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# Antral computerized tomography pre-operative evaluation: relationship between mucosal thickening and maxillary sinus function

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**Key words:** computerized tomography, maxillary sinus, mucosal thickening, sinus augmentation, sinusitis

**Abstract**

**Objectives:** To assess the correlation between maxillary sinus inferior mucosal thickening and sinus outflow obstruction.

**Material and methods:** The study included 280 computerized tomography (CT) scans (560 maxillary sinuses). CT aimed to assess sinusitis; trauma to the face and intubated patients were excluded. Mucosal thickening was graded as $<5$ mm (1), $<10$ mm (2), $<15$ mm (3), $<20$ mm (4) and $>20$ mm (5), and classified by appearance as normal, rounded, circumferential, irregular, or complete. Maxillary sinus outflow was classified as patent or obstructed.

**Results:** Mucosal thickening was found in 36.1% of the maxillary sinuses, graded as 31.2% (1), 34.2% (2), 12.9% (3), 5.4% (4) and 16.3% (5), and classified as rounded (11.8%), irregular (10.4%), circumferential (8.8%) and complete (5.2%). Sinus outflow was obstructed in 15% of the scans. Mucosal thickening of $<5$ mm (11.1%), $<10$ mm (36.2%) and $>10$ mm (74.3%) was associated with sinus obstruction ($P<0.0001$). Rounded (6.1%), circumferential (55.2%), irregular (38.8%) and complete (100%) mucosal appearances were associated with sinus obstruction ($P<0.001$). When statistically combined, a substantial risk for sinus obstruction was observed with irregular mucosal appearance of $>5$ mm (56.5% for grade 2 up to 82.6% for grades 3–5) and circumferential appearance (21.4% for grade 1 up to 100% for grades 3–5). A low risk for obstruction was found with the rounded appearance (mean 6.1%).

**Conclusions:** Irregular ($>5$ mm), circumferential and complete mucosal appearance are associated with an increased risk for sinus outflow obstruction and an ENT consultation is recommended. A rounded mucosal appearance of any grade is associated with a low risk for sinus obstruction. Routine CT scans, including the maxillary sinus ostium, are recommended.

The opening of the maxillary sinus (maxillary ostium) is located high up in the sinus medial wall. The mucous secreted from the mucociliary cells is constantly transferred toward the ostium. From the ostium to the nasal cavity, the mucous passes through the infundibulum (part of the ethmoidal system). Damage to the function of the mucociliary cells or sinus outflow obstruction could lead to mucous retention and rhinosinusitis (Alho 2004; Brook 2009).

The most common etiologic factor for developing these disturbances is viral infection, which may be accompanied by secondary bacterial infection. Obstruction of the maxillary sinus can also be caused by edema as a result of an allergic reaction, trauma, barotrauma, polyp or tumor (Brook 2009).

Other factors than obstruction of the sinus ostium can cause mucosal thickening in the floor of the maxillary sinus, e.g., retention cyst, pseudocyst, tumor (Avrahami et al. 1991), reaction to dental treatment (Connor et al. 2000), dental implants (Peleg et al. 1999; Jung et al. 2007) and periodontal disease (Glassberg & Abrahms 1996).

Dentists, especially periodontists and oral surgeons, are increasingly involved in implant surgery, including augmentation procedures in the maxillary sinus, in cases of resorbed alveolar ridge. Augmentation of the maxillary sinus is a well documented (Nkenke & Stelzle 2009; Zijderveld et al 2009) and conventional procedure, which allows the rehabilitation of the atrophic posterior maxilla using osseointegrated dental implants. This procedure was first introduced by Tatum at the annual meeting of the Alabama implant study group in 1977 and later on published by Boyne & James (1980) and Tatum Jr (1986). Surgery includes window drilling at the anterolateral maxillary sinus bony wall, intra-maxillary submucosal dissection and placement of a bone graft between the Schneiderian membrane and the maxillary sinus floor. Implants are placed at the same stage or several months later depending on the height of the residual alveolar ridge. The procedure is predictable, with over 90% implant success and survival rates over time (Jensen et al. 1998; Wallace & Froum 2003; Del Fabbro et al. 2004, 2008; Pjetursson et al. 2008).

Since its introduction, complications associated with the procedure and its impact on implant success and survival have been described. Rhinosinusitis, a well-known complication (Barone et al. 2006), can lead to patient agony and frustration. The clinical picture usually includes post-operative ipsilateral facial pain or pressure, nasal congestion, thick purulent discharge and malodor sensation. Additionally, wound infection could lead to oro-antral fistula. The possible presence of foreign bodies in the maxillary sinus cavity could cause the acute phase to turn to a chronic, recalcitrant course (Fig. 1). Treatment includes prolonged courses of antibiotics and decongestants. Surgery is indicated when medical treatment fails. Surgical options include trans-canine maxillary sinus cleaning and/or endoscopic sinus surgery. However, these unfortunate consequences are commonly associated with bone graft or implant loss.

*Fig. 1.* Computerized tomography, coronal section. Four months post-bilateral sinus lift – the left maxillary and ethmoid sinuses are filled with secretions and bone graft particles. Only endoscopic sinus surgery relieved the patient's symptoms.

In many patients, sinusitis develops secondary to iatrogenic sinus membrane perforation. When the perforation occurs, bone graft particles that advanced through the oral flora could migrate into the sinus cavity. Perforation of the sinus membrane during sinus augmentation procedures is the most common complication reported, with an incidence rate of approximately 30% (Barone et al. 2008; Becker et al. 2008; Hernández-Alfaro et al. 2008; Pjetursson et al. 2008). However, sinusitis is caused by only a small portion of iatrogenic perforations.

In this study, we assume that a compromised maxillary drainage system is associated with a higher risk of post-operative sinusitis. Therefore, pre-operatively, it is crucial to know whether the maxillary sinus drainage system is functional.

A dental computerized tomography (CT) scan is routinely required before sinus lift. The scan is limited to the alveolar ridges to reduce exposure to radiation. Thus, the CT scan of the maxilla includes only the inferior one-third to one-half of the maxillary sinus and does not include the ostium, infundibulum and ethmoidal cells. These limitations do not allow an assessment of the maxillary sinus drainage system, and the dental surgeon does not have the tools to predict the safety of the planned procedure. When the demonstrated lower portion of the maxillary sinus is completely aerated, dentists usually assume normal sinus function and continue with their surgical plan. Commonly, maxillary sinus floor mucosal thickening is present, and in these circumstances, dentists tend to refer the patient for ENT evaluation. However, these physicians also find it hard to evaluate the sinus function without a demonstration of the maxillary sinus outflow.

The objective of this study is to provide the dental surgeon and ENT specialist with better tools for pre-operative assessment and management by asking: (1) What is the incidence of maxillary sinus mucosal thickening in the normal population?, (2) Which mucosal characteristics in the lower half of the maxillary sinus can predict outflow obstruction? and (3) When should the dental surgeon refer the patient to an ENT specialist for further evaluation?

## Methods and materials

The Ethics Committee for Medical Research at Tel Aviv Medical Center reviewed and approved the study protocol. From its computerized database, 280 CT head scans (560 maxillary sinuses) were selected. There were 145 (51.8%) males and 135 (48.2%) females, with an average age of 60.8 years (range 20–85, SD ± 18.8). Scans were usually ordered by the emergency room medical team for various reasons. CT that were requested to assess sinusitis, or trauma to the face, such as car accidents or gun shot injuries, as well as intubated patients [due to the association between intubation and sinus mucosal thickening (Hilbert et al. 2001)], were excluded.

CT scans were performed in the axial plane using various types of helical scanners. Exposure parameters were 120 kVp and 250–300 mA. Two sets of images were routinely reconstructed for clinical use, one of 3-mm-thick overlapping slices with a negative gap of 1–1.5 mm and a second set of high-resolution 1.5 mm thick overlapping slices with a negative gap of 0.5 mm. The second set was subsequently reformatted into a coronal set of images used for this study. The first series of cases was evaluated by two of the investigators (G. C. and Y. S.) for calibration and reproducibility, followed by complete measurement of the principal one (G. C.).

Measurements in the sagittal sections were aligned 90° to the center of the palate for standardization. Mucosal thickening was classified according to height and appearance. Height was divided in accordance to the metric thickening of 0–5, 5–10, 10–15, 15–20 and 20 mm and above, and classified by grades of 1–5, respectively (Table 1). The measurement occurred at the most severe thickening. Appearance was classified as normal, rounded, irregular, circumferential, or complete (Fig. 2). Mucosal thickening of the floor and the adjacent medial or lateral wall of the maxillary sinus was evaluated.

Open infundibulum, or an aerated track between the sinus cavity and the nasal cavity is the best evidence for good maxillary sinus function, and can be easily assessed as patent or obstructed. The ostiomeatal complex was also evaluated after a computerized reconstruction of the axial sections (to coronal ones), and infundibular patency was classified as patent or obstructed (Fig. 3). Blocked infundibulum at the nasal cavity side was considered an obstruction.

### Statistical analysis

The Pearson $\chi^2$-test was used to test the association between mucosal thickening and ostium obstruction and to test the association between mucosal appearance and ostium obstruction. The combined association between mucosal appearance and grade was also associated with sinus ostium obstruction using the same test.

***Table 1*. Classification and distribution of mucosal thickening by grade**

| Grade | | *n* | % |
|---|---|---|---|
| 1 | Up to 5 mm | 63 | 31.2 |
| 2 | 5–10 mm | 69 | 34.2 |
| 3 | 10–15 mm | 26 | 12.9 |
| 4 | 15–20 mm | 11 | 5.4 |
| 5 | Above 20 mm | 33 | 16.3 |

## Results

Maxillary mucosal thickening was found in 202 CT scans of the maxillary sinuses (36.1%).Table 1 shows the distribution of mucosal thickening by grade. Table 2 shows the distribution of mucosal thickening by appearance and association between mucosal thickening appearance and ostium obstruction ($P<0.001$).

Obstruction of the sinus ostium was observed in 84 CT scans (15%). All scans with an obstructed ostium (41.6%) had mucosal thickening (of any appearance or grade) ($P<0.001$), and no scan had an obstructed ostium without mucosal thickening (of any appearance or grade).

Table 3 shows the association between the grade of mucosal thickening and sinus ostium obstruction. Because the number of scans with grades 3, 4 and 5 were relatively small (26, 11 and 33, respectively), these were combined. The obstruction was found in 11.1%, 36.2% and 74.3% of the cases at sites with mucosal thickening of up to 5, 5–10 and 10 mm and above, respectively ($P<0.001$).

The combined association of mucosal appearance and grade with ostium obstruction is shown in Table 4 ($P<0.001$).

***Table 2*. Distribution of mucosal thickening by appearance and association ($\chi^2$-test) between mucosal thickening appearance and ostium obstruction***

| | Mucosal appearance | | Obstructed ostium | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| Normal | 358 | 63.9 | 0 | 0 |
| Rounded | 66 | 11.8 | 4 | 6.1 |
| Irregular | 58 | 10.4 | 32 | 55.2 |
| Circumferential | 49 | 8.8 | 19 | 38.8 |
| Complete | 29 | 5.2 | 29 | 100 |

*$P<0.001$.

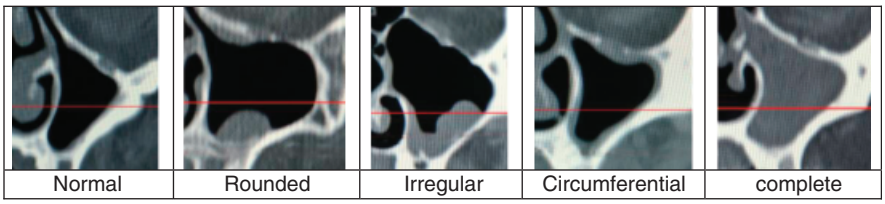


*Fig. 2*. Classification of mucosal thickening appearance. The horizontal line demonstrates the upper limit of dental computerized tomography.

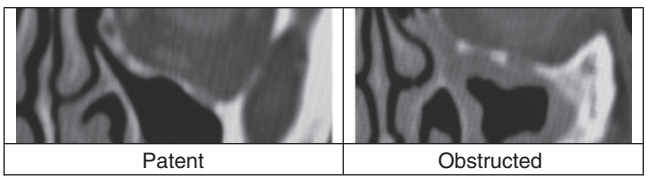


*Fig. 3*. Classification of infundibular patency.

## Discussion

CT is the most useful technique to diagnose signs and symptoms, a recent trauma, and before maxillofacial surgery (Whyte & Chapeikin 2005). Evaluation of CT scans before implant surgery or sinus augmentation procedures has extreme clinical importance. It includes the height and width of the residual alveolar ridge, evaluation of anatomic structures, such as septae, width of the lateral wall, presence of blood vessels and thickening of the Schneiderian membrane.

In this study, various types of helical scanners were used due to a comprehensive need for head and neck purposes. However, for oral and maxillofacial applications, the cone beam computerized tomography (CBCT) has been provided as an alternative for conventional CT with a lower dose and a lower cost. CBCT dose was found to be up to four times fold (25%) less than conventional CT (Ludlow et al 2006).

Peleg et al. (1999) made a post-operative CT evaluation, 8–10 months after augmentation of 24 maxillary sinuses with simultaneous implant placement. Patients who have an obstructed ostium before surgery are prone to complications and therefore caution is advised.

Doud Galli et al. (2001) stated that obstruction of the sinus outflow tract by mucosal edema and particulate graft material may result in sinusitis. They presented 14 cases of chronic sinusitis following a sinus lift surgery.

Timmenga et al. (1997) evaluated the influence of sinus lift on the development of maxillary sinus pathology using endoscopy. Only two of the 45 patients (4.5%) developed sinusitis. Post-operative maxillary sinusitis was detected in two of the five patients with a predisposition for sinusitis, but not in the other 40 patients. It was concluded that the occurrence of post-

***Table 3.*** **Association between grade of the mucosal thickening and the ostium obstruction***

| Grade | Mucosal thickening | *n* | Obstructed ostium | |
|---|---|---|---|---|
| | | | *n* | % |
| 1 | Up to 5 mm | 63 | 7 | 11.1 |
| 2 | 5–10 mm | 69 | 25 | 36.2 |
| 3–5 | Above 10 mm | 70 | 52 | 74.3 |

*$P<0.001$.

***Table 4.*** **Combined association between appearance and grade of the mucosal thickening and ostium obstruction***

| Mucosal appearance | Grade (*n*) | | | Obstructed ostium | |
|---|---|---|---|---|---|
| | | | | *n* | % |
| Normal | | | (358) | 0 | 0 |
| Rounded | 1 | Up to 5 mm | (23) | 1 | 4.3 |
| | 2 | 5–10 mm | (28) | 2 | 7.1 |
| | 3–5 | Above 10 mm | (15) | 1 | 6.7 |
| Irregular | 1 | Up to 5 mm | (12) | 0 | 0 |
| | 2 | 5–10 mm | (23) | 13 | 56.5 |
| | 3–5 | Above 10 mm | (23) | 19 | 82.6 |
| Circumferential | 1 | Up to 5 mm | (28) | 6 | 21.4 |
| | 2 | 5–10 mm | (18) | 10 | 55.6 |
| | 3–5 | Above 10 mm | (3) | 3 | 100 |
| Complete | | | (29) | 29 | 100 |

*$P<0.001$.

operative chronic sinusitis appears to be limited to patients with a predisposition for this condition and that these predisposing factors need to be considered before performing a sinus lift procedure.

Barone et al. (2006) evaluated 70 patients and 124 sinus lift procedures. Suppuration of the maxillary sinus was shown in seven patients (10%) who were administered systemic antibiotics and required drainage. Two patients showed persistent signs of infection despite drainage and required endoscopic treatment to enlarge and liberate the maxillary ostium.

Beaumount et al. (2005) and recently Pignataro et al. (2008) both emphasized the importance of thorough clinical and radiographic evaluation before performing sinus augmentation, but it remains unclear what this ''thorough'' investigation should include.

The basic assumption of this study is that maxillary sinus outflow obstruction significantly enhances the risk of developing sinusitis. According to the literature, membrane thickening and perforation rate is very high and still sinus infection occurrence is surprisingly low. It is likely that when the sinus outflow is patent, the bone graft particles are efficiently delivered from the sinus cavity to the nasal cavity and the digestive tract. However, in an obstructed sinus, the particles, which advance through the oral flora, are trapped and optimal conditions for local infection develop.

The dental surgeon typically continues with the surgical plan when CT demonstrates a well-aerated maxillary sinus. However, when mucosal thickening is observed at the maxillary sinus floor, it is unclear if this finding lacks clinical significance or is an important clue for sinus dysfunction and a higher risk for sinusitis and augmentation failure. In these circumstances, the dental surgeon frequently asks for the advice of an ENT specialist. Unfortunately, for both professionals there is no available data to predict sinus function by the degree of mucosal thickening.

The study goals are to provide guidelines to the dental surgeon and otolaryngologist when faced with maxillary sinus mucosal thickening. The surgeon should make an educated decision whether to continue with the surgical plan or to refer the patient to an otolaryngologist, who may either approve the procedure or consider further endoscopic and radiological evaluation (Nemec et al. 2009). If sinus dysfunction is documented, medical or surgical treatment may be recommended before considering sinus lift.

In this study, the appearance and grade of the mucosal thickening were classified. A statistically significant association was found between different appearances and grades of mucosal thickening and an obstructed ostium.

The risk for obstruction was low (up to 7.1%) with a rounded appearance. This can be explained in that rounded formations usually represent retention cysts that their pathogenesis is clearly unrelated to the patency of the maxillary sinus. However, caution should be taken if a retention cyst occupies most of the sinus cavity, because membrane elevation could cause ostium obstruction by the cyst. Additionally, the probability of sinus obstruction with a rounded appearance still exists and each patient with this finding and accompanying sinusitis symptoms may need an ENT evaluation.

The risk for obstruction sharply increased with mucosal thickness in circumferential and irregular appearances of higher grades. An irregular or circumferential appearance of more than 5 mm (56.5%, 55.6%, respectively) or 10 mm (82.6%, 100%, respectively) was associated with obstructed sinus. All scans with complete opacification of the observed partial maxillary sinus had ostium obstruction.

As long as pre-operative scans include only the lower portion of the maxillary sinus, dental surgeons and otolaryngologists can assess the sinus outflow patency based on these study findings. Clearly, a dental CT scan that routinely includes the maxillary sinus ostium level obviates the need for unnecessary speculations and therefore preferable. The possible disadvantage of expanding the screening field is a higher exposure to radiation. However, not all sinuses need to be included and the additional radiation is minimal.

## Conclusions

The appearance of an irregular (>5 mm), circumferential or complete mucosal thickening is associated with an increased risk for sinus outflow obstruction and therefore an ENT consultation is recommended. A rounded mucosal appearance of any grade is associated with a relatively low risk for sinus obstruction, but ENT consultation is required if accompanying sinusitis symptoms exist.

It is recommended to expand the routine dental CT scan to include the maxillary sinus ostium.

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