The Evaluation Methods of the Maxillary Sinus for Ensuring Predictability in the Sinus Graft Surgery

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I . Introduction

The edentulous posterior maxillary region presents unique and challenging conditions in implant dentistry compared with other regions of the jaws. The available bone is lost from the inferior expansion of the sinus and residual ridge resorption after tooth loss. These factors increase stress to the implants. However, despite these concerns, treatment methods designed specifically for this area allow it to be as predictable as any other intraoral region.

During the middle 1970s, Tatum developed a surgical technique for elevating the floor of the sinus along with simultaneous implant placement in the augmented space under the Schneiderian membrane. In 1980, Boyne and James presented a technique in which particulated cancellous bone marrow was used to graft the maxillary sinus with simultaneous placement of blade implants. After these reports, several techniques were reported for successful sinus augmentation.

In 1986, Misch reported that the sinus graft procedure has been the most predictable method with a graft success rate and an implant survival rate greater than 98%. In 1996, at the Sinus Graft Consensus Conference, extremely high success rates were reported for all materials and combinations, with the exception of demineralized freeze-dried bone when used alone. In 2007, McAllister and Haghighat reported that in humans, several techniques were reported for successful sinus augmentation, with average implant success rates, 92%

Although significant complications with sinus augmentation have a low incidence, the following have been reported: infection, bleeding, cyst formation, graft slumping, membrane tears, ridge resorption, soft tissue encleftation, sinusitis, and wound dehiscence. To prevent those complications, precision pre-operative evaluation must be required.

To evaluation for maxillary sinus pathology and to determine the anatomic features, such as residual bone, sinus topography, and septa locations, prior to initiation of a sinus augmentation procedure, a CT (computed tomography) scan evaluation may be performed.

In this report, we reviewed anatomic considerations of the maxillary sinus and presented the evaluation methods for ensuring predictability in the sinus graft surgery, clinically and radiographically. And especially we had regard for using CT images as pre-operative evaluation modality of sinus graft surgery.
II. Anatomic Considerations

Bony Walls of the Maxillary Sinus

The maxillary sinus is surrounded by six bony walls, which contain many structures of concern during surgery. Knowledge of these structures is crucial for both preoperative assessment and postsurgical complications.

In the anterior wall of maxillary sinus, the infraorbital nerves & blood vessels lie directly on the bone and within the sinus mucosa. Tenderness to pressure over the infraorbital foramen or redness of the overlying skin may indicate inflammation of the sinus membrane from infection or trauma. The infraorbital neurovascular structures may be less than 10 mm from the crest of the severe atrophic anterior maxilla and should be avoided when performing the sinus graft.

In the superior wall, dehiscence may be present, resulting in direct contact between the infraorbital structures and the sinus mucosa. Eye symptoms may result from infections or tumors in the superior aspects of the sinus region and include proptosis and diplopia.

The posterior wall of the maxillary sinus corresponds to the pterygomaxillary region, which contains the posterior superior alveolar nerve and blood vessels, including the internal maxillary artery and pterygoid plexus. This wall should not be perforated during surgery to limit bleeding complications from the pterygoid plexus or branches of the internal maxillary artery.

In the medial wall, the maxillary ostium is located in its most superior aspect and is a 7~10 mm lingual passage several millimeters in diameter located in the anteroposterior position of the first molar. Repeated sinus infections may also erode an accessory opening through the medial wall. A surgical curette may inadvertently perforate this very thin wall during the sinus graft surgery.

The lateral wall may be several millimeters thick in the dentate patient, especially in the presence of parafunction. This wall gradually decreases in thickness over time, with the loss of posterior teeth. Reinforcement webs for force transfer in the dentate patient often exist on the floor with lateral wall septa. In the sinus floor, The maxillary molars & premolars remain separated from the sinus mucosa by a thin layer of bone but may occasionally be in direct contact with the mucosa. Perforations of this wall are common from past infections or trauma associated with teeth or implants.

Sinus Membrane

According to the literature, the lining is a mucoperiostium consisting of three layers. However, Sharawy and Misch suggested that the periosteal portion of this membrane is not similar to the periosteum covering the cortical plates of the maxillary or mandibular residual ridges and jaws. Thickness varies but is generally 0.3 to 0.8 mm (Fig. 1). Thickness varies but is generally 0.3 to 0.8 mm (Fig. 2).

Fig. 1. The anatomic structure of sinus membrane. (presented from Jung WY DDS Ph.D)
The cilia of the columnar epithelium beat toward the ostium at 15 cycles per minute with a stiff stroke through the serous layer, reaching into the mucoid layer (Fig. 3). The maxillary sinus ostium and the infundibulum link the maxillary sinus with the middle meatus of nasal cavity. These structures are referred to as the osteomeatal unit\textsuperscript{12} (Fig. 4).

### III. Clinical Assessment

The ostium of the sinus can be partially or completely occluded by swollen mucosa and may occur as a result of sinus membrane manipulation during sinus grafts. A decrease in oxygen tension results, which provides a favorable anaerobic environment for bacteria proliferation, which may lead to infection.

Acute, allergic, or chronic maxillary sinusitis may be difficult to diagnose by patient history and clinical examination alone. These symptoms are usually nonspecific and include the presence of a common cold or allergic rhinitis\textsuperscript{13}. Misch summered a physical examiantion as\textsuperscript{14} (Table 1).

In 2003, Falace reported that the signs and symptoms consistent with a diagnosis of rhinosinusitis are classified into major and minor categories (Table 2) and the minor factors achieve diagnostic significance when 1 or more of the major factors are present among the symptoms\textsuperscript{15}.

<table>
<thead>
<tr>
<th>SITE</th>
<th>SIGNS OF INFECTION</th>
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<tbody>
<tr>
<td>Inferior Wall</td>
<td>Bulge in hard palate, ill-fitting denture, loose teeth, hyperesthesia or nonvital teeth, bleeding, palatal erosion, oroantral fistula</td>
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<tr>
<td>Medial Wall</td>
<td>Nasal obstruction, nasal discharge, epistaxis, cacosmia, visible mass in nostril</td>
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<tr>
<td>Anterior Wall</td>
<td>Swelling, pain, skin changes</td>
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<tr>
<td>Lateral Wall</td>
<td>Trismus, bulging mass, exudate from incision line</td>
</tr>
<tr>
<td>Posterior Wall</td>
<td>Midface pain, hyperesthesia of one-half of face, loss of function of lower cranial nerves</td>
</tr>
<tr>
<td>Superior Wall</td>
<td>Diplopia, proptosis, chemosis, pain or hyperesthesia, decreased visual acuity</td>
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In 2003, Falace reported that the signs and symptoms consistent with a diagnosis of rhinosinusitis are classified into major and minor categories (Table 2) and the minor factors achieve diagnostic significance when 1 or more of the major factors are present among the symptoms\textsuperscript{15}.
IV. Radiologic Examination

The radiologic examination modalities can be used for the evaluation of the maxillary sinus. They are as follows: Waters' projection, Panoramic radiography, Conventional tomography, CT, and Magnetic Resonance Imaging. The Waters' projection represents a better view than a panoramic view to illustrate cloudiness and sclerotic changes of the maxillary sinus (Fig. 5). And it is accurate in showing air/fluid levels. In the panoramic radiography, contour and detection of cystlike densities of the sinus are better illustrated (Fig. 6). And the floor of the antrum and the amount of available bone can be determined glossy.

<table>
<thead>
<tr>
<th>Major Factors</th>
<th>Minor Factors</th>
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<tr>
<td>1. Facial pain</td>
<td>1. Headache</td>
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<td>2. Facial pressure</td>
<td>2. Fatigue</td>
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<tr>
<td>3. Facial congestion</td>
<td>3. Fever</td>
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<tr>
<td>4. Nasal obstruction</td>
<td>4. Dental pain</td>
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<tr>
<td>5. Paranasal drainage</td>
<td>5. Halitosis</td>
</tr>
<tr>
<td>7. Hyposmia</td>
<td>7. Ear pain / fullness</td>
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Generally, the conventional Radiography underestimate the degree of chronic inflammatory disease due to superimposition of fine bony structures. Therefore, computed tomography is the modality of choice in evaluation of paranasal sinus and accurate depiction of anatomy of osteomeatal channels and extent of disease\(^{16,17,18}\). Traditional CT used for medical purpose conducts the examination for paranasal sinuses by two scanning methods. One is the screening sinus CT (only coronal scan using bone algorithm) and the other is the complete CT (coronal and axial scan using bone & soft tissue algorithm). Recently, the dental CT (Cone Beam CT) has been used in the dental field. The dental CT can reduce radiation exposure for examination of the maxillary sinus and has a more precise slice pitch along the axial direction. A dental CT set up our dental hospital (i-CAT\(^{TM}\), ISI, USA) presents spatial resolution 0.2 mm\(^3\) or 0.4 mm\(^3\).
V. The Assessment of the Maxillary Sinus using the Dental CT

The shape and volume
The assessment of the shape and the volume must be required for the sinus graft surgery to design the range of mucosal elevation or to estimate the amount of graft material. In 1989 Lang reported that the average volume of the maxillary sinus is 15cc. However, the result was different when compared with that of Ariji et al (20.5cc) or that of Uchida et al (13.6cc). A study conducted in LivingWell Dental Hospital with 65 sinuses represented the average volume of the maxillary sinus as 18.3±4.4 cc. The mean of the volume in the maxillary sinus was different markedly according to the studies. In addition, the individual variation was noted widely. Therefore, the measurement must be estimated individually with CT scan. The reconstructed 3 dimensional image reformatted from the dental CT scan can show the shape of the maxillary sinus and estimate the volume of that easily(Fig. 7, 8).

Fig. 7. Separation of left maxillary sinus from the axial image.

Fig. 8. A reconstructed 3 dimensional image of the maxillary sinuses in both sides.

Fig. 9. The simulation of the sinus graft in the Simplant™ (Materialize, Belgium), image reformattting software estimates the volume required in surgical procedure.

Septa of the maxillary sinus
The floor of the maxillary sinus cavity is reinforced by bony or membraneous septa joining obliquely or transversely the medial and/or lateral
walls with buttresslike webs. The location and the shape of septa must be considered in making a lateral window for sinus graft surgery or osteotome procedure for socket lift, because septa obstruct that surgical procedure. Kim et al reported that the prevalence of maxillary segment with one or more septa was found to be 53/200 (26.5%) in Korean. The dental CT images can be used to evaluate the location and the shape of the septa of maxillary sinus (Fig 10–12).

**The branch of PSAA (Posterior Superior Alveolar Artery)**

In 1999, Solar et al reported that the internal branch of PSAA was located at the height of 19 mm from the alveolar ridge averagely and the findings of this study indicate that the bony window, through which the grafting material will be placed, should be as small as possible so that the vascular stumps of the endosseous anastomosis extend as close to the center of the graft as possible. In 2005, Elian et al reported that the average distance of the that artery from the alveolar crest was about 16 mm and recommended that the superior osteotomy cut will be made approximately 15 mm from the alveolar crest for preventing cut of that
artery. The study conducted in LivingWell Dental Hospital showed that the average distance was about 16mm which was similar to the value reported by Elian et al. But the distance was closer than the average value in the first molar area (13.5mm). And the variation was markedly noted in each patients or in each sinuses of same patient. Therefore the dental CT scan must be required for accurate assessment of that artery's course (Fig. 13-15).

**The Ostium**

The ostium may be at any point along the ethmoid infundibulum, usually in the posterior third. A 7-10 mm long angular passage several millimeters in diameter. When the cross-sectional dimension of this structure is reduced to less than 5 mm, an anaerobic environment is likely to develop in the maxillary sinus and result in a sinus infection (Fig. 16).

Fig. 13. The bony indentation of the branch of PSAA noted in the conventional panoramic view. That is not identified easily.

Fig. 14. The reconstructed images from the dental CT scan show the course of that artery precisely.

Fig. 15. In these crosssectional views of each sides in same patient demonstrate the variation of the location in the course of that artery.

Fig. 16. The scheme of the anatomic structure of ostium. INF (infundibulum), U (uncinate process), M (maxillary sinus)
Conventional radiographic modalities are not shown the anatomical structure of the ostium. Therefore, CT scanning is required for evaluation of ostium and its patency (Fig. 17).

**Pathologic Conditions**

The floor of the maxillary sinus is anatomically very close to the root apices of the maxillary posterior teeth, and these roots frequently extended into the sinus cavity. Understanding the close relationship of the sinuses and the etiology of paranasal sinus inflammation and infection, and being familiar with appropriate treatment guidelines are important for the dentist who examines patients with maxillary discomfort. Sinusitis of odontogenic origin occurs in approximately 10% of cases (Fig. 18). Clinical symptoms may be minimal despite extensive radiographic findings. A study conducted by LivingWell Dental Hospital reveals that an apical protrusion of the root apex over the sinus floor was observed in about 42% of the maxillary first
molars and about 40% of the maxillary second molars\(^{29}\) (Fig. 19).

**Postoperative evaluation**

The CT scanning after the sinus graft surgery provides very useful information for postoperative care. The evaluation of mucosal thickening of the sinus membrane and patency of ostium influences medication and postoperative care. If swelling of the sinus membrane was marked resulting obstruction of ostium, the medication of decongestant must be considered to release related signs and symptoms (Fig. 20). A study conducted by LivingWell dental Hospital shows that the ostium size after sinus graft surgery was smaller than that before. And complete obstruction cases of the maxillary sinus was noted in 2 of 40 cases\(^{30}\) (Fig. 21).

**Anatomic Variation of Sinonasal Cavity**

Anatomical variations of sinonasal cavity related with obstructive sinonasal inflammatory disease. These variations must be considered in preoperative diagnosis. The list of anatomic variations is summarized in (Table 3).

<table>
<thead>
<tr>
<th>1) Middle turbinater variations</th>
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<td>. Concha bullosa</td>
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<td>. Paradoxical middle turbinater</td>
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<th>2) Uncinate variations</th>
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<tr>
<td>. Medial deviation</td>
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<td>. Pneumatization of uncinate tip</td>
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<th>3) Ethmoidal variations</th>
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<td>. Haller cell</td>
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<td>. Larger ethmoidal bulla</td>
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<td>. Agger nasi cell</td>
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<th>4) Nasal Septal deviation</th>
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Table 3. Anatomical variations related with obstructive sinonasal inflammatory disease.
Large concha bullosa (pneumatization of middle turbinate) can obstruct the middle meatus and infundibulum (Fig. 22). Paradoxical middle turbinate (pronounced convexity of middle turbinate toward the lateral nasal wall) narrows middle meatus (Fig. 23). Medial deviation of free edge of Uncinate process (Fig. 24) also influence obstruction of the middle meatus (Fig. 24). Pneumatization of uncinate process narrows infundibulum (Fig. 25). Haller cell (air cell in the roof of the maxillary sinus) can narrow infundibulum and ostium (Fig. 26). Large pneumatization of ethmoidal bulla can obstruct infundibulum and middle meatus (Fig. 27). Agger nasi cell (pneumatization of lacrimal bone) can obstruct frontal recess (Fig. 28). Severe case of nasal septum deviation may occur middle meatal obstruction (Fig. 29).

VI. Conclusion

In this study, we deals with anatomic structures of the maxillary sinus related with the sinus graft surgery. And critical points for clinical and radiologic assessment of the maxillary sinus are presented for diagnosis or preoperative treatment planning of the sinus graft surgery. The CT scanning gives a very useful information related with anatomic structures or pathologic conditions for surgical site and also presents informations about the postoperative assessment and prognosis after sinus surgery.

REFERENCES


상악골거상술의 안정성을 증가시키는 상악동의 평가 방법

이장렬, 김현철, 박일해, 이상철
리빙웰 치과병원
리빙웰 치의학 연구소

상악구치부에서의 임프란트 식립은 치아상실후 나타나는 치조골의 흡수와 상악동의 함기화로 인하여 가용골량이 부족하고 또한 얇은 피질골과 낮은 골밀도로 인한 불량한 골절 그리고 저작시 가해지는 높은 교압력으로 인해 식립조건이 보다 까다로우며 예지성 있는 식립과 식립후 합병증 방지를 위해 보다 세밀한 진단을 필요로 한다. 상악동거상술은 1970년대 중반 Tatum에 의해 상악동 점막 거상후 점막 하방에 골이식을 시행하고 임프란트를 식립하는 외과적 술식이 고안 되었으며, 1980년에는 Boyne과 James 등이 particulated cancellous bone marrow를 이용한 상악동거상술을 보고하였다. 그 후 상악동거상술을 위한 외과적 술식에 관한 몇몇 보고가 있었다. 이러한 상악동거상술은 현재 상악구치부에서의 임프란트 식립을 위한 매우 예지성 있는 술식으로 평가되고 있으며 골이식 성공률과 임프란트 생존율이 98%이상으로 평가되어지고 있다. 비록 상악골거상술 시행후 중대한 술후 합병증에 대한 빈도는 매우 낮으나 감염, 출혈, 술후 남중 형성, 이식재의 손상, 상악동 점막의 침공, 치조제 흡수, 연조직 개창 그리고 상악동염 등이 있다. 이러한 합병증을 외소화하기 위해서는 상악동에 대한 기존 질환에 대한 검사와 함께 해부학적인 형태에 대한 평가가 이루어져야 하고 잔존골의 형태, 상악동성의 단면 상, 상악동 격벽의 위치 등에 대한 평가가 포함되어야 한다. 상악동거상술을 위한 상악동의 임상적 평가에는 안면 중앙부위에 대한 asymmetry, deformity, swelling, erythema, ecchymosis, hematoma 그리고 facial tenderness 등이 포함되어야 한다. nasal congestion 혹은 obstruction, nasal discharge, epistaxis, anosmia, halitosis 여부에 대해서도 검사하여야 한다. 안와하공, 협측 볼의 연조직, 그리고 구강 점막에 대한 촉진시 tenderness 혹은 discomfort 존재 여부를 확인하여야 하고, 구강내에 치조골에 ulceration, expansion, tenderness, paresthesia 그리고 oroantral fistula 등에 대해 확인한다. 안과적으로도 안구의 proptosis, pupillary level, eye movement, diplopia 등을 확인한다. nasal fluid의 색깔에 대해서도 확인한다.

이외의 임상적 검사로는 transillumination, rhinoscopy 그리고 세균배양 검사 등이 포함될 수 있으며 일반 방사선사진 활영 혹은 CT(computed tomography)나 magnetic resonance imaging을 활용하게 된다. 일반 방사선사진 활영은 주로 Waters' 방사선사진활영이나 파노라마방사선사진활영을 시행하게 된다. Waters' 방사선사진활영은 상악동의 cloudiness 혹은 sclerotic change를 평가하는데 파노라마방사선사진활영보다 우수하다. 그러나 치조골에서부터 상악동저까지의 거리 측정과 상악동 격벽 유무 평가에는 파노라마방사선사진활영이 보다 유용하다. 최근 치과계에 cone beam CT의 보급으로 임프란트 식립 예정 부위에 대한 임상적인 평가가 이루어짐으로써 보다 정확한 술전 진단이 가능하게 되었다. CT를 이용한 방사선학적 술전 진단으로는 우선 해부학적 형태에 대한 평가가 이루어져야 한다. 잔존 치조골의 높이와 폭 그리고 골밀도, 피질골의 두께가 평가되어야 한다. 또한 상악동의 폭경, 상악동 격벽 유무 그리고 상악동맥의 intraosseous branch에 대한 평가가 이루어져야 한다. 또한 병리학적 평가로 점막의 비후 형태, ostium의 형태 그리고 염증발생시 배농에 영향을 줄 수 있는 각종 해부학적 변이에 대해서도 평가가 이루어져야 한다.