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Review

Risk factors, Consequences and Treatment Alternatives of Schneiderian Membrane Perforation: Case Report and Review of the Literature

Schneideryen Membran Perforasyonu için Risk faktörleri, Perforasyonun Sonuçları ve Tedavi Seçenekleri: Vaka Takdimi ve Derleme

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ABSTRACT

Maxillary sinuses are the greatest sinus cavities in the human cranium and they are the closest to the oral cavity. Thus, Schneiderian membrane perforation is a frequently encountered complication that may be experienced during various oral surgery procedures in the molar and premolar regions of the maxilla such as teeth extractions, implant placement or sinus augmentation procedures. Membrane perforations lead to oroantral communications, which may later turn into oroantral fistulas. Moreover, these perforations may cause infections, loss of graft or implant if encountered during sinus augmentation procedures. The purpose of this literature review was to investigate the risk factors associated with this complication and present the various treatment alternatives used to manage this type of complication. In the literature, the selected surgical technique, the thickness of the membrane, the quality and quantity of the residual alveolar bone, the anatomy of the area and patients' habits such as smoking were reported as points to be considered. A long follow-up case of sinus penetration during implant placement and successful management of the complication was also presented.

Keywords: Complications; Maxillary sinus; Risk factors; Schneiderian membrane

ÖZET

Maksiller sinüsler insan kafatasındaki en büyük sinüs boşluklarıdır ve ağız boşluğuna en yakın olanlardır. Bu nedenle Schneideryen membran perforasyonu, maksillanın molar ve premolar bölgelerinde uygulanan diş çekimi, implant yerleştirme veya sinüs ogmentasyon prosedürleri gibi çeşitli cerrahi işlemler sırasında karşılaşılabilecek yaygın bir komplikasyondur. Membran perforasyonları oroantral ilişkilere yol açar ve bu açıklıklar zamanla oroantral fistüllere dönüşebilir. Dahası eğer bu perforasyonlar sinüs ogmentasyon işlemleri sırasında meydana geldiğinde enfeksiyonlara, greft veya implant kaybına neden olabilir. Bu derlemenin amacı bu komplikasyonla ilişkili risk faktörlerini belirlemek ve bu tip komplikasyonları yönetmek için kullanılan çeşitli tedavi alternatiflerini anlatmaktır. Yapılan literatür taramasında, seçilen cerrahi tekniğin, sinüs membranının kalınlığının, rezidüel alveoler kemiğin kalite ve miktarının, bölge anatomisinin ve hastaların sigara kullanımı gibi alışkanlıklarının membran perforasyonları için önemli noktalar olduğu bildirilmiştir. Bu derlemede implant yerleştirilmesi esnasında meydana gelen bir Schneideryen membran perforasyonu olgusunun başarılı tedavisi de sunulmuştur.

Anahtar Kelimeler: Komplikasyonlar; Maksiller sinus; Risk faktörleri; Schneideryen membran

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INTRODUCTION

Perforation of Schneiderian membrane may to occur during surgical procedures at the posterior region of the upper jaw. The variability of shape and volume of the maxillary sinus determines the surgical approach. Planning and performing surgical procedures in the sinus cavity requires detailed knowledge of the sinus and Schneiderian membrane anatomical characteristics. Maxillary sinus morphology varies in shape and size from person to person and even within the same person.[1]

Maxillary Sinus Anatomy

The maxillary sinus is a paranasal cavity with controversial structural and physiological functions including providing the resonance of voice, olfactory function, warming and humidifying of the air during breathing and reducing the cranial weight.[1] It is located in the facial skull as a pyramid-shaped antrum with its base as the nasal wall, its apex in the zygomatic process and its four walls: superior, lateral, anterior and inferior.[2] The maxillary sinus is approximately 25-35 mm medio-laterally, 36-45 mm supero-inferiorly and 38-45 mm antero-posteriorly.[3] The canine-premolar region usually constitutes its anterior limit, and its most convex point usually lies in the first molar region.[2]

The internal walls of the maxillary sinus is covered with a thin, ciliated respiratory epithelium that is very similar to the nasal mucosal epithelium, but is 1mm thicker and less vascularized. The ciliated epithelium facilitates the drainage of pus and mucus to the middle meatus through the internal ostium, which is located at the cranial site and serves as a connection between the nasal cavity and the sinus.[1] The membrane that extends to the walls of the maxillay sinus is called the Schneiderian membrane. It consists of pseudostratified columnar ciliated epithelium with its cilia facing the sinus antrum, a highly vascularized lamina propria under the epithelium and a periosteum-like connective tissue lining beneath, which lacks any hint of osseous activity.[4] However, some studies suggest that the Schneiderian membrane has osteogenetic activity that improves bone formation even without any graft material.[5,6] This theory was supported by the presence of osteoprogenitor cells which may be associated with pericytes in the microvascular walls or subendothelial cells in the the bone marrow.[4] The presence of osteoclasts in the maxillary sinus has also been reported and the thinning of the maxillary sinus walls were partly attributed to the osteoclastic activity of the Schneiderian membrane.[7]

The blood supply of the maxillary sinus originates from the last part of the maxillary artery, which consists of the infraorbital artery, the descending palatine artery and the posterior superior alveolar artery.[1] The alveolar antral artery (AAA) is mainly responsible for the vasculature of the sinus membrane, the periosteum that attaches the membrane to the sinus walls and to the anterolateral wall of the sinus.[8] The AAA's diameter has been reported to be up to 2.5-3 mm.[9,10] Any damage to the AAA, which may have a diameter of up to 2 mm, may cause serious hemorrhage and impaired vision during the surgery, thus causing an increased risk of membrane perforation.[7,8] Thus, it is of utmost importance to keep the anastomosis intact, both to prevent serious bleeding complications and to provoke bone graft neoangiogenesis when sinus augmentation procedures are performed.[8]

Schneiderian membrane perforation

The Schneiderian membrane perforation is very likely to happen when surgical procedures of the maxilla are performed, leading to an oroantral communication (OAC). More specifically, it is a frequent complication encountered during the extraction of upper posterior teeth, implant placement or sinus augmentation procedures (Figure 1); due to the close proximity of the roots of the upper posterior teeth and the sinus floor and the lack of distance between the sinus floor and alveolar crest, which varies from 1-7 mm.[11] According to previous research, second molar roots have the closest proximity to the sinus floor followed by the first molars, third molars, second premolars and first premolars.[11]

Extractions of upper wisdom teeth are common in the dental practice, making it important to keep in mind their association with a greater chance of membrane perforation by penetrating the floor of the sinus cavity or the Schneiderian membrane. Fully impacted teeth are prone to cause OACs more often compared to partially impacted or totally erupted teeth because of the close proximity to the sinus due

to their superior location and increased difficulty level of the operation. On the other hand, teeth with open apices have a lower incidence of causing damage to the sinus membrane than fully developed teeth.[12]

Figure 1. Schneiderian membrane perforation observed during external sinus lifting procedure.

Implant placement is another treatment alternative frequently performed in the edentulous maxilla that may possibly be associated with disruption of the integrity of the Schneiderian membrane. In cases with insufficient amount of bone, sinus floor elevation procedures using various graft materials may be required in order to achieve adequate vertical bone height under the sinus membrane for implant placement. During this procedure, sinus membrane perforations are one of the most common complications with a percentage of 11% to 56%.[13,14] However, it is necessary to keep the membrane imperforated in order to avoid scattering of the graft material into the sinus cavity and so as not to lose the direct contact of the membrane's vascularity and the graft.[1] In a recent study, the survival rates of implants inserted after membrane perforations were reported to have a negative correlation with the extent of the perforation.[15] Another study by Hernandez *et al*.[16] also confirms these findings.

Risk Factors Associated with Perforations

There are some generally accepted factors concerning the Schneiderian membrane characteristics, which increase the potential risk of perforation and should be taken into consideration.

One of the factors that favors the presence of complications during the surgical implant placement is the surgical technique that is selected for the procedure. It is mentioned in some studies that membrane elevations with piezoelectric surgical devices, instead of conventional methods, decrease the number of unfavorable situations and eliminate the possibility of perforating the membrane, by operating at a low frequency and consequently producing micro-vibrations that are ideal for the osteotomy without damaging the soft tissues.[17,18] Piezoelectric surgery techniques improve intraoperative visibility and reduce intraoperative bleeding and surgical trauma.[18] Moreover, the reaming approach, which is applied by preparing the alveolar bone transcrestally with an implant drill until the sinus floor is penetrated, is also considered as a surgical technique that decreases the perforation rates. It does not cause damage to the membrane during the osteotomy and it is very useful in the presence of septae (Figure 2), which constitutes another main cause of perforations.[19,20]

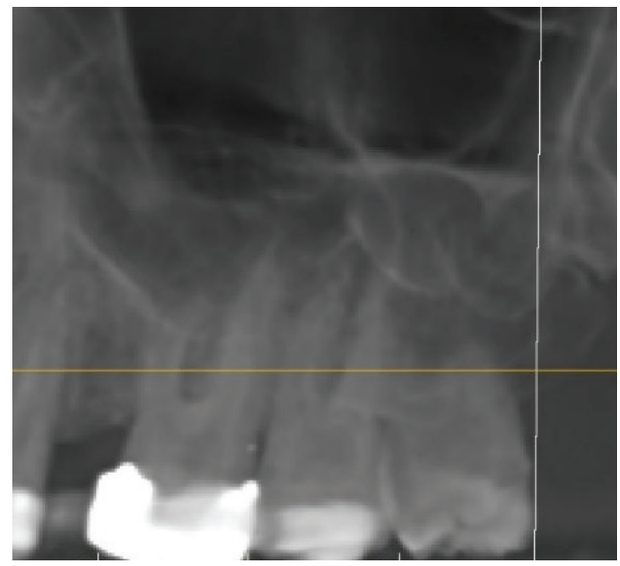

Figure 2. Multiple sinus septae

Previous studies have revealed a solid positive correlation between membrane thickness and perforation rates. If the membrane is too thin or too thick, then the possibility of membrane perforation increases. The thinner the membrane is, the less resistant it is to the mechanical forces applied during sinus floor elevation or bone grafting.[21] Thick membranes do not have a proper, healthy epithelium, lamina propria and periosteum-like lining, with the durability

of a healthy sinus membrane. A thick membrane is likely to be seen in patients with edentulous posterior maxilla. Moreover, severe periodontal bone loss and decreased residual bone height is associated with a thicker sinus membrane.[19] The greatest incidence of perforations have been reported for membrane thickness of <1 mm and ≥2 mm.[19,21] Various factors have influence on the sinus membrane thickness; such as gender, smoking habits, sinus diseases, the presence of endodontic or periodontal lesions, the presence of septae and lastly gingival phenotype of the patient. Smoking and sinus diseases cause thickening in the sinus mucosa, thickening of the sinus mucosa is more frequent during cold weathers, females generally have thinner Schneiderian membranes than men, septae and spines are usually regions where the membrane becomes thin and a thin gingival biotype is positively correlated with a thin membrane.[21, 22]

Large perforations are difficult to avoid when the oral mucosa is in contact with the sinus mucosa, which is more common in severe resorption and traumatic bone loss situations.[1,19] Wen *et al*.[19] reported a higher tendency for perforation in patients with residual bone height <2 mm. Ardekian *et al*.[23] reported in their study that a residual bone height of 3 mm, has a perforation risk rate up to 85%; in contrast to a residual bone height of 6 mm, for which the rate is 25%. Thus, a positive correlation between alveolar bone height and membrane perforation should be noted. This correlation is possibly connected to technical difficulties that occur during elevating a large portion of the membrane from the lateral wall in vertical bone loss.[19]

In some cases, the lateral wall of the sinus cavity is very thin and perforation of the membrane during window preparation is highly possible. In these cases, a diamond round bur is recommended to reduce the perforation risk.[7] A window with rounded corners is a surgical advantage and decreases the risk of perforation incidence. Moreover, the sinus cavity should be filled with enough graft material to provide sufficient bone for implant placement; but not so much that it may cause necrosis and perforation of the sinus membrane and result in scattering of the graft material into the sinus, provoking sinus infections.[1]

The angle between the lateral and medial walls of the maxillary sinus is an important risk factor since angulation influences the accessibility of the sinus floor during membrane elevation. The sharper the angles between the walls of the sinus are the more likely is the membrane to be damaged, particularly in the second premolar region. A study has proved that angles of ≤30°, 31° - 60° and ≥61° are associated with perforation rates of 37.5%, 28.6% and 0%, respectively.[7]

Recurrent surgeries involving the sinus mucosa sometimes may constitute a contraindication for maxillary sinus surgeries, because the presence of anatomical abnormalities (such as scars) may pose an obstacle for proper elevation of the sinus mucosa.[7] Cone-beam computerized tomography (CBCT) scan is the most valuable method to gather the necessary information about the shape, size, proximity to the roots of teeth and general health status of the maxillary sinus and the Schneiderian membrane.[24]

Perforation consequences and treatment

After surgical interventions where the sinus membrane is involved and there is a suspicion of its perforation, it can be controlled either by direct visualization or the Valsalva maneuver.[19] With this method an OAC is determined by gentle nose blowing or by carefully probing the area of possible perforation with a blunt sinus probe.[12] The presence of epistaxis during surgeries may be indicative of a membrane perforation.[7] Imaging techniques such as panoramic radiographs and CBCT may be a useful tool in diagnosing this type of trauma.[24]

Schneiderian membrane acts as a biologic barrier that encompasses the sinus cavity. Membrane perforation increases the risk of bacterial invasion from and to the sinus cavity. Particularly after sinus augmentation procedures, the graft may be exposed to infective bacteria, leading to an increased chance of infection.[7,25]

The most common complication OF OACs is sinusitis, which is the reason OACs require urgent treatment.[26] When large perforations occur on sinus membrane, bony fragments or graft material placed under the membrane may disperse into the maxillary sinus and become contaminated, thus causing sinus infections.[23] Consequently, the surgeon should

prioritize to remove any foreign bodies such as graft material, clean out the infected and degenerated mucosa from the walls of the sinus and remove any infected bone fragments. In case of a severe sinusitis that was present prior to the membrane perforation, Caldwell-Luc procedure that includes the total removal of the infected sinus mucosa through a lateral window is recommended.[11,27]

The decision of the treatment of OACs should be based on size, the existence of acute inflammation and infection and the time of diagnosis. The healing and treatment of a perforated membrane is more difficult in the presence of maxillary sinusitis, oroantral fistula, osteomyelitis, foreign bodies, dental cysts, abscesses or tumors; which all usually result in chronic fistulas.[11]

Vlassis and Fugazzotto[28] published a classification regarding the types of sinus membrane perforations and the appropriate treatment methods for each type of perforation in 1999. Years later a simplified version of the classification was reported by the same authors; according to which, resorbable membranes were used to manage all types of perforations (Table 1).[29]

Table 1. Fugazzotto PA & Vlassis J simplified classification[29]

Type of perforation	Description	Treatment method
Type I	Perforation in the most apical part of the window	Spontaneously healing Or a collagen membrane
Type IIA	Perforation near the lateral or coronal walls of the window.	Osteotomy is enlarged until intact membrane is exposed. Perforations <3 mm: collagen tape; Perforations ≥3 mm, a synthetic or resorbable membrane
Type IIB	Perforation located at the border of the maxillary sinus (extention of the osteotomy not possible)	Resorbable membrane placed over the window and fixed outside the window
Type III	Perforation anywhere within the borders of the window	Resorbable membrane placed over the window and fixed outside the window

On a later study, sinus perforations were classified considering their size and treatment methods were suggested. According to this study, perforations <5 mm should be either covered with a collagen membrane or sutured with a resorbable suture material if possible. Perforations between 5-10 mm should be covered with a collagen membrane and the piece of lamellar bone previously removed from the the lateral sinus wall in order to form a window. Perforations >10 mm should either be closed by replacing the lateral sinus wall that was previously removed to form a window or Bichat's fad pad should be dissected and used to cover the sinus opening as a flap. Lastly a block graft may be harvested from the symphysis or ramus of the mandible to cover the lateral window to prevent an OAC from forming. The authors of this study believe that the perforation of the sinus membrane should not be considered a definite contraindication to proceed with the operation.[16]

Shlomi *et al*.[30] argue that using resorbable collagen membranes for covering sinus mucosa perforations may not support bone formation and the implant survival rate while Zijderveld *et al*. advocate collagen membranes for weak spots such as small perforations or thin sinus membranes.[7,30] Even though the implant survival rates are higher in the absence of membrane perforations, no significant difference was reported considering the success rates of implants placed in augmented sinuses with membrane perforations versus no perforations.[7, 31]

According to literature, the most common factor that effects the treatment method is the size of the perforation. Small perforations <2 mm will heal without treatment if it is in a place where the membrane will fold onto itself.[7,16] Perforations <5mm can be managed by using sutures of resorbable material such as polyglactin sutures, placing a collagen membrane or performing buccal flap

techniques.[11, 31, 32] Perforations ≥5 mm tend not to heal spontaneously and require decent surgical treatment.[33] In literature, closure of the perforation with palatal flap techniques, buccal fat pad pedicle graft, freeze-dried human lamellar bone sheet graft, autogenous graft, collagen membrane and the lamellar wall previously removed from the lateral sinus wall to form a window are the recommended methods.[7,11,31] In addition, many researchers have preferred different methods for sinus perforation repair. Dagba *et al*.[34] used collagen sponges in large perforations both as a barrier and a space maintainer while mucosal and bony healing takes place. Choi *et al*.[35] used fibrin glue to close membrane perforations; which resulted in a newly formed healthy layer of epithelium. Öncü *et al*.[36] preferred platelet-rich-fibrin, which is an autogenous bioactive material obtained from the patient's own blood that is comprised of a wide range of proteins and growth factors, to mend membrane perforations. It was reported that because of the slow release of its ingredients during would healing, bone and membrane healing is promoted while inflammatory processes are repressed.

CASE

A 64-year-old male patient applied to the dentoalveolar clinic of Aristotle University of Thessaloniki Faculty of Dentistry for an implant-supported restoration in the maxilla. Panoramic and CBCT scans were analyzed and implant surgery was planned (Figure 3). During the surgery, the surgeon felt a "falling into gap" sensation while drilling the first premolar region. A round tipped probe was used to check for perforations. No large perforations were distinguished, however, there was still a chance of a smaller perforation. Large particle allograft material was placed into the sinus through the implant socket and the implant was inserted. During the post-operative period, no complications were encountered. Panoramic radiography confirmed the perforation of the sinus floor. The patient was followed-up annually for a decade and no complications were reported on implant function or the health status of the sinus

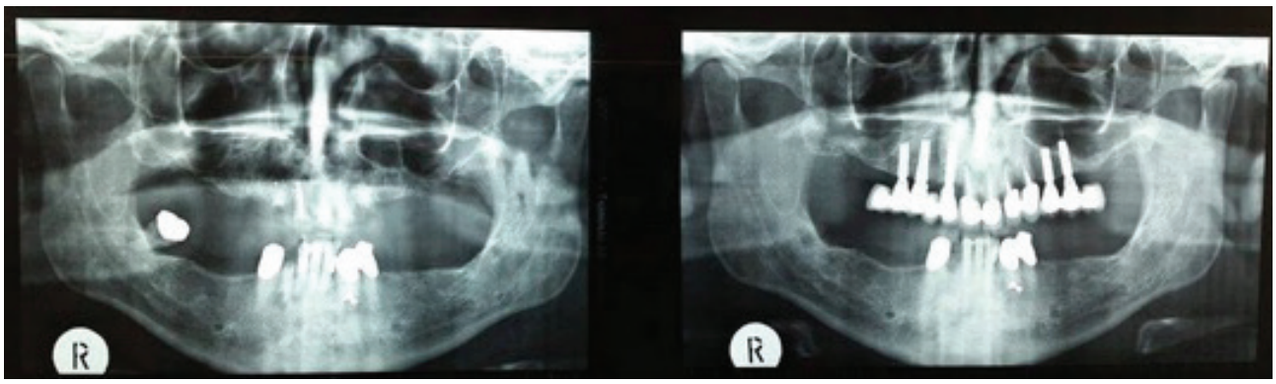

Figure 3. Panoramic radiograph taken before (left) and after (right) implant placement.

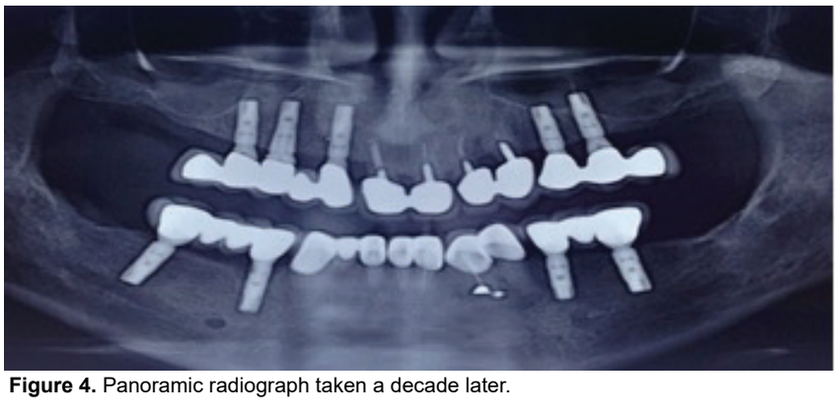

Figure 4. Panoramic radiograph taken a decade later.

antrum (Figure 4).

CONCLUSION

The Schneiderian membrane perforation is an important trauma that may occur during surgical procedures resulting to unfavorable conditions. Although, such an incidence does not always come with a failure of the procedure and it can be successfully managed in several ways. The surgeon should always take into consideration all the clinical, anatomical and radiographic evidence in order to prevent sinus perforations.

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