Chapter 2

Management of the Complications of Maxillary Sinus Augmentation

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Additional information is available at the end of the chapter

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Abstract

Dental implant rehabilitation of the posterior maxillary region has always been a challenging issue due to both alveolar ridge atrophy and sinus pneumatization. Maxillary sinus augmentation is a well-known and predictable procedure in vertical deficiencies of the posterior maxilla. To date, various techniques have been described based on the physiology of intrasinus bone repair to obtain better outcomes. Nevertheless, these procedures could also be associated with several intra- and postoperative complications such as perforation of the sinus membrane, hemorrhage, infection, graft resorption, and loss of the graft or implants. The aim of this chapter is to review the contemporary methods for maxillary sinus augmentation and to present both recommendations for prevention and management of the associated complications.

Keywords: dental implants, complication, management, sinus augmentation, sinus lift

1. Introduction

Oral rehabilitation with dental implants has been widely practiced with a success rate well over 95% in complete, partial, or single edentulism [1]. However, dental implant placement in the posterior maxillary region is frequently compromised due to certain anatomical and physiological conditions including postextraction alveolar ridge atrophy, pneumatization of the maxillary sinus, and poor quality of residual alveolar bone [2]. Therefore, vertical alveolar ridge augmentation is often mandatory before or in conjunction with the installation of implants [3].

In this regard, maxillary sinus augmentation is a well-known, predictable, and largely required procedure for increasing residual alveolar bone height by elevation of the Schneiderian membrane [4]. Since the introduction of the surgical technique by Tatum [5] in 1976 and Boyne [6] in 1980, various approaches have been extensively studied.

Access to the Schneiderian membrane may generally be achieved directly by lateral approach or indirectly through transcrestal osteotomy. To date, numerous modifications using both approaches have been described, and the vast majority of them have proved their worth and efficacy over the years. Nevertheless, the procedure could also be associated with several intra- and postoperative complications, which may result with a negative impact on the patient's quality of life by additional surgery, hospitalization, and prolonged recovery time. Subsequently, the outcome of the implants and the success of the oral reconstruction procedure may be compromised [4].

Maxillary sinus augmentation procedures are increasingly performed by oral and maxillofacial surgeons, periodontists, dentists, and otorhinolaryngologists worldwide. Prevention and management of the associated complications principally begin with having a thorough knowledge of the sinus augmentation techniques. Thus, the purpose of this chapter is to review the contemporary methods for maxillary sinus augmentation and to present both recommendations for prevention and management of the associated complications.

2. Internal sinus lifting (crestal approach)

The crestal approach involves the elevation of both the Schneiderian membrane and bony floor of the sinus indirectly through the alveolar crest without a preparation on the lateral wall of the sinus. With this technique, the elevation of the sinus floor up to 5 mm without any perforations was shown microscopically [7]. Internal sinus lifting through the transcrestal approach is a well-validated surgical option for situations where there is a minimum of 5–6 mm residual bone height [8]. The technique is considered to be more conservative than the conventional lateral approach and may reduce the operation time and postoperative morbidity [4].

2.1. Surgical technique

Since its introduction in 1986 by Tatum [5], the crestal approach has undergone several modifications in an effort to expand its feasibility and obtain greater success rates with reduced complications [9]. Some of these modifications rely on using medical devices and instruments that are specific to their particular technique. All of these techniques have demonstrated high rates of success; however, there is still insufficient evidence from prospective studies to validate their utility in clinical practice.

2.1.1. Osteotome-mediated sinus floor elevation (OSFE)

OSFE is based on the use of a socket former for the selected implant size for preparing the implant site and hand tapping it in a vertical direction to accomplish a "green-stick fracture" of the sinus floor. Subsequently, implants are placed to support the elevated floor of

the maxillary sinus. In 1994, Summers [8] described a modified approach for OSFE by using a set of conical osteotomes with increasing diameters for both implant site preparation and sinus floor elevation (**Figure 1**). This technique allows to increase the bone density, resulting in better primary stability of inserted dental implants.

2.1.2. Bone added osteotome-mediated sinus floor elevation (BAOSFE)

BAOSFE, also referred to as the "Summers technique," is a combination of the OSFE technique with the addition of a bone graft material. The mass of the native bone and the graft material is utilized as a hydraulic plug by the upward push of the osteotome to elevate the sinus floor. Subsequent placement of the implants facilitates the elevation of the sinus membrane by tenting it with their apical end. Various graft materials may be used such as autogenous bone, allografts, xenografts, and alloplastic bone materials [10]. There have been a number of studies claiming the necessity of bone graft material to keep the volume of the sinus membrane [11], whereas others have reported favorable results and reduced risk of infections without the use of any bone graft [12].

2.1.3. Minimally invasive antral membrane balloon elevation (MIAMBE)

MIAMBE is a modification of the BAOSFE method in which sinus lift is performed by the insertion of a specially designed balloon through the osteotomy site on the alveolar crest, insufflating it with saline solution through a catheter in order to detach the sinus membrane. This technique is intended to be applied to alveolar crests measuring 3 mm or less and provide a gain in height up to 10 mm with few intraoperative complications [13].

2.1.4. Hydrostatic sinus lift

Hydrostatic sinus lift technique, first proposed by Chen et al. [14] in 2005, relies on the principle of lifting the Schneiderian membrane using hydraulic pressure. Following the initial drilling, the drill is connected to a pump that produces high hydraulic pressure, which is used to break the sinus floor and to lift the membrane. Along with the recent developments, this technique is supposed to provide reduced risk for sinus membrane perforation, minimal trauma, and postoperative complications for sinus lifting surgery [15].

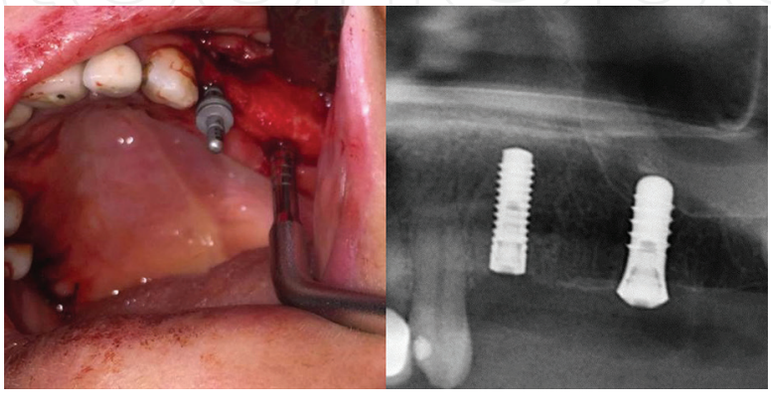

Figure 1. Use of conical osteotomes for both implant site preparation and sinus floor elevation and simultaneous implant installation.

2.2. Internal sinus lift complications: Prevention and management

Internal sinus lifting is associated with several intraoperative and postoperative complications, which may compromise the outcomes of the treatment and health of the patient. An in-depth overview on causes, prevention, and management of these complications is presented later.

2.2.1. Intraoperative complications

2.2.1.1. The Schneiderian membrane perforation

The main drawback of this procedure is the uncertainty of a possible perforation of the Schneiderian membrane because the sinus lifting procedure is performed blindly due to the impossibility to visualize the sinus floor [5, 6]. The incidence of membrane perforations in osteotome-mediated sinus lift has been reported to range between 4 and 25% [16], while such complication has been described in 25–44% of external sinus lifting cases [17]. It should also be noted that microlacerations are impossible to detect in many cases; thus, the true incidence may be higher than currently reported. Perforation of the sinus membrane may lead to the development of sinusitis, epistaxis, exfoliation of graft particles from the nose, or a patent oral-antral communication. Development of a sinus tear during the internal lifting may not always be determined with the Valsalva maneuver or more accurately by the inspection with an endoscope [18].

Membrane perforation may occur due to several factors related with anatomy, excessive tapping, or overzealous elevation. One possible anatomical challenge may be an oblique sinus floor at the site of preparation, which may lead difficulty in initial in-fracturing and resultant membrane perforation. Likewise, thin sinus mucosa and irregularities of the bony sinus floor such as sharp ridges, antral septa, and spines may pose risks for membrane perforation [19]. Furthermore, elevation of the Schneiderian membrane beyond its capacity may also cause the membrane to tear. To date, a wide range between 2 and 10 mm has been reported for height of sinus elevation using transcrestal techniques [2, 7, 13, 18]. A thorough clinical and radiological examination should be carried out to evaluate the anatomy of the sinus, the presence of sinus pathology, and the residual alveolar bone height. Additionally, intraoperative use of sinuscopy has been suggested to allow for elimination of any sinus pathologies, control of the graft position, and reduction of the risk of sinus membrane perforation and postoperative complications [7].

Although it has been reported that a gain up to 10 mm in alveolar height can be achieved using several modifications of transcrestal approach, it has commonly been assumed that the Schneiderian membrane can be safely elevated for 5 mm through the internal sinus lifting [7, 20]. Therefore, it should be kept in mind that the maximum elevation height obtainable with transcrestal techniques differs interindividually because it highly correlates to the elastic properties of the Schneiderian membrane and the maxillary sinus anatomy as well as the surgical technique of force transmission [21]. The osteotomes should not be tapped or advanced beyond the sinus border. Further attempts for the prevention of membrane perforation may include inserting a collagen membrane into the osteotomy and not to use the particulate graft materials with sharp nature.

Unfortunately, when membrane perforation is detected during the procedure, there is no possibility to repair the torn membrane without changing to a lateral surgical approach because

of the limited access [18]. A number of researchers have reported that small perforations show complete recovery in 6 months spontaneously, and it is not required to abort the simultaneous placement of implants or bone grafts [18, 19]. However, if high risk of infection is suspected or the size of perforation is large, postponing the surgery or repairing the perforation through a lateral approach should be considered.

2.2.1.2. Inadequate primary stability

Implant stability initially relies on the host bone present at the created osteotomy site, while future additional support is potentially gained by the consolidation and amalgamation of the grafted material with newly formed host bone. Optimal primary stabilization at the time of implant placement is essential for implant success and survival [22]. Lack of primary stabilization may be related to insufficient bone height/width, poor bone quality, or overtreatment with the osteotomes. In cases where poor bone quality is encountered, consideration might be given to greater use of the osteotome versus drilling to increase the bone density and implant stability [22]. Further attempt might include the underpreparation of implant bed with either osteotomes or drills and insert a substantially larger diameter implant to maximize the primary stability. However, it should also be kept in mind that underpreparation may lead to excessive compression during the implant installation and resultant fracture of the bony trabeculae and poor recovery of vital bone. By the same token, the use of tapered implants versus parallel-walled implants has been shown to increase the primary stability in low-density bone as they have higher insertion torque during the placement [23]. Moreover, rough-surface implants are also recommended because they are more prone to adhesion of the bone fragment surfaces resulting in an increased bone formation [24].

2.2.1.3. Displacement of the implant to the sinus cavity

Although reportedly uncommon, accidental displacement of the implant into the sinus cavity may occur due to poor bone quality, untreated membrane perforation, and the use of excessive force during the installation [25]. The prevalence is probably underestimated due to the lack of cohort studies and few case reports that have been published [26]. A displaced implant should be removed from maxillary sinus as soon as possible to avoid further complications such as maxillary sinusitis, narrowing of the ostium, or reduced ciliary movements, impaired mucociliary clearance, pseudocyst formation, aspergillosis, migration into the ethmoid sinus, orbital floor, sphenoid sinus, or even the cranial fossa, orbital cellulitis and optic nerve damage, meningitis, or brain abscess [27–31]. Different techniques have been proposed for the removal of a displaced implant from the sinus using a transnasal or transoral approach [32]. The use of transnasal endoscopy has the advantages of a low morbidity, rapid recovery, and treatment of paranasal sinusitis, which, however, has several limitations including the requirement of a specific equipment, specialized surgery rooms, and often general anesthesia [33]. Moreover, the location and size of the implant have to pass through the ostium [25]. Alternatively, a transoral approach with the creation of a bony window in the anterior-lateral wall of the maxillary sinus can be performed. Transoral surgical techniques may remove implants successfully allowing a better visibility combined with the ability to remove even large implants under local anesthesia [32]. On the other hand, since this approach diminishes the integrity of the lateral wall of the maxilla, the access window may not completely reossify [34].

2.2.2. Postoperative complications

Postoperative infection, implant loss, benign paroxysmal positional vertigo, hemorrhage, nasal bleeding, blocked nose, hematomas, and loosening of cover screws are among the reported complications following the OSFE procedure.

2.2.2.1. Infection

Site infection is not only the most common postoperative complication but also among the foremost etiologies of possible complications. Infection may occur due to poor oral hygiene, contamination of the implant surface or graft material, and underlying diseases of the sinus. Particular attention should be paid to minimize the bacterial load during the surgery. The site should be evaluated for the presence of any active periodontal disease or endodontic infection. Moreover, the use of preoperative and postoperative antibiotics and antiseptic mouth rinses is also recommended to decrease potential pathogenic bacteria [35].

2.2.2.2. Benign paroxysmal positional vertigo (BPPV)

BPPV is a common vestibular end organ disorder characterized by short, repeated, brief periods of vertigo that are triggered by certain head movements in the plane of the posterior semicircular canals [36]. Recent evidence suggests that BPPV may occur as an early postoperative complication following OSFE [37]. It has been reported that the percussive forces of the surgical mallet may lead to the detachment of the otoliths from the otoconia layer of the utricular macula and cause them to float around in the endolymph [36, 38]. Moreover, hyperextension of the head during the operation favors the displacement of these free-floating particles into the posterior semicircular canal, creating the position- or motion-induced vertigo [39].

The diagnosis of BPPV is commonly established by the Dix-Hallpike test [40]. The patient experiences vertigo and a characteristic torsional nystagmus when moved quickly into a supine position with the head turned, so that the affected ear is 45° below the horizontal plane [41]. The direction of nystagmus is essential to specify the affected canal as both the vertical and the horizontal semicircular canals may be affected. The posterior canal is by far the most frequently affected canal (80–90%); involvement of the horizontal (lateral) canal is accounting for 5–30%, and the anterior canal is 1–2% of patients [42–44].

The treatment modalities of BPPV include follow-up of the patient, vestibulosuppressant medication, vestibular rehabilitation, repositioning maneuvers, and surgery [45]. Recent evidence supports that the repositioning maneuvers may effectively help in eliminating the vertigo due to BPPV, reducing the risks of falling, and improving the quality of life [44]. To date, several methods with different sequential head movements have been proposed to move otoconial debris from the semicircular canal to the utricle. Among these, the Epley maneuver (canalith repositioning procedure, CRP) and the Semont maneuver (the liberatory maneuver) have been proposed for the treatment of posterior-canal-type BPPV, while the lateral-canal-type BPPV is usually treated with the Lempert maneuver [46–48]. In addition, self-treatment exercises such as the Brandt-Daroff exercise have also been recommended for treatment of any types of BPPV [42, 49].

The incidence of OSFE-induced BPPV has been reported to be less than 3%, and the condition is self-limiting as symptoms subside or disappear within 6 months of onset [39]. However, the symptoms involved may be sufficiently severe to significantly alter the patient's daily life [41]. It is important to be aware of and inform patient about BPPV when performing OSFE. To prevent this complication, gentle hammering with a safe head position should be taken during the procedure. In suspected cases of BPPV, immediate referral to an otorhinolaryngologist is highly recommended.

2.2.2.3. Implant loss

Despite the high success rate, implant failures may occur as a consequence of abovementioned complications and patient-related local and systemic factors [50]. It has been reported that implant failures associated with OSFE usually occur before loading [51]. A subantral bone measured 4 mm or less at the time of implant placement has been shown to be associated with an almost 10–20% increase in implant failures [52]. Osteotome technique is usually recommended when more than 6 mm of residual bone height is present, and an increase of about 3–4 mm is expected.

3. External sinus lifting (lateral window technique)

Maxillary sinus floor augmentation using the lateral window technique was originally described by Tatum [5] in 1977 and subsequently published by Boyne [6] in 1980. This technique is still the most frequently used method to increase the amount of bone in the posterior maxilla before or in conjunction with implant placement [53].

3.1. Surgical technique

The technique is mainly based on the sequential steps of a trapdoor osteotomy on the lateral wall of the maxillary sinus and elevation of the Schneiderian membrane to create a confined space for the placement of graft material and dental implant. Over the past 30 years, lateral window technique has undergone numerous modifications including different techniques, graft materials, and implant placement protocols to increase the predictability of the procedure and reduce the rate of complications [53].

3.1.1. Antrostomy techniques

An antrostomy is made in the lateral sinus wall to get through to the Schneiderian membrane in order to create a space for the placement of the bone graft material and the implant. The size of the window should be wide enough to achieve sufficient access and vision to perform the membrane elevation and graft placement without complications. On the other hand, redundant expansion of the window should be avoided because it would compromise the blood supply to the graft.

Osteotomy can be made with either the rotary technique or the piezoelectric technique. The rotary technique is performed using a high-speed handpiece or surgical motor and

preferably a round diamond or carbide bur. In line with the recent trend toward minimally invasive surgery, the use of piezosurgery has been reported to eliminate the "drag" created by rotary instrumentation and be less associated with the damage to the blood vessels or the Schneiderian membrane [54]. Furthermore, different approaches have also been described regarding the creation technique of the window. One method of creating the access window is abrading away all of the bone in the window area with a lateral cutting motion. As the bone is thinned, the sinus membrane is visualized as a blue shadow, and the thin bony layer is gently removed, creating a complete osteotomy (**Figure 2**). Another method is performing a trapdoor osteotomy in which the superior osteotomy cut is kept partially incomplete, and the lateral wall "window" is rotated (hinged) inward and upward to a horizontal position (**Figure 3**). Alternatively, a complete osteotomy can be performed extending 360° to create a bony island in the center. This can remain pedicled to the membrane and being elevated with it, or it can be removed to be used later for recovering the window (**Figure 4**). In reviewing the literature, there is no evidence that one approach is more favorable than another.

3.1.2. Bone grafting materials

A considerable amount of literature has been published on different types of biomaterials including autograft, allograft, xenograft, alloplast, and growth factors; however, debate continues about the ideal graft material for the maxillary sinus floor augmentation [55].

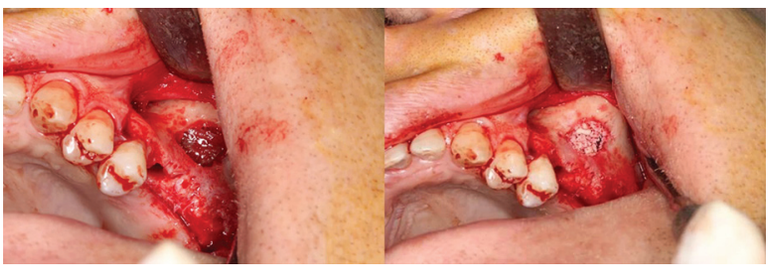

Figure 2. Access to the sinus through the abrasion of the bone and graft placement.

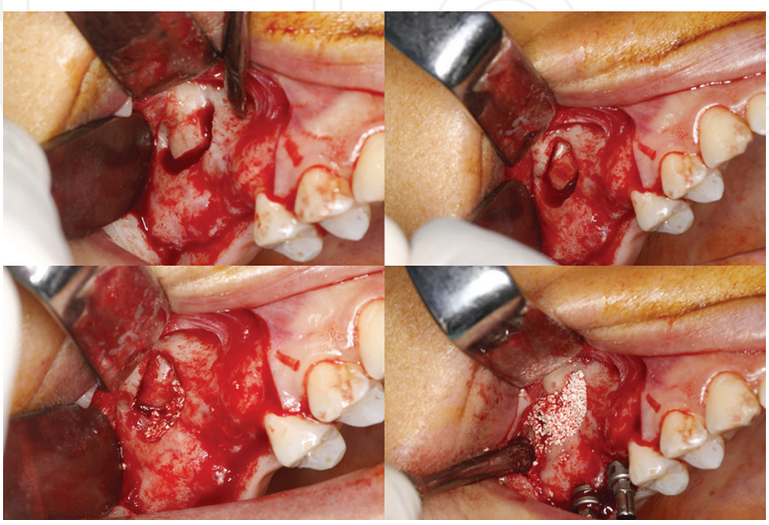

Figure 3. Access to the sinus performing a trapdoor osteotomy and simultaneous implant placement.

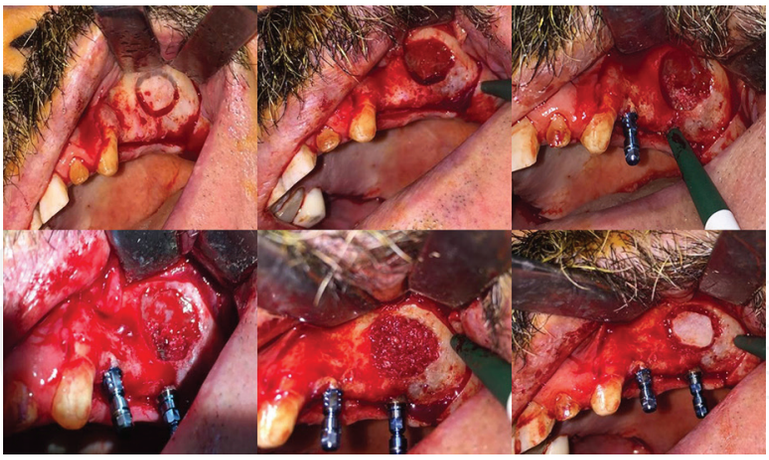

Figure 4. Access to the sinus by creation of a bony island and simultaneous implant placement. The bony island is used to re-cover the window.

Although autogenous bone graft has always been considered the gold standard in augmentation procedures due to its osteoinductive, osteogenic, and osteoconductive characteristics, the procedure is also associated with increased morbidity and significant graft resorption [56]. Therefore, the use of various bone replacement grafts of biologic or synthetic origin has become a major area of interest in order to simplify the surgical procedure by eliminating the need for bone harvesting [57]. Recent evidence suggests that implant survival rates with bone replacement grafts, particularly xenografts as the most rigorously evaluated substitute, are equal to or better than that achieved with autogenous bone [55].

On the other hand, there has also been an alternative concept of lateral window technique, which relies on using the implant to tent the membrane without a bone graft material [58]. Subsequent to the elevation of the Schneiderian membrane similar to the surgical protocol described above, simultaneous implant placement is performed. The blood clot formed around the exposed implant tip or a centrifuged autogenous blood product is used as the sole grafting material. Although several studies have demonstrated favorable results with high survival rates, there is still a lack of long-term clinical and radiographic studies on the amount of bone formation and final treatment outcome with this surgical intervention [58]. Thus, further research is needed to validate the outcomes and predictability of maxillary sinus lift applying the lateral window technique without a graft material and simultaneous implant installation.

3.1.3. Timing of implant placement

A one- or two-stage implant placement approach has been suggested in conjunction with lateral window maxillary sinus lift procedures. In two-stage technique, following the sinus augmentation and a healing period of 6 months or more, implants are placed with a second surgical intervention. Therefore, the one-stage procedure has been proposed in order to shorten the total period of treatment and to eliminate the requirement of a second surgery, thus reducing morbidity and cost [59]. Traditionally, a minimum of 4–5 mm of residual bone height is recommended for simultaneous implant placement with direct sinus lift to ensure initial stability [60]. On the other hand, recent clinical evidence also suggests that the simultaneous placement of implants with direct sinus lift may be a feasible treatment modality as

long as adequate primary stability can be ensured, regardless of the recommended minimum residual bone height [61].

3.2. External sinus lift complications: Prevention and management

Although complication rate associated with the direct sinus lift procedure in the literature is quite low, several potential complications have been reported that increase the morbidity and jeopardize the treatment outcome [62].

3.2.1. Intraoperative complications

Surgical difficulties encountered during the course of the procedure may lead to the occurrence of several intraoperative complications. These difficulties may arise from the presence of complex anatomic situations, the choice of less predictable treatment options, inadequate systemic or local diagnosis, or operator error. The most frequent intraoperative complications are the Schneiderian membrane perforation and bleeding, while the others include the obstruction of the antral meatal ostium complex, dislocation of the implant into the sinus cavity, perforations in the buccal flap, and less frequently, injury to the infraorbital nerve [17, 63].

3.2.1.1. The Schneiderian membrane perforation

Sinus membrane perforation, being the most common complication during the sinus lift surgery, has been reported to occur with a range of incidence comprised between 20 and 44% of cases [17]. Membrane perforation may be encountered during different phases of the procedure including preparing the antrostomy, removal or turning over the bony window, raising the membrane, and placing the graft. Moreover, thin membrane, the presence of Underwood's septa, thick or convex lateral walls, a sharp angle between the buccal and palatal walls of the antral cavity, especially when below 30°, irregularities of the sinus floor due to the protrusion of the root profiles, previous interventions of the sinus, and a decreased residual alveolar height less than 3.5 mm are among the anatomical risk factors that prompt the occurrence of membrane perforation [64].

A precise evaluation using computed tomography (CT) may aid to determine the 3D anatomy of the sinus to minimize the rate of perforation. When septa are known to be present, lengthening the window in the anteroposterior direction is recommended in order to allow for a lateral-to-medial elevation of the membrane from both sides of the septum. An alternative to this approach is the creation of two separate windows; however, one should consider that this technique may result in small windows, which can complicate the access and vision [65]. Use of piezoelectric surgery has been proposed to be a valuable adjunct to sinus surgery, which has been shown to result in decreased membrane perforation rates [54]. Other considerations to prevent membrane perforation include using diamond burs and elevation of the membrane from lateral to medial while keeping the instrument in contact with the bone at all times.

Nevertheless, perforation is unavoidable in some cases despite accurate presurgical radiographic evaluation and ideal surgical maneuvers. Perforation of the sinus membrane may result in bacterial contamination and infection of the graft and dispersion of the particulate, leading to impairment of the functional homeostasis of the antral cavity [60]. Once the

perforation is confirmed, the exact size of the perforation should be detected by gently raising the surrounding membrane to reduce the tension and to avoid further tearing. Minor perforations of less than 1 mm may self-repair by membrane foldover or clot formation, thus permitting simultaneous implant placement. In perforations smaller than 5 mm, using fibrin glues, collagen tapes, and bioabsorbable membranes or suturing the membrane is usually sufficient for closure that allows simultaneous implant placement. Membrane perforations larger than 5 mm may require bioabsorbable membranes, lamellar bone plates, suturing either alone or in combination with fibrin glue, or abandoning the intervention. Regardless of the size and repair method of the sinus membrane perforation, there should be no doubt about the stability of the perforated area to contain the graft material.

Since large perforations constitute an enormous challenge, several authors have studied and suggested specific repair methods based on the use of collagen membranes, local flaps, and autogenous bone blocks. Among these methods, "the Loma Linda pouch technique," which was introduced by Proussaefs et al. [66] in 2003, involves covering all internal bony walls of the sinus using a slow resorbing collagen membrane simulating the natural membrane and folding the membrane on the lateral wall with external tack fixation. However, pouch formation surrounding the graft material can impair the blood supply coming from the walls of the sinus, thus representing an impediment for the maturation of the graft and the recovery period [67]. More recently, "the intrasinusal locking technique" has been proposed by Sindel et al. [68], which allows for simultaneous implant placement in the presence of a large membrane perforation aiming to decrease the number of surgical interventions and the complications related to surgery. In this technique, autogenous bone ring blocks harvested from mandibular symphysis are placed internal to the floor of the maxillary sinus and stabilized with the simultaneously installed dental implant, using a mechanism similar to that of a screw and nut (**Figure 5**). The authors reported an implant survival rate of 90% without any postoperative complications such as maxillary sinusitis or infection.

3.2.1.2. Excessive bleeding

Intraoperative bleeding is the second most common intraoperative complication of sinus lift procedure [63]. Massive bleeding frequently occurs from damage to the alveolar antral artery (AAA), which is an intraosseous anastomosis between the posterior superior alveolar artery (PSAA) and the infraorbital artery. There is also a possibility of bleeding from extraosseous anastomosis of PSAA and infraorbital artery during the flap elevation and from posterior lateral nasal artery [69].

Although being usually minor, in some cases, bleeding may be difficult to control in a timely manner and induce additional complications such as membrane perforation, impairment of blood supply, and displacement of the graft material [63]. Preoperative evaluation using cone beam–computed tomography (CBCT) may help to create a window respecting the integrity of vascular structures [70]. Further attempts to decrease the risk of bleeding may include preparing the window through the piezosurgery or preferring the diamond burs than carbide burs when rotary instrumentation is used [54]. Management of vascular bleeding during the sinus lift procedure can be carried out by raising the head, applying the direct and firm pressure on the bleeding point, crushing the bone around the vessel, using local vasoconstrictor agents

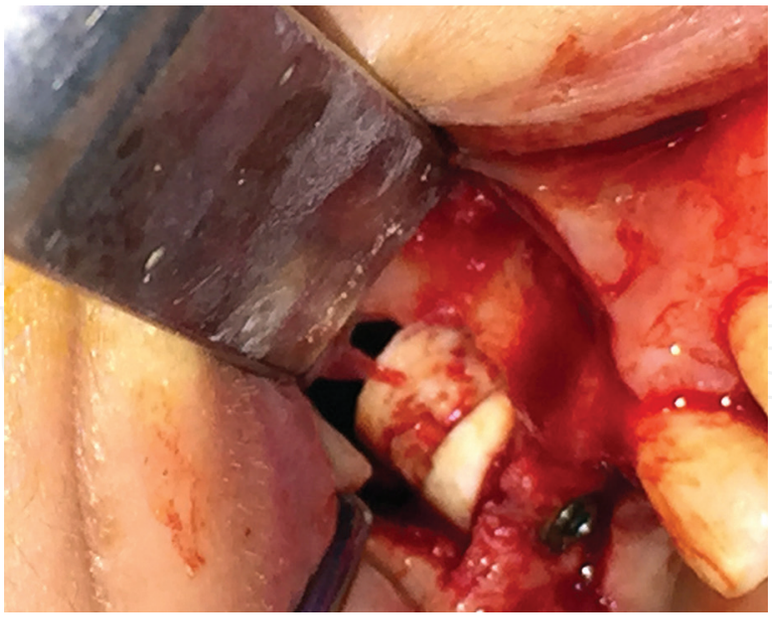

Figure 5. "Intrasinusal locking technique": Autogenous bone ring inside the sinus cavity is locked to the alveolar crest through the dental implant.

or bone wax, and suturing the vessels [17]. In addition, bleeding can be controlled through the use of electrocautery; however, much attention should be paid not to cause membrane perforation [71].

3.2.1.3. Other complications

Improper surgical technique may lead to the tears in the buccal flap while trying to achieve a tension-free closure. Hence, redundant release of the buccal flap should be avoided respecting to the thickness of the flap and convexity of the malar eminence. Likewise, advanced closure methods such as pedicled buccal mucosal flap should be considered in cases where sufficient tension-free closure could not be achieved by buccal flap release. Yet, another complication related to poor surgical technique is the infraorbital nerve damage, which may result from pressure during the flap retraction or dissection for releasing the flap for closure [72]. Care should be taken to identify and protect the nerve while performing surgery near the infraorbital nerve. Additionally, overfilling of the graft material should be avoided because it may lead to the obstruction of the antral meatal ostium complex [63].

3.2.2. Postoperative complications

Infection of the graft, acute sinusitis, flap dehiscence, over-filling necrosis, loss of graft material, formation of oroantral fistula, migration of dental implants into the sinus cavity, implant failure, cyst formation, and BPPV are among the postoperative complications specific to external sinus lift procedure. Furthermore, a number of nonspecific patient responses may also be encountered including edema, hematoma, minor nosebleed, and mild congestion likewise any other surgical procedure.

3.2.2.1. Graft infection

Sinus graft infection is a rare but important complication with a reported incidence up to 4.7% [73]. Various factors have been reported to predispose the graft infection such as preexisting sinus infection, membrane perforation, contamination of the graft with saliva, wound dehiscence, and inadequate aseptic technique. The symptoms of the graft infection include tenderness, fistulation, suppuration, severe pain, facial swelling, abscess, elevated body temperature, and loss of graft particles through the fistulous tracts (popcorn sign).

The condition needs to be urgently treated due to the risk of quick spread of the infection to the adjacent structures, which may result in infraorbital abscess, orbital cellulites, and even brain abscess [74]. Several modalities involving irrigation, drainage, administration of systemic antibiotics, and partial or total removal of the graft material have been proposed for the treatment [75]. Superficial infections may be treated with the use of antibiotics alone; however, this modality may result in further progression of the infection requiring the complete removal of the graft. Recently, Mahler et al. [76] have described "the Dome phenomenon," which refers to a dense, solid, hard tissue maintained in the superiormost aspect of the grafted area in case of a graft infection. They reported successful outcomes with partial removal of the infected graft until this dome-shaped area indicating the regenerative potential of the Schneiderian membrane. Generally, the use of a new augmentation material is not recommended to prevent repeated infection because the thorough elimination of infected graft material can enable spontaneous bone fill in majority of the cases.

3.2.2.2. Acute maxillary sinusitis

The altered anatomic relation of the antral floor along with a hematoma or a seroma that fills up the maxillary sinus may lead to the obliteration of the osteomeatal unit [77]. Furthermore, the displacement of the graft materials through the sinus membrane or overfilling of the sinus may also result in the impairment of mucociliary clearance. Apart from these, aberrant anatomical factors such as ostium stenosis or preexisting sinus disease may also facilitate the development of acute sinusitis following the sinus lifting procedure [78]. Acute maxillary sinusitis may jeopardize the survival of the implants and the graft. Medical treatment with decongestants and antibiotics should be obtained in patients with a predisposition to sinusitis. In addition, consultation with an otolaryngologist should be considered to confirm whether the management of sinusitis can be carried out conservatively or the sinus patency requires additional surgical intervention.

3.2.2.3. Other complications

Increased intrasinus pressure may result in overflow of the graft material through the window and consequent wound dehiscence in the early postoperative period. This rare complication may be avoided by placing and stabilizing a membrane over the window or recovering it with the intact bony window.

As well as being an intraoperative complication, the dental implant migration into the maxillary sinus may also occur after several months or even years of its adequate functioning [79].

Various factors have been suggested to explain the mechanism of late migration including the changes in intrasinusal and nasal pressures, the lack of osseointegration, peri-implant bone destruction due to an autoimmune reaction, and the resorption produced by an incorrect distribution of occlusal force [80]. (See Section 2.2.1 for the management.)

Another unusual complication of direct sinus lift procedure is the formation of an oroantral fistula, which results from the progressive sinus infection and ostium blockage [81]. Following the elimination of the sinus infection, different techniques such as buccal flap, palatal rotation-advancement flap, and buccal fat pad can be used for the treatment of the oroantral communication.

4. Conclusion

Maxillary sinus augmentation, either crestal or lateral window approach, is a well-known, predictable, and often mandatory procedure to increase the alveolar bone height in posterior maxilla for dental implant rehabilitation. However, the procedure is also associated with certain complications that may influence the outcome of the therapy and patients' quality of life. A thorough knowledge of prevention and proper management of these complications is essential to obtain better treatment outcomes.

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