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Comparative analisis of closed sinus-lifting: anatomical, surgical and clinical aspects

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ABSTRACT

The article presents a structured analysis of modern techniques of closed (transalveolar) sinus lift, based on 15 clinical and experimental studies published between 2018 and 2025. Both technical aspects and long-term outcomes are considered, providing a comprehensive view of current trends in implantology and bone surgery.

Key anatomical factors influencing surgical decision-making are discussed, including sinus pneumatization, bone wall thickness, septa, mucosal thickening, and anatomical variations. These parameters determine the complexity of the procedure, the risk of complications, and the feasibility of minimally invasive approaches.

A comparative review of major techniques is provided: osteotome, hydraulic, balloon-assisted, piezosurgical, osseodensification, combined, and graft-less protocols. Each is evaluated in terms of invasiveness, risk of Schneiderian membrane perforation, surgical time, long-term implant survival, and complication rates.

The review highlights that the osteotome technique remains the most widely used but carries a higher risk of perforations; hydraulic and balloon methods are more tissue-preserving but require specialized equipment and experience; piezosurgery reduces trauma yet prolongs surgery; osseodensification improves peri-implant bone density but is limited in highly pneumatized sinuses.

The importance of individualized surgical planning is emphasized, taking into account residual bone volume, ridge width, patient's systemic condition, and surgeon's expertise. The use of CBCT and careful preoperative assessment are identified as key factors for achieving reliable and safe outcomes in closed sinus lift procedures.

Keywords: closed sinus lift, open sinus lift, maxillary sinus, pneumatization, Schneiderian membrane

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Сравнительный анализ методов закрытого синус-лифтинга: анатомо-хирургические и клинические аспекты

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АННОТАЦИЯ

В статье представлен систематизированный анализ современных методик закрытого (трансальвеолярного) синус-лифтинга, основанный на данных 15 клинических и экспериментальных исследований, опубликованных в 2018–2025 гг. Рассмотрены как технические аспекты вмешательства, так и долгосрочные результаты, что позволяет оценить эволюцию подходов в имплантологии и костной хирургии.

Описаны ключевые анатомо-топографические факторы, влияющие на выбор хирургической тактики: степень пневматизации синуса, толщина костных стенок, наличие перегородок и мукозальных утолщений, анатомические аномалии. Эти параметры определяют сложность операции, риск осложнений и возможность применения минимально инвазивных техник.

Сравнительно проанализированы основные методики: остеотомная, гидравлическая, баллонная, пьезохирургическая, оссеоденсификация, комбинированные и безграфтовые (graftless) протоколы. Каждая оценена по инвазивности, риску перфорации мембраны Шнайдера, длительности операции, долгосрочной выживаемости имплантатов и частоте осложнений.

Выявлено, что остеотомная техника остается наиболее распространенной, но сопряжена с риском перфораций; гидравлическая и баллонная более щадящие, однако требуют оборудования и опыта; пьезохирургия снижает травматичность, но увеличивает время вмешательства; оссеоденсификация повышает плотность кости, но ограничена при выраженной пневматизации. Подчеркнута необходимость индивидуализированного выбора тактики с учетом анатомических особенностей, объема остаточной кости, соматического статуса пациента и уровня подготовки хирурга. Отмечена роль конусно-лучевой компьютерной томографии и тщательного планирования как ключевых условий безопасности и эффективности закрытого синус-лифтинга.

Ключевые слова: закрытый синус-лифтинг, открытый синус-лифтинг, гайморова пазуха, пневматизация, мембрана Шнайдера

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Closed sinus lift (also known as bone augmentation through the alveolar ridge) is a minimally invasive surgical procedure aimed at increasing bone height in the upper jaw when it is insufficient for implant placement, but allows avoidance of lateral access to the maxillary sinus.

The indications for closed sinus lift are:

- insufficient bone height in the lateral sections of the upper jaw (usually 5–8 mm);
- planned implant placement in the premolar or molar region of the upper jaw;
- absence of pronounced sinus pneumatization (or acceptable in terms of volume);
- patients who do not have a history of pronounced inflammation in the sinus area.
- Advantages of this method:
- without increasing the bone volume, it is impossible to ensure stable implant fixation;
- the procedure avoids more traumatic lateral access;
- the method is used as an alternative to bone grafting in cases of moderate atrophy.

The success of osseointegration with closed sinus lifting is comparable to the classic method, while the risk of complications is significantly lower with the right indications.

Up to 40% of patients undergoing implant placement in the upper jaw are suitable for closed sinus lift. This makes it one of the most commonly used augmentation methods in clinical practice.

ANATOMICAL AND TOPOGRAPHICAL FEATURES OF THE SINUS

The maxillary sinus is the largest of the paranasal sinuses, occupying the body of the upper jaw and located lateral to the nasal cavity (*cavitas nasi*). It has a pyramidal shape with its base facing the nasal cavity and its apex pointing toward the zygomatic bone. The walls of the sinus are thin, especially the floor, which often recedes between the roots of the molars and premolars, causing it to be closely connected to the dentofacial system. The inner surface is lined with a mucous membrane — Schneider's membrane, which is highly sensitive and has a weak regenerative capacity in case of perforation [1, 2].

The thickness of the bone wall of the sinus floor varies between 0.5 and 2.5 mm, and in areas of pronounced pneumatization, it may be represented only by a thin bone plate or be completely absent. Sinus pneumatization progresses with age and is especially active after the loss of chewing teeth. This leads to a decrease in the height of the alveolar ridge, which, in turn, limits the possibility of primary stabilization of implants.

The most important parameters when planning a sinus lift are:

- **Residual Bone Height** (RBH) — the residual bone height between the sinus floor and the alveolar ridge;
- **basal bone width** determines the accessibility of the lateral or transalveolar approach;
- **sinus shape and volume** — a narrow, V-shaped sinus complicates instrumentation and increases the risk of membrane damage, while wide and voluminous sinuses require a larger volume of osteoplastic material.

The presence and location of septae are also important, as they can hinder access and require modification of the lateral window shape. *Septae* are more common in areas with multi-rooted teeth and can be either complete or partial, creating a false floor and increasing the risk of perforation.

It is also necessary to take into account the presence of mucosal thickening, cysts, chronic sinusitis, as well as the anatomical location of the the artery of the canalis sinuosus and alveolar vessels in the lateral wall. In cases of pronounced venous outflow or varicose veins in the sinus area, the risk of intraoperative bleeding increases.

The individual anatomy of the maxillary sinus dictates the choice of sinus lift technique — lateral (open) or transalveolar (closed) — the volume of osteoplastic material, the access route, and the instruments used. Correct assessment of these characteristics using cone beam computed tomography and clinical examination minimizes the risk of complications and ensures the predictability and durability of implant treatment.

DESCRIPTION OF CLOSED SINUS LIFTING TECHNIQUES

1. Osteotomy technique (BAOSFE)

The osteotomy technique, or BAOSFE (bone-added osteotome sinus floor elevation) method, originally proposed by R.B. Summers, remains one of the most widely used. The technique involves the use of osteotomes of various diameters, which are used to sequentially prepare the bed and fracture the sinus floor. The formed space is filled with augmentation material, and the Schneider membrane is lifted. The method is effective for RBH ≥5 mm. However, it is associated with the risk of barotrauma, dizziness, and membrane perforation (up to 15% of cases). The advantages include relative simplicity and accessibility, especially in conditions of limited budget. The disadvantages include high invasiveness and limited visualization of the intervention area [5].

2. Hydraulic lifting

Hydraulic sinus lifting involves the injection of sterile saline solution under pressure through the osteotome to gently detach the membrane from the bone bed. The method is safe, especially when using biomaterials and membranes. It is often combined with the use of plasma enriched with growth factors (PRF), which enhances the regenerative effect. The technique requires accurate calculation of the volume of the injected liquid. Errors in dosage can lead to excessive tissue hydration and epithelial detachment. Suitable for RBH from 3 to 5 mm. The efficiency is comparable to balloon technology, especially in modified protocols.

3. Balloon sinus (MIAMBE)

Minimally invasive alveolar balloon expansion (MIAMBE) is a gentle lifting method using a sterile balloon inserted through an osteotomy opening [7]. The balloon expands under controlled pressure, lifting the membrane evenly. The perforation rate is less than 3%. The method provides lifting up to 10 mm. The high survival rate of MIAMBE implants has been clinically proven. However, the technique requires specialized equipment, strict adherence to protocols, and medical training. Applicable for RBH of 3 mm and above. One of the main advantages is the low injury rate and high reproducibility of the result.

4. Osseodensification (Densah burs)

Osseodensification is an innovative technique that makes it possible not to remove bone, but to compact it using special rotating grooved drills (Densah burs). This ensures an increase in the primary stability of the implant, especially in conditions of D_3–D_4 bone. The method allows for safe and controlled lifting of the Schneider membrane due to internal pressure. The frequency of perforation is 5–7%. The method is well combined with non-membrane protocols and single-stage implantation. In addition, osseodensification reduces the need to use bone material for lifting less than 4 mm.

5. Piezosurgical lifting

Piezosurgery is a method based on the use of ultrasound vibrations for precision bone incision without damaging soft tissues [7, 8]. The advantage is high precision and minimal risk of membrane perforation. The procedure takes longer but is associated with minimal tissue trauma and quick rehabilitation. It is often used in patients with severe sinus pneumatization and thin membrane. With an RBH of 3 mm and above, stable results can be achieved [9]. High-quality visualization and a doctor's experience in handling piezo technologies are needed.

6. Combined and graft-less techniques

Combined techniques are a combination of two or more methods (for example, osteotomy + osseodensification or piezo + balloon) [10, 11]. The goal is to enhance the lifting effect while minimizing injury. Graft-less (graft-free) techniques are aimed at stimulating autogenous osteogenesis without the use of bone substitutes. The success of these approaches depends on the blood supply, the height of the residual bone, and the stability of the membrane. They are most often used at RBH ≥5 mm [12]. The data on implant survival are encouraging, but careful patient selection is needed.

7. The Fugazzotto technique

The essence of the technique is to use trepanators with limited depth to create a central channel in the crest of the alveolar process, after which the removed bone cylinder is used as a hydraulic piston to gently lift the Schneider membrane. After membrane detachment, an osteoplastic material (most often xenogenic or allogeneic) is inserted into the subantral space, and then the implant is installed simultaneously.

In a study involving 132 clinical cases, a 96.2% survival rate of implants was achieved, which is comparable to the results of more invasive techniques with significantly less injury and shorter treatment time [13].

The key point of the technique is predictability and control: unlike the classical osteotomy approach, the trepan method avoids excessive pressure on the membrane, reducing the risk of its perforation. Moreover, the resulting bone cylinder can be used as an autogenous osteoconductive material.

COMPARATIVE ANALYSIS OF TECHNIQUES: EFFECTIVENESS, COMPLICATIONS AND CONTRAINDICATIONS

The differences between closed sinus lifting techniques are of critical importance when choosing a surgical approach. The most important criteria for comparative analysis are: injury, the risk of perforation of the Schneider membrane, the potential for bone regeneration, technical complexity, cost, the need for specialized equipment and the nature of complications.

1. **Osteotomy techniquea**: нdespite its wide availability, it demonstrates a relatively high level of injury. The main complications are short-term dizziness, pain in the postoperative period, partial membrane perforation (up to 15%) [13]. The presence of anatomical variations (septa, hyperpneumatization) increases the risk of insolvency. The method is of limited use at RBH <5 mm.

2. **Osseodensification**: provides a significant increase in the primary stability of implants due to the compression of the trabecular bone. Complications are rare and most often associated with technical errors (for example, excessive rotation). Perforations are observed in 5–7% of cases. The method is suitable for both single-stage and delayed implantation. The advantage is to improve the quality of the surrounding bone, especially in D_3–D_4.

3. **Balloon lifting:** has the least invasiveness among all techniques. The complication rate is less than 3%, mainly microperforations. However, there are cases of insufficient lifting of the membrane or technical failures of the cylinder. It requires careful pressure control. It is excellent for thin membranes and low RBH (3–5 mm). There is no visual control, which requires skill and precision.

4. **Hydraulic method:**: the risk of perforation is comparable to the balloon technique, especially with adequate fluid injection technique. The main complication is epithelial detachment with excessive pressure. The technique is the least expensive among low-traumatic alternatives, but it requires practical experience. It is especially promising when using autogenous growth factors (PRF, PRP) [14].

5. **Piezosurgery**: бa safe and visually controlled method that uses spot ultrasound. Complications include insufficient lifting due to limitations in the power of the equipment, as well

as the risk of overheating of the tool. It is suitable for patients with a thin membrane and severe pneumatization [15]. It is characterized by high accuracy and minimal bleeding.

6. **Combined and graft-less approaches**: combine the advantages of different methods, allowing individualized treatment. Complications depend on the components of the technique: osteotome + balloon — microperforation is possible; piezo + PRF — prolongation of the operation. Graftless approaches are promising, but they are strictly indicated for patients with sufficient vascular network volume and bone height. The lack of bone material can be compensated by the PRF and osteo-inductive properties of the membrane.

7. **Fugazzotto technique:**
- minimal invasiveness (compared to lateral access);
- simultaneous implantation (when primary stability is achieved);
- reducing the risk of perforation of the Schneider membrane; accelerated postoperative recovery;
- high clinical predictability with proper patient selection.

Indications and limitations

The method is recommended for:
- residual height of the alveolar ridge ≥4 mm;
- absence of chronic sinusitis;
- the normal thickness of the bone walls of the sinus;
- good visualization and diagnosis (cone beam computed tomography is required).

Limitations include anatomical variations (multicameral sinuses, pronounced septa), a high degree of pneumatization, an inadequate osteotomic bed, and the inability to achieve implant stability.

Thus, the Fugazotto technique remains relevant today as a tool in the arsenal of minimally invasive preimplantation surgery, providing high efficiency and comfort for the patient while observing the protocol.

The osseodensification and balloon sinus lifting methods are characterized by the lowest risk of perforation of the Schneider membrane and provided a high level of primary stability of the implants. Piezosurgery is preferred for complex sinus anatomy. The classical osteotomy technique was characterized by greater invasiveness. The hydraulic method showed high efficiency, but required strict pressure control. The combined techniques have demonstrated encouraging results with appropriate preparation of the operating field. The Fugazzotto technique demonstrates accelerated recovery with proper application and operator experience and technical skill.

The literature data emphasize the importance of an individualized approach in choosing a sinus lifting method. The anatomy of the sinus, the presence of septa, the thickness of the Schneider membrane, the shape of the sinus and the height of the alveolar process — all this should be taken into account when planning a surgical intervention. In addition, despite the availability of promising graft-free techniques, a thorough assessment of the clinical situation and the competence of the doctor remain crucial factors.

Thus, based on the analysis of modern publications on the results of the use of closed sinus lifting techniques, it can be concluded that the safest and most predictable techniques are osseodensification and balloon lifting. With proper planning and protocol compliance, each of the techniques can be effective.

ADDITIONAL INFORMATION

Author contribution. All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

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