcate the outline of the lateral wall window on the buccal plate of bone. Position of the antrostomy is determined by the size and location of maxillary sinus. Coronal outline of the window will depend on the height of the graft, length of the implant to be placed, and location of posterior superior alveolar artery. Apical outline of the window should be approximately 3 mm above the sinus floor. Mesial outline of the window should be as close to anterior wall and distal outline will depend on the number of implants to be placed. Size of the window should be 20 mm mesiodistally and 15 mm apicocoronally which is sufficient to guarantee easy surgical access. When the surgeons experience level increases then he/she can easily elevate the membrane with reduced access and a smaller, more conservative access window can be made. This will retain a large source of blood supply to the lateral wall and enhance maturation of graft. High-speed handpiece with number 8 diamond bur is used to outline the window until bluish hue is visible with gentle brushing or paintbrush stroke. The shape of the window is usually oval and should not have sharp edges that may cause perforation of the membrane. Bone tampers are used to in-fracture the sinus bony access window. Antrostomy can either be elevated or completely removed. It is elevated when there is good surgical access and the thickness of the cortical wall is<2 mm. It is completely removed when surgical access is difficult, in the presence of septa and in shallow sinus.
4) **Sinus membrane elevation.** Detach the sinus membrane with blunt instrument. Elevation should be preceded only when the membrane detaches [26]. Membrane should be elevated carefully starting on the sinus floor and then extending to the anterior and posterior walls with the help of sinus curettes. The final elevation is up to the medial wall to the full height of the expected graft placement. Sinus membrane integrity can be tested by asking the patient to breathe in deeply while observing the membrane lifting.
5) **Preparation of implant site.** If there is minimum of 3—4 mm of residual crestal bone of good quality, it is possible to place implants simultaneously or else place the implant after 4—6 months. Since the maxillary bone is a low-density bone, undersize the implant osteotomy site. Protect the sinus membrane with periosteal elevator to avoid damaging with drills.
6) **Graft placement.** Sinus membrane should be protected with collagen membrane. Implants are placed in the prepared implant sites. Bone grafts are placed in the least accessible area first. Anterior and posterior recesses are filled first followed by the area along the medial sinus wall. Do not compact the bone graft too tightly as it prevents vascularization. But some authors showed that sinus lift can be performed using the lateral approach with whole blood as the sole filling material with promising results. Thus, sinus augmentation with simultaneous implant placement can be done using platelet-rich fibrin as a sole grafting.
7) **Membrane placement.** Resorbable membrane is placed over the window (collagen membrane adheres over the bone which does not require fixation screws and does not require removal).
8) **Suturing/incision closure.** Nonresorbable monofilament suture and horizontal mattress sutures are used to suture the flap (does not require any advancement).

The major drawback associated with lateral antrostomy is that it requires the raising of a large flap for surgical access. This approach is more technique sensitive and time-consuming. The procedure's success relies mainly on the amount of residual bone [27—29].

Indirect/osteotome technique/ crestal approach/transalveolar approach

Indirect osteotome maxillary sinus floor elevation is generally indicated where the residual bone height is equal to or>6 mm [30]. Following are the steps of osteotome technique:

1) **Anesthesia.**
2) **Incision.** Crestal incision should be extended distally in some cases, to the tuberosity area where autologous bone needs to be harvested.
3) **Flap.** To expose ridge crest, full-thickness mucoperiosteal flap is elevated.
4) **Drilling.** Start the osteotomy preparation with pilot drill of 2 mm diameter keeping it 2 mm short of the sinus floor. Here, confirmatory radiograph should be taken by inserting pilot drill. Either the widened drills or set of osteotomes of varying dimensions can be sequentially used to widened the osteotomy site to the same level, i.e., 2 mm short of sinus floor. In low-density bone (D3 and D4), osteotomes are preferred to laterally condensed the bone and to enhance the density of the bone.
5) **Grafting.** Once the largest osteotome has expanded the implant site, particulated bone substitutes (mixed with autogenous bone) are added to the osteotomy as the grafting material. Composite bone graft composed of 25% autogenous and 75% hydroxyapatite graft should be preferred. Graft is inserted in the osteotome site, before the in-fracture of the sinus floor.

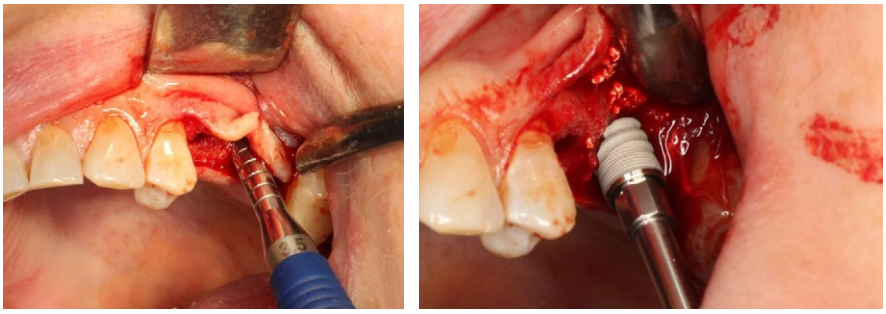

Fig. 5. A — Indirect sinus lift performed using osteotomes; B — implant placement completed

6) **Fracture.** An osteotome of lesser diameter than the implant body is inserted in the prepared osteotomy site and tapped gently to fracture up the sinus floor. Look out for the change in sound while in fracturing the sinus floor. When sinus floor fractures different pitch of sound can be heard;
7) **Sinus floor elevation.** This is done by reinserting the largest osteotome in the implant site with the graft material in place. The added bone graft exerts pressure onto the sinus membrane which elevates it further. Bone graft can be added and tapped to achieve the desired amount of sinus membrane elevation. Do not exceed the stretching limit of the membrane;
8) **Implant placement.** Implant fixture to be placed should be slightly larger in diameter than the osteotomy created by the final osteotome.

To prevent the sinus membrane perforation, Nkenke et al. (2009) recommended limiting sinus lift height to an average to 3.0±0.8 mm with the osteotome technique [20]. Soltan et al. (2012) introduced the antral membrane balloone elevation technique [31]. This minimally invasive elevates the sinus membrane but requires specialized instrumentation. Kher et al. (2014) proposed a minimally invasive transcrestal approach utilizing hydraulic pressure from calcium phosphosilicate putty to elevate the sinus membrane following initial osteotomy with Summers' technique [32].

Although this technique offerst advantages such as atraumatic sinus lining elevation, the putty contacts both the implant apex and membrane, poyentially leading to eventual bone volume loss over time. The autogenous core lift technique offers the advantages over other methods by placing an autogenous bone core at the implant apex, reducing the need for bone grafts and maintaining apical bone volume. Limitations include trephine use, which carries a high perforation risk when used by inexperienced clinicians. It also requires precite residual bone volume assessment using advanced imaging like CBCT, which may not be readily availible. Furthermore, long-term studies on bone volume stability with this technique are lacking [31, 33—36].

Maxillary sinus floor augmentation using blood without graft material

Bone grafts for sinus augmentation demonstrate high success rates but carry drawbacks: second surgical sites for autogenous harvesting, increased complications, higher costs, and prolonged surgery. Lundgren et al. (2017) first reported spontaneous bone formation below the sinus floor after cyst enucleation, revealing the Schneiderian membrane's osteogenic potential [17]. Subsequent studies confirmed successful implant rehabilitation "without" bone grafts, demonstrating new bone formation via blood clot-induced osteogenesis (guided tissue regeneration principle). The maxillary sinus membrane itself exhibits significant osteogenic capacity [23, 32, 37—41].

As studies validated implant success without grafting, focus shifted to developing minimally invasive protocols.

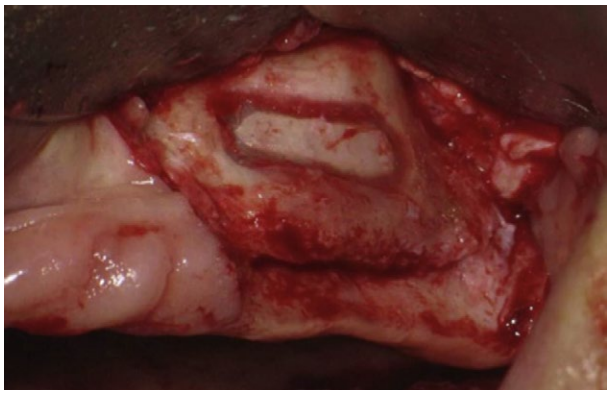

Fig. 6. Maxillary sinus floor augmentation using blood without graft material. surgical approach with a total mucoperiosteal flap. The osteotomy was realized with an area of approximately 1 cm² [52]

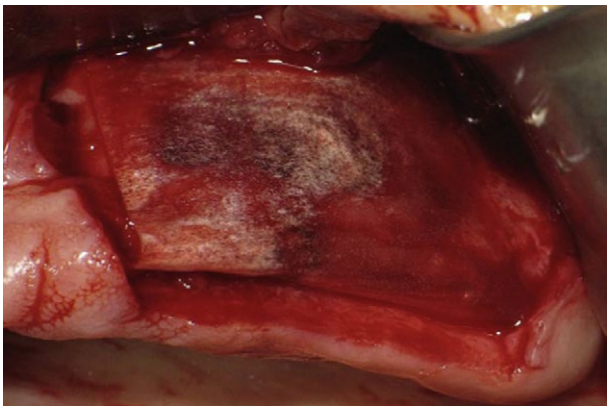

Fig. 8. The peripheral blood filled the maxillary sinus between the sinus floor and the roof [52]

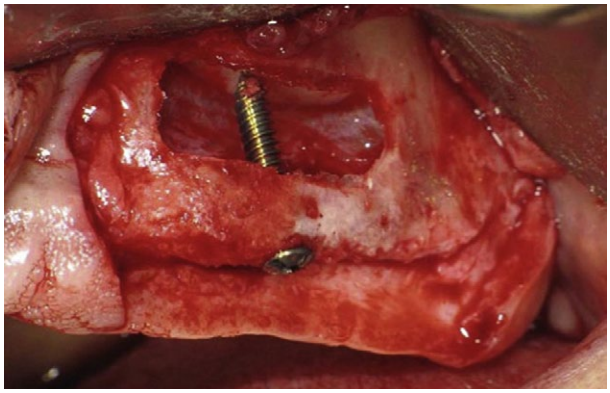

Fig. 7. A 12-mm screw installed in the maxillary sinus. The superior part of the screw is a support for the bone tissue with a sinus membrane [52]

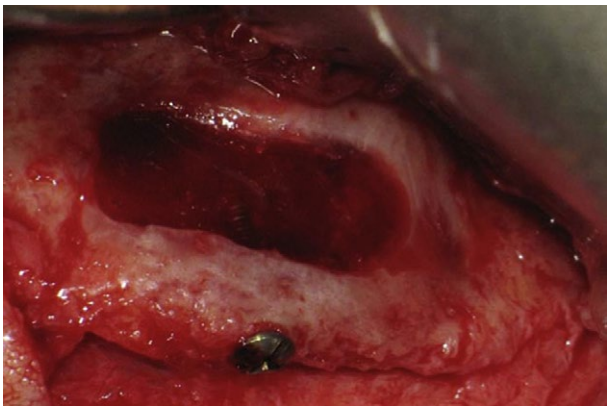

Fig. 9. An absorbable membrane was installed in the lateral bony windows and closed with an absorbable suture [52]

Graftless sinus lift applies to both lateral and crestal approaches with high success. Crestal techniques offers:

- Superior conservatism and reduced invasiveness;
- Lateral compression/expansion of adjacent bone;
- Enhanced manual control for optimal implant axis positioning (preventing dehiscence/fenestration) [42—44].

Surgical protocol:

1) Anesthesia. Local administration.
2) Access. Mucoperiosteal flap via alveolar ridge incision, vertical releasing incision (anterior to defect).
3) Osteotomy. Vertical/horizontal cuts with number 8 spherical diamond bur (20,000 rpm).
4) Membrane elevation. Detach sinus mucosa while preserving bony window attachment. Fracture sinus floor via gentle malleting. Axially elevate Schneiderian membrane.
5) Closure. Suture flap for submerged healing

While systematic reviews assess graftless sinus lift, *no review exclusively includes human RCTs comparing de novo bone formation in graftless vs. bone-substitute-augmented sinuses (lateral approach).

Complete maxillary edentulism causes severe 3D atrophy with osteoporotic-like bone:

- Thin cortical layers often preclude primary implant stability;
- Tenting-created spaces exceed those in partial edentulism;
- Stable blood clot formation (essential for osteogenesis) becomes challenging.

Lie et al. (2022) remains the sole study exclusively involving complete edentulism [45]. Outcomes may be influenced by:

- Space maintainer variations;
- Heterogeneous bone substitute materials;
- Mean residual bone height [46, 47].

Study on rabbits

Sohn et al. (2010) compared graftless versus grafted sinus lift outcomes in a rabbit model [48]. The experimental group received no graft material, while the control group received Bio-Oss.

Key findings:

- Earlier and denser new bone formation occurred in the graftless group;
- The replaceable bone window acted as an autologous barrier, accelerating early osteogenesis compared to collagen membranes over bone grafts;
- Both the bone window and elevated sinus membrane demonstrated osteoinductive properties [17].

Hydraulic sinus lift technique (hysilift)

The hydraulic pressure technique via the crestal approach has recently been used for sinus membrane elevation. This method facilitates Schneiderian membrane detachment by injecting fluid followed by spontaneous expulsion or aspiration, creating a sub-Schneiderian space for subsequent graft material insertion.

Advantages: conceptually, using liquid-state graft material simplifies the procedure — hydraulic injection simultaneously elevates the mucosa and fills the sub-Schneiderian space. The technique offers a short learning curve, minimal invasiveness, and high precision. *Disadvantages:* conventional single-use syringes provide limited piston progression feedback, relying entirely on operator tactile sensitivity [49].

Balloon elevation technique

Minimally invasive antral membrane balloon elevation (MI-AMBE) is a modification of the bone-added osteotome sinus floor elevation (BAOSFE) technique. This approach elevates the sinus membrane through a 3.5 mm osteotomy site using a specialized balloon catheter [49, 50].

Advantages:

- Predictable flapless implant placement;
- Preservation of crestal bone architecture;
- Maintenance of peri-implant mucosal health;
- Disadvantages:
- Limited antral membrane elevation capacity;
- Technically demanding (requires advanced surgical skills);
- High risk of membrane perforation, even with endoscopic guidance [49, 50].

CONCLUSIONS

Within the study limitations, maxillary sinus elevation and augmentation provide predictable regeneration of deficient bone in the posterior maxilla. This offers significant advantages for long-term success of implant-supported rehabilitation. Two principal approaches exist: the direct (lateral window) technique and the indirect techniques: osteotome-mediated sinus floor elevation, bone-added osteotome sinus floor elevation (BAOSFE), minimally invasive transalveolar approach, antral membrane balloon elevation, and graftless modifications. While some authors report greater reliability with graft-based techniques, others demonstrate comparable success without grafts. Technique selection should prioritize anatomical factors, particularly defect topography and volume.

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