The purpose of this study is to review the literature to assess the incidence of maxillary sinus disease before sinus floor elevation surgery (SFE) as identified by cone-beam computerized tomography (CBCT). Only studies in which CBCT was performed in patients for dental implant placement in the past 10 years were considered. Eleven studies were identified. A total of 1792 patients were collected. All the studies reviewed reported on thickening of the sinus mucosa as a criterion for sinus disease with different threshold values. All studies reported mucosal thickening (MT) ranging between 25.5% and 93.1%. The mean incidence of MT was 54.99%. Two studies examined the correlation of MT with clinical symptoms. Three studies reported evaluation of the ostiomeatal complex (OMC). There is a high probability of detecting a certain degree of MT in patients referred for SFE. There is no consensus regarding the threshold values beyond which MT is considered pathological. Independently from the threshold values or the type of MT, the studies lack correlation with clinical data regarding patients' sinusitis-related history or symptoms. CBCT with a large field of view to evaluate the OMC is appropriate in patients scheduled for SFE. Future studies should include a systematic correlation with clinical symptoms and the possible presence of OMC obstruction. A clinical assessment that includes nasal endoscopy is indicated when MT and obstruction of the OMC are identified. Surgical correction of OMC obstruction seems to be appropriate to increase the success rate and to avoid possible complication after SFE.

Key Words: cone-beam computerized tomography, maxillary sinus, mucosal thickness, sinus floor elevation

INTRODUCTION

Sinus floor elevation surgery (SFE) is a widely used procedure to increase the bone height for implant placement in the posterior maxilla. Despite the high survival rate of dental implants inserted in maxillary sinuses that have undergone SFE with bone grafting, complications still occur.1,2

Multislice computerized tomography (CT) is considered the radiologic gold standard for sinus diagnosis. Recently, cone-beam computerized tomography (CBCT) was introduced for dental and maxillofacial imaging.3 CBCT has several advantages over traditional CT, including lower radiation dose, higher image resolution, and lower cost of the machine. CBCT resolution can be as small as 0.125 mm compared with 0.5 to 1 mm for CT. CBCT scanners are capable of imaging with a field of view (FOV) of various dimensions. Larger FOVs are capable of imaging the entire maxillofacial skeleton. CBCT is an accepted diagnostic imaging modality for the evaluation of the maxillary sinuses and alveolar bone before SFE.4

The presence of sinus mucosal abnormalities may pose problems when SFE is planned.5 The most common alteration observed with CBCT before SFE is the presence of lesions such as mucosal thickening (MT), mucus retention cysts, and polyps, which are often asymptomatic.6

Vogiatzi et al7 recently published an interesting review of the literature to analyze available evidence on the incidence of anatomic variations or disease of the maxillary sinuses as identified by CBCT. Twenty-two studies were analyzed, and the main indications for CBCT were dental implant treatment planning. However, among the 22 studies reviewed in 13 studies, the indications for CBCT were not reported or were different from implant treatment planning.

The purpose of this study was to review the literature of the past 10 years to assess specifically the incidence of maxillary sinus disease before SFE surgery as identified by CBCT. Only studies in which patients had performed CBCT for dental implant placement were considered.

RESULTS

Eleven publications concerning investigation by CBCT in patients referred for dental implant treatment were identified...
in the past 10 years. The Table lists the studies included in the present investigation.5–18

In one study,17 the incidence of men and women was not reported. A total of 1792 patients, equally distributed between men (n = 819) and women (n = 923), were collected. Two studies17,18 did not report age information about the sample. The mean age of the remaining 9 studies was 54.18 years, compatible with the average age of implant treatment rehabilitation.

All of the studies reviewed reported on thickening of the sinus mucosa as a criterion for sinus disease, but 2 studies (18.2%) did not define a clear threshold value.16,17 Two studies (18.2%) defined disease as a thickening of >1 mm,10,18 most studies (n = 5; 45.45%) provided a value of 2 mm or greater,5,9,12,14,15 and some (n = 2; 18.2%) defined a value of 3 mm or more as pathologic.11,13 All studies reported an MT ranging between 25.5% and 93.1% of the sample. The mean incidence of MT was 54.99%.

Only 2 studies examined correlation of MT with clinical symptoms or respiratory disease.18 The remaining studies (n = 9; 81.8%) did not analyze correlation of clinical signs and symptoms with radiologic findings from CBCT imaging.

Only 3 studies5,12,13,17 reported evaluation of the ostiomeatal complex (OMC) by CBCT.

DISCUSSION

Extensive bone resorption and sinus pneumatization in the posterior maxilla after tooth loss complicate the insertion of dental implants without additional surgical procedures such as SFE and bone grafting. Assessment of maxillary sinus disease before SFE is essential to prevent postoperative complications such as sinusitis.19,20

Use of CBCT for treatment planning was the recently recommended approach for sinus augmentation.21 Vogiatzi et al17 in their recent review concluded that the main reason for maxillofacial CBCT is assessment of the residual alveolar ridge and maxillary sinus prior to sinus floor elevation or dental implant placement.

From the studies reviewed, there is clearly a high incidence of sinus disease in patients referred for implant treatment and possibly SFE. It can be assumed that half of the patients analyzed may exhibit varying degrees of sinus disease. Differences in the classification of mucosal findings are problematic in the consistent and valid assessment of health and disease of the maxillary sinus.

The 11 studies reviewed reported several methods of measuring the thickness of the sinus membrane and above all different threshold values beyond which it is considered pathologic. It is clear that defining a sinus membrane as pathologic when it exceeds a millimeter of thickness can lead to an increase in the incidence of pathology compared with the studies in which the threshold value is higher. Most studies (n = 7; 63.6%)9,11–15 considered 2 mm or more the pathologic threshold value, but it is not clear how it has come to the definition of this value.

Cagici et al22 stated that mucosa could be seen only at a thickness of 2 mm or greater, and therefore, historically 2 mm was considered a reliable threshold for pathologic mucosal swelling.

Janner et al9 reported that a high incidence of mucosal pathology could be due to the use the 2-mm threshold value to define a pathologic Schneiderian membrane, and the clinical significance of this value has to be regarded with some caution, as it remains to be addressed how many of these findings and which type of MT require therapy.

Yoo et al8 established 2 mm of mucous membrane as the threshold because thickness of less than 2 mm is a normal finding in the ethmoidal sinus23 and difficult to measure. Phothikhun et al10 established a threshold of 1 mm because the normal thickness of the maxillary sinus mucosa is reported to be 0.8 to 1 mm.24

Manji et al13 concluded that there is no consensus as to the exact prevalence of maxillary sinus pathology, and therefore, different thresholds for what is considered pathologic MT are reported. They established a threshold of 5 mm considering that such patients would benefit from referral to a specialist in otolaryngology.

Several studies attribute a threshold on the basis of previous reports.11,12,14,15,18

We also found variability in the classification of the type of sinus MT. Two studies9,14 classified MT according to criteria adapted from Soikkonen and Ainamo25:

1. Flat: shallow thickening without well-defined outlines
2. Semispherical: thickening with well-defined outlines rising
3. Mucocele-like: complete opacification of the sinus
4. Mixed flat and semispherical thickenings
5. Other MT types or pathologic findings

Yoo et al8 differentiated only between MT and completely radiopaque membrane. Phothikhun et al10 differentiated between MT and mucosal cyst. Shanbhag et al12 classified MT as “flat thickening,” or dome-shaped “polypoid thickening” on the sinus floor. Manji et al13 assigned different categories according to the level and pattern of sinus inflammation: healthy, MT (>5 mm), polypoidal MT, partial opacification and/or air/fluid level, or complete opacification.

Irrespective of the threshold value used or the type of MT classification, only 2 studies examined symptoms of the patients.

Jenner et al9 evaluated the following anamnestic parameters in their sample: age and gender, tobacco use, known rhinologic disease, and weeks since last tooth/teeth removal in the examined maxillary segment. Only gender had a statistically significant influence on the thickness of the sinus mucosa, with male subjects having higher mean values.

Maska et al18 evaluated gender, respiratory diseases, cardiovascular diseases, diabetes, and smoking. They did not find any correlation.

The remaining studies did not analyze correlations between MT on CBCT and related clinical symptoms of sinusitis.

Phothikhun et al10 reported an evident limitation in their sample of patients since there was no sinus examination or questionnaire regarding the individual’s sinus condition. Therefore, the prevalence of sinus disease in their sample was unknown. Also, Shanbhag et al12 reported a limitation of their study represented by the absence of clinical data regarding
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>No. of Patients</th>
<th>Male</th>
<th>Female</th>
<th>Mean Age, y</th>
<th>Mucosal Disease Threshold, mm</th>
<th>Incidence of MT</th>
<th>Clinical Correlation</th>
<th>Evaluation of OMC</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yoo et al</td>
<td>2011</td>
<td>103</td>
<td>61</td>
<td>42</td>
<td>51.5</td>
<td>&gt;2</td>
<td>46%</td>
<td>No</td>
<td>No</td>
<td>Periodontal disease resulted in more severe thickening of the mucous membrane.</td>
</tr>
<tr>
<td>Janner et al</td>
<td>2011</td>
<td>143</td>
<td>67</td>
<td>76</td>
<td>57.5</td>
<td>&gt;2</td>
<td>54.76%</td>
<td>Yes</td>
<td>No</td>
<td>Gender seems to be the most important parameter influencing mucosal thickness in asymptomatic patients. Future studies are needed to assess the therapeutic and prognostic consequences of mucosal alterations in the maxillary sinus.</td>
</tr>
<tr>
<td>Phothikhun et al</td>
<td>2012</td>
<td>250</td>
<td>110</td>
<td>140</td>
<td>46.1</td>
<td>≥1</td>
<td>42%</td>
<td>No</td>
<td>No</td>
<td>Severe periodontal bone loss was significantly associated with MT of the maxillary sinus. Mucosal cysts were not associated with any dental findings.</td>
</tr>
<tr>
<td>Lana et al</td>
<td>2012</td>
<td>500</td>
<td>238</td>
<td>262</td>
<td>52</td>
<td>&gt;3</td>
<td>62.6%</td>
<td>No</td>
<td>No</td>
<td>The amount and significance of the anatomic variations and lesions detected in this study reinforce the importance of computerized tomography in preoperative dental implant planning.</td>
</tr>
<tr>
<td>Shanbag et al</td>
<td>2013</td>
<td>128</td>
<td>76</td>
<td>52</td>
<td>57.27</td>
<td>&gt;2</td>
<td>60.62%</td>
<td>No</td>
<td>Yes</td>
<td>Thickened sinus membranes were highly prevalent in this sample of patients. Membrane thickening &gt;5 mm, especially of a polypoid type, is associated with an increased risk for ostium obstruction. In the presence of these findings, an ear, nose, and throat referral may be beneficial prior to implant-related sinus floor elevation.</td>
</tr>
<tr>
<td>Manji et al</td>
<td>2013</td>
<td>275</td>
<td>115</td>
<td>160</td>
<td>54.8</td>
<td>&gt;5</td>
<td>25.5%</td>
<td>No</td>
<td>Yes</td>
<td>It is proposed that, based on the findings of this study, 45.1% patients would require further consultation before proceeding with maxillary sinus augmentation surgery.</td>
</tr>
<tr>
<td>Schneider et al</td>
<td>2013</td>
<td>131</td>
<td>65</td>
<td>66</td>
<td>54.39</td>
<td>&gt; 2</td>
<td>64.49%</td>
<td>No</td>
<td>No</td>
<td>Sex was the only factor influencing the dimension of the sinus membrane. Future studies should address which types of MT require interdisciplinary therapy.</td>
</tr>
<tr>
<td>Nunes et al</td>
<td>2013</td>
<td>122</td>
<td>56</td>
<td>66</td>
<td>57.5</td>
<td>&gt;2</td>
<td>34.9%</td>
<td>No</td>
<td>No</td>
<td>Analysis of the sinus membrane revealed 88 sites (34.9%) with increased mucosal thickness (&gt;2 mm). CBCT is indicated in most patients for proper treatment planning.</td>
</tr>
<tr>
<td>Shiki et al</td>
<td>2014</td>
<td>61</td>
<td>13</td>
<td>48</td>
<td>56.6</td>
<td>NR</td>
<td>49%</td>
<td>No</td>
<td>No</td>
<td>CBCT is important for patients hoping to undergo implant-supported restorations of the maxilla because of the MT in the maxillary sinus in such patients and their lower detection rates on panoramic radiographs.</td>
</tr>
<tr>
<td>Tadinada et al</td>
<td>2015</td>
<td>50</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>72%</td>
<td>No</td>
<td>Yes</td>
<td>Three-dimensional evaluation of the sinus with CBCT was significantly more reliable in detecting pathology than panoramic imaging.</td>
</tr>
<tr>
<td>Maska et al</td>
<td>2017</td>
<td>29</td>
<td>18</td>
<td>11</td>
<td>NR</td>
<td>≥1</td>
<td>93.1%</td>
<td>Yes</td>
<td>No</td>
<td>These data support the concept that physiologic MT in varied ranges is not associated with implant or grafting failure in the maxillary sinus.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>1792</td>
<td>819</td>
<td>923</td>
<td>54.18</td>
<td>54.99%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*OMC indicates ostiomeatal complex; CBCT, cone-beam computerized tomography; MT, mucosal thickening; NR, not reported.
patients’ sinusitis-related history or symptoms. They concluded that future prospective studies should be designed to include clinical data on patients’ sinonasal symptoms.

MT may be related to several factors: retention cysts, reaction to dental treatment, periodontal disease, and obstruction of the sinus ostium.

The presence or absence of clinical symptoms at the time of CBCT execution or in the anamnestic history of the patients is important since some of the MT may be related to sinus ostium or OMC obstruction.

The opening of the maxillary sinus ostium is located high up in the sinus medial wall. The mucous secreted from the mucociliary cells is transferred toward the ostium. From the ostium to the nasal cavity, the mucous passes through the infundibulum. This area is named OMC. Sinus outflow obstruction at this level could lead to mucous retention and rhinosinusitis. The most common etiologic factor for developing these disturbances is viral infection. Obstruction of the maxillary sinus ostium can also be caused by edema as a result of an allergic reaction, trauma, barotrauma, polyposis, or tumor. Also, anatomic variants in the nasal cavity such as deviated nasal septum, accessory maxillary ostium, concha bullosa or paradoxical curvature of the middle turbinate, Haller cells, and bending of the uncinate process can contribute to the blockage of the OMC and consequently may lead to difficult sinus outflow.

The nasal septum is an osseocartilaginous wall that divides the nasal cavity. Severe nasal septal deviation has been related to sinusitis by interfering with the OMC. Concha bullosa is a pneumatization of the middle turbinate. Paradoxical curvature of the middle turbinate is known as a convexity pointing toward the middle meatus. These common anatomic variants might cause the risk of obstruction of the middle meatus and mucosal pathologies. Another common anatomic variant is the presence of infraorbital ethmoidal cells, also known as Haller cells, which can be found between the maxillary sinus and orbital floor. It has been assumed that the Haller cell is an etiologic factor in recurrent maxillary sinusitis due to reduction of the OMC. Accessory maxillary ostium (AMO) is seen in 30% of the patients with chronic maxillary sinusitis and in 10% to 20% of healthy subjects. AMO is usually located on the posterior fontanelle of the lateral nasal wall. The active mucociliary transport in the maxillary sinus is directed toward the natural ostium. AMO causes the mucus circulation, which is from the natural ostium and sinus toward the nasal cavity, to be redirected into the sinus (ie, the reentry of mucus drained through the natural ostium to the maxillary sinus through accessory ostium). It was identified that the presence of accessory maxillary ostium is associated with an approximate threefold increase in the incidence of mucus retention cysts and a nearly 2-fold increase in MT and maxillary sinusitis incidence.

Considering the influence of anatomic variants of OMC, it is recommended that candidates for SFE with any radiologic or anamnestic evidence suggesting impaired maxillary sinus conditions should undergo a radiologic evaluation of the OMC.

In the studies reviewed, only 3 (27%) evaluated OMC with CBCT. It is therefore not surprisingly that all 3 of these studies emphasized the opportunity to refer patients to a specialist if maxillary sinus ostium obstruction is suspected.

Shanbhag et al stated that the presence of a polypoid lesion (pseudocyst) may not itself contraindicate SFE but is associated with an increased risk of ostium obstruction and may warrant a prior ear, nose, and throat (ENT) referral, especially in patients with coexisting sinonasal symptoms or a history of chronic sinusitis. They also proposed a flowchart for ENT referral prior to SFE based on CBCT evaluation.

Manji et al concluded that 45% of the patients examined in their study required further specialized consultation before surgery.

Tadinada et al divided the radiographic findings into 4 classes to provide guidelines regarding maxillary sinus floor augmentation for dental implant therapy. In their classification, radiographic thickening of 2 to 5 mm is not an absolute contraindication for augmenting the sinus, but caution should be exercised and the necessity for a comprehensive clinical examination prior to attempting surgery is stressed. Radiographic thickening measuring 6 to 9 mm, with or without partial obliteration of the sinus, and complete obliteration of the sinus are a contraindication for sinus augmentation. They concluded that referring patients with such findings to an ENT surgeon is indicated to ensure that the pathology is addressed.

Considering the high incidence of MT in the studies reviewed and the possibility of OMC obstruction, it is our opinion that CBCT with a large FOV in order to examine these areas is appropriate. This is especially true if MT is observed, and a subsequent evaluation with a nasal endoscopy is required to avoid the need for execution of another CT to evaluate the OMC.

After considering all the studies reviewed, it can be said that there is no consensus as to the exact prevalence of maxillary sinus pathology as measured by CBCT. Studies are mainly focused on the presence and typology of thickening. What is missing, in our opinion, is a systematic correlation with clinical symptoms and the possible presence of OMC obstruction.

The presence of MT in the maxillary sinus is not necessarily a contraindication to sinus augmentation. This creates a dilemma for the clinician as to when it is safe to enter the sinus to perform augmentation and when it is contraindicated. Unfortunately, no clear guidelines exist to help the clinician plan augmentation of the maxillary sinus. The most common polyoid sinus lesions are antral pseudocysts appearing as dome-shaped radiopaque thickenings of the sinus floor mucosa. Asymptomatic pseudocysts do not always necessitate removal or contraindicate SFE. Several authors have reported successful outcomes of SFE/augmentation performed in the presence of antral pseudocysts in asymptomatic patients. However, polyoid sinus floor lesions are significantly associated with ostium obstruction. Therefore, although the presence of a polyoid lesion may not itself contraindicate SFE, it is associated with an increased risk of ostium obstruction and may warrant a prior endoscopic evaluation, especially in patients with coexisting sinonasal symptoms or a history of chronic sinusitis.
Even if a high rate of implant and grafting success is noted despite large and varied MT, there is general consensus on the necessity of a clinical assessment, which should include nasal endoscopy in patients with MT and obstruction of the OMC. This preventive-diagnostic step should be dedicated to detect irreversible and potentially reversible contraindications to SFE. Reversible contraindications should be removed before SFE mainly with the aid of endoscopic surgery. The standard approach is 2-step surgery in which the first procedure is represented by treatment of the nasal-sinusal impairment performed with functional endoscopic sinus surgery, and, second, augmentation of the maxillary sinus floor can be performed.

Recently, the 1-step procedure has been proposed with apparently good results.

CONCLUSIONS
Based on the findings of the 11 studies reviewed, we can draw the following conclusions:

- There is a high probability (54.99%) of detecting by CBCT a certain degree of MT in patients referred for SFE.
- There is no consensus regarding the threshold values beyond which MT is considered pathologic.
- Independently from the threshold values or the type of sinus membrane thickening, the studies lack correlation with clinical data regarding patients’ sinusitis-related history or symptoms.
- Since a considerable number of patients with MT may have OMC obstruction, CBCT with a large FOV in order to examine this area is appropriate.
- Future studies should include a systematic correlation with clinical symptoms and the possible presence of OMC obstruction.
- No clear guidelines exist to help the clinician plan augmentation of the maxillary sinus if MT is present.
- In the event that after performing CBCT with large a FOV, MT and obstruction of the OMC are suspected, especially with previous symptoms suggestive of sinusitis history, a clinical assessment that includes nasal endoscopy is indicated.
- Surgical correction of OMC obstruction, when identified, seems to be appropriate to increase the success rate and to avoid possible complications after SFE.

ABBREVIATIONS
- AMO: accessory maxillary ostium
- CBCT: cone-beam computerized tomography
- CT: computerized tomography
- ENT: ear, nose, and throat
- FOV: field of view
- MT: mucosal thickening
- OMC: ostiomeatal complex
- SFE: sinus floor elevation surgery

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REFERENCES


