Open Sinus Lift Surgery and the Importance of Preoperative Cone-Beam Computed Tomography Scan: A Review

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Abstract:
Open sinus lift surgery is a form of pre-prosthetic surgery for increasing the quality and quantity of bone in the posterior region of the maxilla. Pre-operative assessment of the maxillary sinus is essential for the success of this surgery. PubMed search was carried out in English language literature for open sinus lift surgery and cone-beam computed tomography (CBCT). The results focused on anatomic variants, vascular anatomy, complications, osteotomy/ostectomy window dimensions and thickness of the Schneiderian Membrane. 59 articles were included in this review. Features other than the height and the width of residual alveolar ridge that should be evaluated in preoperative CBCT scan include the thickness of the lateral maxillary sinus wall, the presence of the alveolar antral artery and its diameter, the maxillary sinus floor width and angulation, irregularity of sinus floor, intimate relation of Schneiderian membrane with the roots of the adjacent teeth, sinus septum, and the quality of subantral bone. Other conditions that occasionally may be observed in special situations are also explained. More than ten parameters should be checked in evaluating CBCT images of paranasal sinuses other than the width and the length of the residual ridge in the posterior region of the maxilla. Each of them may have a significant impact on the results of the open sinus lift surgery.

Key Words: Cone-beam computed tomography scan, maxilla, open sinus lift

Introduction
In the posterior region of the upper jaw, tooth replacement in the edentulous ridge with dental implants requires sinus lifting surgery when the maxillary sinus is pneumatized, extending toward the alveolar process. This surgery is a form of pre-prosthetic surgery for increasing the quality and quantity of bone in the posterior region of the maxilla. Pre-operative assessment of the maxillary sinus is essential for the success of this surgery.

If the amount of bone, between the ridge crest and the maxillary sinus floor is inadequate, (<5 mm) then open sinus lift procedure is indicated. Pre-operative cone-beam computed tomography scan (CBCT) before open sinus lift surgery has been recommended by Dobele et al. and Nunes et al. Much more information can be obtained from CBCT other than the width and length of subantral bone as explained in this article. The CBCT is not the sole tool for this purpose. Comprehensive intraoral examination and carefully taken medical and dental histories are very important tools in this respect. However, when CBCT is used for pre-operative evaluation of the maxillary sinus and the edentulous region, as much information as possible should be obtained from this radiographic technique.

Sinus Lift Surgery and CBCT Scan
PubMed search was carried out in English language literature for open sinus lift surgery and CBCT. The results focused on anatomic variants, vascular anatomy, complications, osteotomy/ostectomy window dimensions, and thickness of the Schneiderian membrane.

Fifty-nine articles were included in this review. Features other than the height and the width of residual alveolar ridge that should be evaluated in preoperative CBCT scan include the thickness of the lateral maxillary sinus wall, the presence of the alveolar antral artery and its diameter, the maxillary sinus floor width and angulation, irregularity of sinus floor, intimate relation of Schneiderian membrane with the roots of the adjacent teeth, sinus septum, and the quality of subantral bone. Other conditions that occasionally may be observed in special situations are also explained.

Features other than the height and the width of residual alveolar ridge that can commonly be observed in CBCT are:

a) Thickness of the lateral maxillary sinus wall.

b) Presence of alveolar antral artery and its diameter.

c) Maxillary sinus floor width.

d) Irregularity of sinus floor.

e) Intimate relation of Schneiderian membrane with the roots of the adjacent teeth.

f) Maxillary sinus septum.
g) Estimation of the bone/biomaterial volume needed for sinus lifting.

h) Evaluation of the quality of subantral bone.

**Thickness of the Lateral Maxillary Sinus Wall**

If the lateral maxillary wall is thick, then the open sinus lift procedure becomes harder and takes more time. If the trapdoor technique is designed to be used, then reducing the thickness of bone is necessary to minimize complications.

Excessive convexity of this wall compels the surgeon to choose the ostectomy technique for lateral antrostomy instead of the lateral inverted window.

**Presence of Alveolar Antral Artery and its Diameter**

A large-diameter artery in the osteotomy/ostectomy window can provoke profuse bleeding, resulting in obscuring the vision in the surgical field. This will increase the possibility of Schneiderian membrane perforation. If the whole artery is enclosed by the bone, management by electrocautery is all that is needed but when this artery is in close contact with Schneiderian membrane, use of electrocautery will lead to membrane perforation. It has been suggested that it is possible to prevent injury to this artery with the use of a piezosurgery device, or careful bone removal and changing the osteotomy window from oval or round shape to longitudinal trough above/below this artery.

Alveolar antral arteries with a diameter more than 0.5 mm can be observed on CBCT images and profuse bleeding should be expected if the artery has a diameter more than 3 mm. This artery is responsible for intra-operative hemorrhage which is the second frequent complication of sinus lift procedure after membrane perforation (Figure 1).

**Maxillary Sinus Floor Width**

The distance between the lateral maxillary sinus wall and the medial maxillary sinus wall (lateral nasal cavity boundary) and the formed angle are also important. In very narrow and very wide sinuses and sharp angulation between these two structures, the open sinus lift surgery becomes difficult. In narrow sinuses, the trapdoor technique is contraindicated.

**Irregularity of Sinus Floor**

Irregularities of the maxillary sinus floor make the surgery more difficult in comparison with the flat-surface bone (Figure 2).

**Intimate Relation of Schneiderian Membrane with the Roots of the Adjacent Teeth**

If Schneiderian membrane comes in contact with the root(s) of the teeth adjacent to the edentulous space the risk of membrane perforation during sinus lift procedure increases. This is the reason why this procedure is more difficult in single-tooth edentulous spaces. Restricted surgical access and irregular nature of the overlying bone, located between the root apices, are the other reasons for high rate of maxillary sinus membrane perforation during local sinus lift for single-tooth implants.

**Maxillary Sinus Septum**

Maxillary septa: Approximately, 22.5-33% of CBCTs shows the presence of septa in the maxillary sinus. A septum on the floor of the maxillary sinus influences the design of the osteotomy window and changes the one-window technique to two smaller windows on either side of the maxillary sinus floor septum or the w-shaped trapdoor. Closed sinus lift below the sinus floor septum is also a difficult procedure.

**Estimation of the Bone/Biomaterial Volume Needed for Sinus Lifting**

If the estimated volume of the bone for open sinus lift is large and the autogenous bone is the choice, then the iliac crest and tibia should be selected as the donor site. Chin bone is considered when a small amount of bone is needed or when composite graft (mixture of autogenous bone and biomaterial) is to be used.

**Evaluation of the Quality of Subantral Bone**

Quality of subantral bone can be estimated through the CBCT. Other conditions that occasionally may be observed in special situations are:

1) Mucous membrane thickening.
2) Pathologic lesions of the sinus.
3) Previous Caldwell-Luc surgery.
4) Previous maxillary or zygomatic fracture.

Sinusitis of the maxillary sinus should be treated before sinus lift surgery. This can be medical or in advanced stages can be managed with endoscopic sinus surgery.

Normal maxillary mucous membrane thickness is 0.3-0.9 mm or simply speaking <1 mm. Mucosal swelling more than 2 mm is considered as pathologic thickening. There is a significant correlation between perforation rate and membrane thickness. The perforation rate is lowest when the thickness is 1.5-2 mm.

Pathologic lesions of the maxillary sinus such as cysts and tumors should be treated surgically before open sinus lift surgery. The exception is maxillary mucous retention cyst that can be drained or aspirated simultaneously with sinus augmentation.

**Previous Caldwell-Luc surgery**

If the maxillary sinus has undergone a previous Caldwell-Luc surgery, especially if oroantral fistula has occurred following tooth extraction, the current open sinus lift surgery is not indicated. Because of surgical scar, fibrosis and adherence of the tissue, this procedure will probably fail. In this situation bone graft strategies with special techniques, such as press-fit and triple layer closure, are indicated. If Caldwell-Luc surgery is used for removal of a foreign body or pathologic lesions, fibrous tissue, and osteoneogenesis fills some part of the maxillary sinus (auto-obliteration).

**Maxillary and zygomatic fracture**

Zygomatic process of the maxilla is a thick bone and acts as one of the vertical buttresses of the face; therefore, it is used for internal fixation in Lefort I, II, and zygomaticomaxillary complex fractures.

If the edentulous space present with internal fixation devices is visible on CBCT images, then their removal should be considered concomitant with the sinus lift procedure.

Usually, the length of the screws is more than the thickness of the maxillary buttresses and their tip is in the maxillary sinus; as a result, under the best conditions the surgeon confronts with perforated Schneiderian membrane.

Finally, there is a situation that is not pathologic but may have an influence on the open sinus lift surgery: "Extension of the maxillary sinus into the nasal floor" (palatonasal recess) (Figure 3).

It is ectopic pneumatization of maxillary sinus toward the palatal processes of maxillary bone, which is called, by some authors, the palatal recess. Elevating thin Schneiderian membrane from this recess is difficult.
than in more severely resorbed ridges. In such a situation, the superior boundary of the ostectomy window approaches the infraorbital nerve and special care should be taken during the surgery to avoid iatrogenic injury to the infraorbital structures.

Lateral window interferes with the alveolar antral artery (which is an intraosseous anastomosis between the infraorbital artery and the posterior superior alveolar artery) in the lateral maxillary sinus wall in 10-30% of the cases.\(^{47,48}\)

It should be pointed out that the more resorbed the bone crest, the higher the risk of injuring such a vessel during the sinus augmentation procedure.\(^{49}\)

The position of the maxillary ostium is the other factor that should be checked before any sinus surgery.\(^{50}\) In routine open sinus lift surgery, it is recommended that the medial maxillary mucous membrane should be elevated to better nourish the graft, especially if a biomaterial alone (without adding autogenous bone) is used as the sole graft material for maxillary sinus augmentation.\(^{51,52}\)

Elevation of this membrane very widely may result in the obstruction of the draining route of the maxillary sinus, the maxillary ostium. The altered anatomy of the maxillary sinus and subsequent changes in the function is the result as well as the need for ample biomaterial to fill the created biologic box.

Another importance of this structure is when the buccal fat pad is used as the last resource for the management of large perforations in the Schneiderian membrane.\(^{53}\) This pedicled flap, which is fixed to the medial maxillary sinus should not interfere with the maxillary sinus draining route.

In narrow-field CBCT images, some important information will be missed, including the deviated nasal septum and hypertrophied inferior turbinate (Figure 6). Correction of the deviated septum with septoplasty and inferior partial turbinectomy for alleviating the problem of hypertrophied inferior turbinate is indicated to prevent recurrence of sinusitis.\(^{54}\)

There are some important factors in open sinus lift surgery and other tools other than CBCT should be used for evaluating them. Limitations of CBCT in preoperative evaluation of maxillary sinus before open sinus lift surgery are the following:

The depth of the vestibule may be observed in CBCT of some edentulous posterior maxilla in the form of air bubbles, but it is better determined through comprehensive intraoral examination. In shallow vestibules, the sinus lift procedure is more frustrating. The transverse relation of the jaws, interocclusal distance, and anterior-posterior arch relationship, which have a great influence on decision-making and treatment planning are best determined after thorough intraoral physical examination.
CBCT cannot outline the normal sinus mucosa. Schneiderian membrane perforation is the most prevalent complication of open sinus lift surgery.\(^5\) The mean thickness of the membrane is less than 1 mm, while the CBCT with 2-mm slices can just show mucosal thickening of more than 2 mm.\(^5\) Very thin maxillary sinus mucous membrane is susceptible to perforation even in the hands of the most experienced surgeons.\(^37\)

Panoramic views can reveal sinus septa but with false positive and false negative results.\(^58\) Oblique septa may not appear on panoramic views. The length of the subantral bone is less accurate in panoramic views than the in CBCT images, so relying only on this radiographic technique for deciding about open sinus lifting will overestimate the need for sinus augmentation.\(^59\)

**Conclusion**

More than ten parameters should be checked in evaluating CBCT images of paranasal sinuses other than the width and the length of the residual ridge in the posterior region of the maxilla. Each of them may have a significant impact on the results of the open sinus lift surgery.

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