Maxillary Sinus Membrane Repair: Update on Technique for Large and Complete Perforations

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Maxillary sinus membrane perforation is the most common complication that occurs with sinus elevation augmentation surgery. A technique using a slow resorbing type I collagen membrane for repair of large and complete sinus membrane perforations is described. The biocompatibility and semirigid structural integrity of this membrane, along with external tack fixation, allows for optimal membrane stabilization and maintenance. (Implant Dent 2008;17:24–31)

Key Words: sinus elevation augmentation, osteomeatal complex, collagen membrane, external fixation

Grafting of the maxillary sinus was first described by Tatum,[1] Boyne and James,[2] and later modified by others. It has become a highly predictable surgical technique for posterior maxillary site development and implant reconstruction if proper treatment planning, careful surgical technique, adequate clinician experience, and patient compliance criteria are met.[1,3–8] There are, however, complications associated with this technique that would be expected with any surgical procedure. Although the overall complication rate is low, the most common complication is membrane perforation.[8–10]

The purpose of this article is to report on a modification of a previously published technique that can be used for predictable repair of large and complete sinus membrane perforations.

Anatomy

The maxillary sinus begins at approximately the third month of fetal life as an invagination from the middle meatus of the nasal cavity into the maxilla. It is the first and largest of the paranasal sinuses to develop, and continues to increase in size until the permanent teeth have erupted. Cervin[11] examined 107 people with CT and showed that the mean transverse dimension (mediolateral) and width (anteroposterior) of the normal adult sinus are 27 and 35.6 mm, respectively. This study also showed a direct correlation of adult sinus width with body weight and interzygomatic buttress distance. Another study using axial CT in 115 patients aged more than 20 years showed the average volume of the normal adult maxillary sinus to range from 4.56 to 35.21 cm^3 (mean, 14.71 cm^3).[12]

In a well done cadaver study, Stammberger[13] showed that the height and the width of the maxillary sinus in edentulous specimens are significantly greater than those of dentate cadavers. However, no significant difference in the anteroposterior length or volume was reported. This same study included a simulated sinus lift that revealed an inferior sinus graft volume of 3.5 cm^3 needed for a 15 mm augmentation and 5.66 cm^3 required for a 20 mm augmentation.

The maxillary sinus has a horizontal pyramidal shape consisting of a base, an apex, and 4 sides. The base (medial wall) forms the vertical lateral wall of the nasal cavity, and the apex is at the junction of the maxillary and zygomatic bones. The remaining 3 sides of the pyramid form the superior, anterior, and posterior walls of the sinus. The superior wall makes up the roof of the sinus, which is also the orbital floor. The anterior wall forms the facial portion of the maxillary bone. The posterior and lateral walls merge to form the posterolateral walls of the sinus, and separates the sinus from the infratemporal fossa and forms the maxillary tuberosity and pterygoid fossa.[14]

The medial wall demarcates the maxillary sinus from the nasal fossa and supports the lower and middle conchae. Located in the anterosuperior area of the medial wall is the ostium, a 7 to 10 mm long passage that is variable in size, location, and efficacy in draining the sinus.[15] The ostium, the infundibulum, and the middle meatus are often referred as the osteomeatal complex. This communication between the maxillary sinus and the nasal cavity must be maintained to assure health of the maxillary and adjoining paranasal sinuses.

Maxillary Sinus Physiology

The maxillary sinus is lined with a respiratory mucosa similar to that of the nose and other paranasal sinuses. It consists of a mucoperiosteum with 3 layers: an epithelial covering, a lamina propria, and periosteum.[16] The maxillary sinus membrane varies in thickness, but is generally 0.3 to 0.8 mm.[17]

The epithelial lining is a single layer of pseudostratified columnar ciliated epithelium with few blood ves-

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sels and is thicker than that of the other paranasal sinuses. Numerous goblet cells are present within the mucosa and are the major source of mucous secretion. The highest density of these cells is located near the sinus ostium. The density of ciliated cells is high, ranging from 91.3% to 97.7%, except near the ostium, where the density is decreased by half.[18] The cilia move mucous and debris in a spiral fashion toward the ostium. They beat approximately 1000 times/min while moving the mucociliary blanket[19] at a flow rate of 6 mm/min.[20,21] Normally the cilia can clear the sinus in 10 to 30 minutes under physiologic conditions.[13,22]

The lamina propria consists of a thin layer of connective tissue with few elastic fibers. It is thickest at the medial wall and contains more seromucous glands than the lateral wall.[23] The periosteum is tightly bound to the overlying lamina propria, but is easily detachable from the underlying bone, making membrane separation during the sinus lift procedure relatively easy.

Any factors that compromise mucous production, ciliary function, or patency of the ostium can increase the risk of sinusitis. As a result, with sinus elevation augmentation surgery, it is important to maintain membrane integrity to allow for confinement of the particulate graft and to decrease the risk of infection.

Maxillary Sinus Membrane Perforation and Repair

The most common complication involving sinus elevation augmentation is membrane perforation.[8–10] The incidence of this occurrence has been reported to range from 10% to 56%.[8,9,24–26] A variety of techniques have been proposed to manage these perforations. These include suturing,[27,28] the use of collagen membranes,[9,27–31] fibrin sealants,[32–35] freeze dried human lamellar bone sheets,[27,28,36] and oxidized regenerated cellulose.[37]

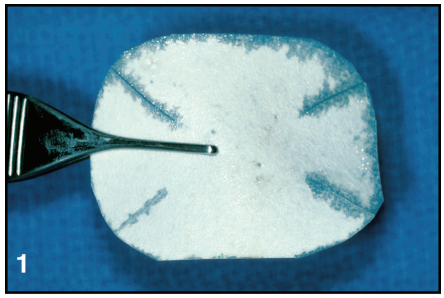
All these techniques involve repair of sinus membrane perforations that range in size from 2 mm to approximately 1.5 cm with one exception.[9,10] Pikos has reported on the use of a slow resorbing collagen membrane for repair of large (>1.5 cm) perforations and for sinuses that involve complete tears.[9]

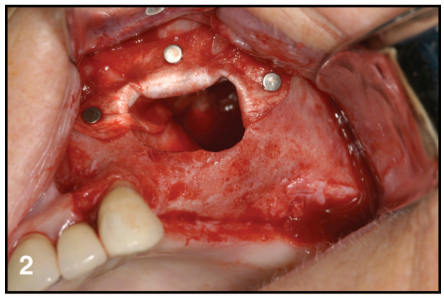
Surgical Technique for Large and Total Perforations

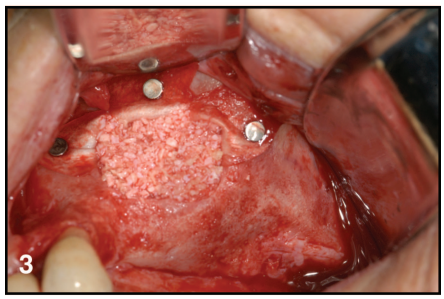
The technique involves a modification of the one reported in 1999.[9] It includes the use of a slow resorbing collagen membrane with adequate structural integrity to adapt and maintain itself within the internal bony anatomy of the sinus.

Once the bony window is outlined it should be removed to allow for visualization of the existing sinus membrane. Remnants of the sinus membrane can then be elevated from the bony floor and all walls including the posterior wall. This is important to allow for direct contact of the graft with its bony blood supply and to prevent epithelial invagination into the graft.

Next, a 30 × 40 collagen membrane (Biomend; Zimmer Dental, Carlsbad, CA) is modified by rounding the corners and creating approximately 1 cm slits at each corner (Fig. 1). The generic cuts allow the membrane to fold on itself after placement within the sinus. It is easier to make these cuts before hydrating the membrane in either saline or PRP (Harvest Technologies, Plymouth, MA). One end of the membrane is then placed at the anterior, posterior, and superior bony window and fixated externally with tacks (Figs. 2 and 3). This stabilizes the membrane and allows it to drape internally as it adapts to the internal anatomy of the sinus. This external fixation is especially important to contain the particulate bone graft in the more pneumatized sinus where the anterior–posterior and/or medial–lateral dimension is larger than normal. As mentioned previously, it is important to not cover the bony floor or inferior segment (~10 mm) of the bony walls (anterior, posterior, medial, and superior). The membrane may need to be custom-trimmed once external fixation is complete. Also, it may be necessary to use a second collagen membrane as an extension that can be sutured with 4-0 chromic suture to the fixated membrane and trimmed appropriately (Fig. 4). The use of platelet rich plasma acts as an adhesive to adapt the membrane to all walls.







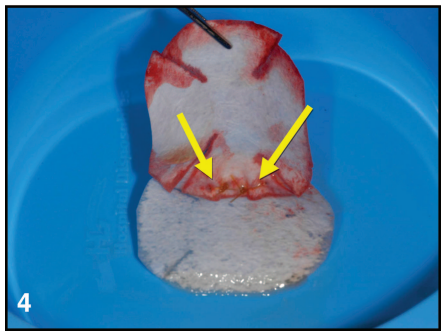
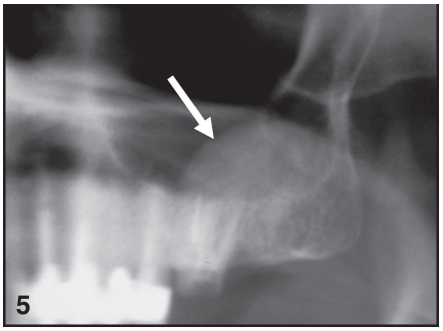
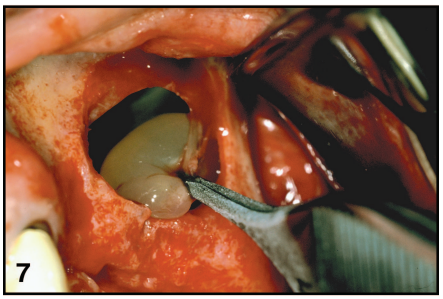


Fig. 1. Biomend collagen membrane (30 × 40 mm^2) with rounded edges and cut corners.
Fig. 2. Biomend collagen membrane with 3 point external tack fixation at anterior, superior, and posterior windows.
Fig. 3. Particulate graft of tibial marrow, Bio-Oss, and PRP.
Fig. 4. Biomend collagen membrane with secondary extension membrane sutured with 4-0 chromic suture (arrows).

Case Reports

A healthy 52-year-old white male was referred for implant evaluation on June 11, 2002. The patient expressed a desire to have permanent teeth to replace his failing dentition in the maxillary left posterior quadrant. His maxillary arch treatment





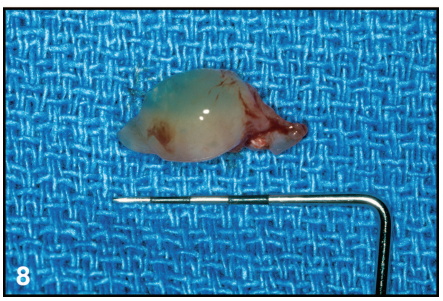
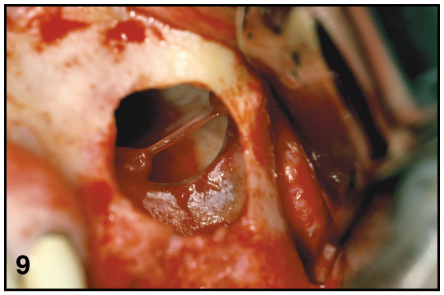
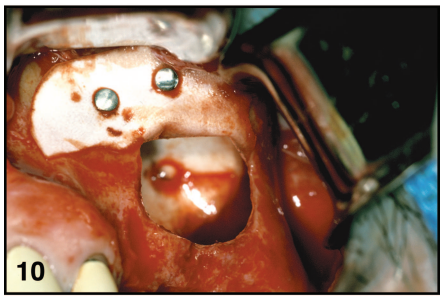
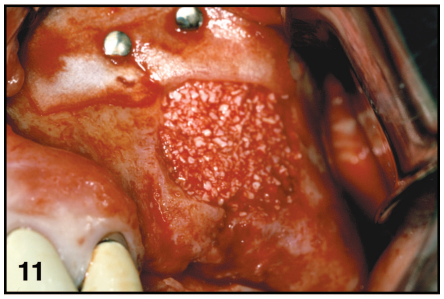


Fig. 5. Panoramic radiograph indicating extent of mucous retention cyst. Maxillary left second bicuspid and first molar subsequently extracted before sinus elevation.
Fig. 6. CT showing mucous retention cyst of left maxillary sinus.
Fig. 7. Removal of mucous retention cyst via intentional perforation of sinus membrane.
Fig. 8. Mucous retention cyst.







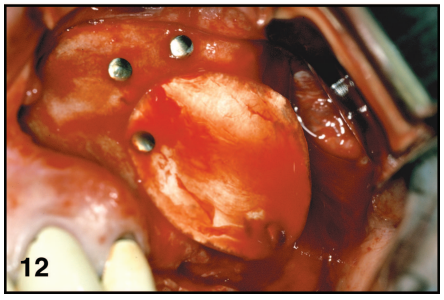


Fig. 9. Complete membrane perforation secondary to cyst removal.
Fig. 10. External fixation of collagen membrane.
Fig. 11. Particulate graft of mineralized irradiated allograft, Bio-Oss, and PRP.
Fig. 12. Biomend Extend collagen membrane (20 × 30 mm^2) placed over window with tack fixation.

plan for reconstruction included a 3-unit implant-supported bridge.

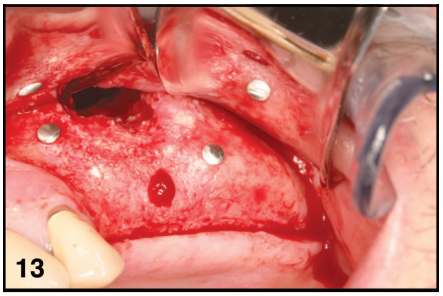
Clinical, panoramic (Fig. 5), and CT (Fig. 6) examinations revealed a partially pneumatized left maxillary sinus with a well-defined radiopaque mass measuring 2.5 × 2.0 cm^2 located on the sinus floor adjoining the posterior wall. Also a failing maxillary left second bicuspid and first molar were noted.

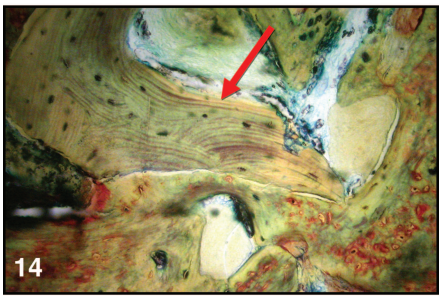
Initial treatment included surgical extraction of the failing teeth with socket graft preservation. This was followed 4 months later by left sinus elevation augmentation surgery that included intentional perforation of the sinus membrane to remove the suspected mucous retention cyst (Figs. 7 and 8) for biopsy. The biopsy report was consistent with the preoperative diagnosis of mucous retention cyst. This resulted in complete membrane perforation (Fig. 9) that required elevation of all mucosal remnants from the bony walls including the floor of the sinus. A 30 × 40 mm^2 Biomend collagen membrane was then trimmed and cut (Fig. 1) to allow for placement into the sinus creating a customized barrier to prevent graft migration. This membrane was fixated externally (Fig. 10) for stabilization. Next, the particulate graft complex of mineralized irradiated cancellous allograft (Puros; Zimmer Dental, Tutogen Medical, Alachua, FL), Bio-Oss (Osteohealth, Shirley, NY 11967), and PRP (Harvest Technologies) was placed into the cul-de-sac created by the slow resorbing collagen membrane (Fig. 11). Careful attention was paid to avoid covering the inferior 10 mm of the bony walls so as to not compromise bony blood supply to the graft.

A 20 × 30 mm^2 Biomend Extend collagen membrane was then placed over the lateral window (Fig. 12) and fixated with 2 titanium tacks. Twelve months later, the graft was found to be well incorporated with only minimal bone resorption found at the anterior superior border (Fig. 13). Core biopsy of the graft revealed many areas of mature bone with a lamellar pattern around the allograft particles (Fig. 14). Three 4.7 × 16 mm^2 tapered, threaded root form implants (Zimmer Dental, Carlesbad, CA) were placed one each in the maxillary left second bicuspid, first molar and second molar sites. Stage II surgery was then followed 3 months later by fabrication of a 3-unit implant-supported bridge (Figs. 15 and 16).

Discussion

An important aspect of sinus augmentation surgery is to maintain the integrity of the native membrane. This is done solely to confine the particulate graft material (excluding use of block bone) within the bony housing of the sinus. The purpose for membrane repair is also to prevent graft extravasation. Sinus membrane perfo-





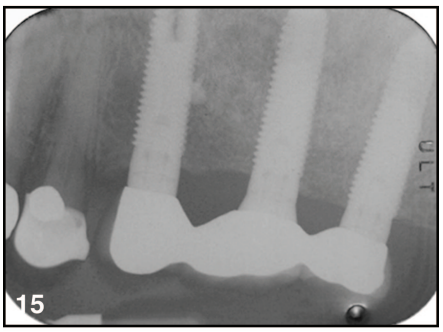


Fig. 13. Re-entry 12 months postgraft. Note well-incorporated graft and slight bone loss at anterior superior margin.
Fig. 14. High power photomicrograph with lamellar pattern of mature bone (arrow) around the allograft particles.
Fig. 15. Radiograph of completed prosthetics— 4 years functional load. Note maintenance of crestal bone height and uniform trabecular bone pattern.
Fig. 16. Completed prosthetics— 4 years.

rations that are not repaired or are inadequately repaired can result in both short-term and long-term complications.[8] Bacterial penetration and mucous invasion into the graft can compromise the amount of bone formation. Graft material may leak through the perforated site, can migrate to the ostium, and be eliminated through the nose or obstruct the ostium and prevent drainage.[8] Ostium obstruction can also occur as a result of swelling of the membrane during surgery. All these conditions increase the risk of infection. Most important to the success of graft incorporation, however, is maintenance of the bony blood supply to the graft. As a result, it becomes critical to not cover the bony floor or the inferior 10+ mm of the anterior, posterior, medial, and lateral bony walls during the repair. This becomes especially challenging for complete membrane perforation. Fugazzotto and Vlassis[28] reported on large sinus membrane perforation repair with a pliable porcine membrane externally fixated and completely covering the internal bony wall anatomy of the sinus. The Loma Linda pouch technique[38] involves use of a slow resorbing collagen membrane with external tack fixation that also results in complete membrane coverage of all internal bony walls including the floor. It is the author's opinion that complete coverage of all internal sinus bony anatomy with a slow resorbing collagen membrane can impede blood supply to the graft and result in incomplete graft incorporation.

Large perforations (>1.5 cm) are the most challenging to repair and can occur for a number of reasons. These include operator error, manipulation of inherently thin membranes (~0.3 mm), presence of septae, presence of pathology, and secondary to previous surgery. The previously mentioned techniques for membrane repair can be problematic and unpredictable for both large perforations and membranes with complete tears.[27–37] Suturing is not possible because the membrane edges cannot be approximated. In addition, these membranes can be thin and will tear upon suturing.

The use of cyanoacrylate adhesive or autologous fibrin glue for membrane repair is also not feasible because these techniques require the membrane edges to be approximated before application of the glue.[34,35] Several authors have proposed the use of freeze dried human lamellar bone sheets for membrane repair.[27,28,36] This material has significant stiffness and is not easily adaptable to the internal bony anatomy for large perforations. The use of oxidized regenerated cellulose[37] is also not practical for large perforations and complete tears because of its lack of rigid structural integrity and fast resorbing properties.

Collagen membranes can be used; however, studies reported by some authors include the use of a fast resorbing collagen membrane that possesses no rigidity and as a result may be inadequate for large perforation repair. Proussaefs *et al*[30] used a split-mouth design with 5 patients and reported that nonperforated sites demonstrated significantly more bone formation (34.40%) than perforated sites (12.80%). Implant survival at second stage surgery was significantly inferior in perforated sites (54.5%) when compared with nonperforated sites (100%). Proussaefs *et al*[31] again used a split mouth design that included 12 patients with bilateral sinus grafting and found that nonperforated sites demonstrated significantly more bone formation (33.58% ± 7.45%) than perforated sites (14.17% ± 7.06%). Perforated sites also demonstrated significantly more soft tissue formation than nonperforated sites. Also, in nonperforated sites, residual graft particles had more of their surface in contact with bone than perforated sites. In both studies, a fast resorbing collagen membrane (Collatape—Zimmer Dental) was used. Choi *et al*[34] reported on the efficacy of autologous fibrin glue in the management of large perforations of the maxillary sinus membrane occurring during sinus lifts. In this double blind study, 6 adult female mongrel dogs were used. A laceration approximately 2 cm in length was made with one side repaired with fibrin glue and the control side covered with a fast acting bioabsorbable collagen membrane. Wound areas were biopsied 2 weeks after the operation. Wounds repaired with fibrin glue showed newly formed continuous epithelium across the previous perforation site. However, wounds treated with the collagen membrane exhibited extensive fibrosis, inflammatory infiltration, and absent epithelium. This study may suggest that utilization of fast resorbing collagen membranes is not adequate for large membrane perforations.

Although small membrane repair using fast resorbing collagen membranes (Collatape) has been well documented, no data are available on the consistent repair of large membrane perforations or repairs with no sinus membrane present. As described herein, the Biomend collagen membrane has been used successfully for predictable membrane repair since 1996[9,10] with no increased incidence of infection. In addition, this material has been successfully used for particulate grafting of sinuses in which no membrane was present as a result of previous surgery or pathology. This membrane has unique physical and biologic properties that make it very suitable for membrane repair or replacement. It is prepared from purified bovine Achilles tendon in a chemically cross-linked form and supplied in sterile individual sections. Its rigid structural integrity is maintained for approximately 6 to 8 weeks before resorbing. This type I collagen is biocompatible and resorbs through catabolic processes, including degradation of extracellular enzymes and collagenolytic enzymes, and may be replaced by new collagen.[39,40] The collagen membrane is well tolerated by soft tissues and possesses biologic properties that aid in optimal healing.[41] Collagen is chemotactic for fibroblasts,[42,43] which aids in promoting cell migration. It also possesses hemostatic properties through its ability to aggregate platelets, which may facilitate early wound stabilization and maturation.[44]

The same collagen membrane has also been used to cover the osteotomy window of the sinus elevation procedure. This protocol has been followed since 1996. This not only prevents soft tissue invagination but also results in formation of a cortical plate as early as 6 to 9 months over the window area. This author recommends use of the Biomend collagen membrane for all perforations regardless of size. The main advantage in using this membrane even for small perforations that would normally be treated with Collatape is that it creates space facilitating graft placement. The biocompatibility and semirigid structural integrity of this membrane allow this versatile application to all size membrane perforations. There is also no need to abort a sinus elevation augmentation procedure when even a complete tear occurs.

Conclusions

This case presentation demonstrates the application of a slow resorbing collagen membrane that can be used not only for repair of large and small sinus membrane perforations, but also for circumstances in which no membrane exists (previous surgery, pathology). The biocompatibility and semirigid structural integrity of this membrane, along with external tack fixation, allow for optimal membrane stabilization and maintenance.

Disclosure

The author claims to have no financial interest, directly or indirectly, in any entity that is commercially related to the products mentioned in this article.

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ID Abstract Translations

GERMAN / DEUTSCH

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Reparatur der Oberkiefersinusmembran: Aktualisierung der Technik bei großen bzw. kompletten Perforationen

ZUSAMMENFASSUNG: Die Perforation der Oberkiefersinusmembran ist die am weitesten verbreitete Komplikation, die bei einem chirurgischen Eingriff zur Sinusanhebung und -anreicherung auftreten kann. Es wird eine Technik unter Anwendung einer langsam resorbierenden Kollagenmembran des Typs I zur Wiederherstellung großer und kompletter Sinusmembranperforationen beschrieben. Die Biokompatibilität und halbfeste strukturelle Integrität dieser Membran zusammen mit einer externen Stiftbefestigung ermöglicht eine optimale Membranstabilisierung und -erhaltung.

SCHLÜSSELWÖRTER: Sinusanhebung und -anreicherung, ostiomeataler Komplex, Kollagenmembran, externe Befestigung

SPANISH / ESPAÑOL

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Reparación de la membrana del seno maxilar: Actualización de la técnica para perforaciones completas y grandes

ABSTRACTO: La perforación de la membrana del seno es la complicación más común que ocurre en la cirugía para aumentar la elevación del seno. Se describe una técnica que usa una membrana de colágeno tipo I de lenta reabsorción para la reparación de perforaciones completas y grandes del seno maxilar. La biocompatibilidad e integridad estructural semirígida de esta membrana, junto con la fijación externa, permite una estabilización y mantenimiento óptimo de la membrana.

PALABRAS CLAVES: aumento de la elevación del seno, complejo osteomeatal, membrana de colágeno, fijación externa

PORTUGUESE / PORTUGUÊS

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Reparo da Membrana da Cavidade Maxilar: Atualização da Técnica para Perfurações Grandes e Completas

RESUMO: A perfuração da membrana da cavidade maxilar é a complicação mais comum que ocorre com a cirurgia de aumento da elevação da cavidade. É descrita uma técnica usando uma membrana tipo I reabsorvente lenta para reparo de perfurações grandes e completas da membrana da cavidade. A biocompatibilidade e a integridade estrutural semi-rígida desta membrana, junto com a fixação da tacha externa, permite ótima estabilização e manutenção da membrana.

PALAVRAS-CHAVE: aumento da elevação da cavidade, complexo ostiomeatal, membrana do colágeno, fixação externa

RUSSIAN / РУССКИЙ

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Восстановление оболочки верхнечелюстной пазухи: усовершенствованный метод, применяемый для широкой и сквозной перфорации

РЕЗЮМЕ. Перфорация оболочки верхнечелюстной пазухи — наиболее часто встречающееся осложнение, которое возникает при увеличении объема альвеолярной части за счет верхнечелюстной пазухи. Описан метод использования медленно ресорбируемой коллагеновой мембраны типа I для восстановления широких и сквозных перфораций верхнечелюстной оболочки. Биосовместимость и полужесткая структурная целостность этой мембраны, а также наружная фиксация обеспечивают оптимальную прочность и сохранность оболочки.

КЛЮЧЕВЫЕ СЛОВА: увеличение объема альвеолярной части за счет верхнечелюстной пазухи, остиомеатальный комплекс, коллагеновая мембрана, наружная фиксация.

TURKISH / TÜRKÇE

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Maksiller Sinüs Membran Onarýmý: Büyük ve Tam Perforasyonlar için Teknik Güncellemesi

ÖZET: Maksiller sinüs membranının perforasyonu, sinüs elevasyon ogmantasyon cerrahisinde en yaygın görülen komplikasyondur. Bu çalışma, büyük ve tam sinüs membran perforasyonlarının onarımında yavaş resorbe olan tip I kollajen membranının kullanıldığı bir tekniği tarif etmektedir. Eksternal tack fiksasyonunun yanı sıra, bu membranın biyo-uyumluluğu ve yarı-rijid yapısal bütünlüğü, optimal düzeyde membran stabilizasyonu ve bakımı sağlar.

ANAHTAR KELÝMELER: sinüs elevasyon ogmantasyonu, ostiomeatal kompleks, kollajen membran, eksternal fiksasyon.

JAPANESE / 日本語

上顎骨サイナス膜修正：広範囲完全穿孔修正技術アップデート

共同研究者氏名： マイケル•A•ピコス（Michael A. Pikos）DDS

研究概要： 上顎骨サイナス膜穿孔はサイナスリフト増大手術に伴って最多発する併発症である。ここでは吸収の遅いタイプIコラーゲン膜を使用する広範囲完全穿孔修正技術を説明する。外側からのタック固定と共に生体適合性と半硬質の構造完全性を持つこの素材はサイナス膜に最大限の安定性と維持性を与える。

キーワード： サイナスリフト増大術, 固有鼻腔と狭い複雑な経路（ostiomeatal complex）、コラーゲン膜、外部固定

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CHINESE / 中国語

上顎竇膜修復：大穿孔與完全穿孔最新技術

作者：Michael A. Pikos, DDS

摘要：上顎竇膜穿孔是竇撐高增高術外科手術最常見的併發症。本研究說明利用慢速吸收的第一型膠原蛋白膜來修復大型和完全的竇膜穿孔。此膜的生物相容性和半堅硬的結構整合加上外部骨釘固定法，提供了最理想的膜安定性和維持性。

關鍵字：竇撐高增高術、鼻竇口鼻道綜合體、膠原蛋白膜

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KOREAN / 한국어

상악동 점막 복구: 크고 완전한 천공에 대한 기술 업데이트

저자: 마이클 에이 피코스(Michael A. Pikos), **구강외과 의사**(DDS)

초록: 상악동막의 천공은 동 거상 확대술로 생길 수 있는 가장 흔한 합병증이다. 제1형 콜라겐 막을 서서히 재흡수하여 크고 완전한 동막 천공을 복구하는 기술을 기술하고 있다. 본 점막의 생물학적 적합성과 반 경질의 보전성과 더불어 외부의 못 고정 정도는 최상의 막 안정화와 유지를 가능하게 한다.

핵심 단어: 동 거상 확대, 부비동 개구 복합체, 콜라겐 막, 외부 고정

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