ACTA ODONTOLOGICA SCANDINAVICA, 2017
VOL. 75, NO. 8, 623–633
https://doi.org/10.1080/00016357.2017.1372803

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REVIEW ARTICLE

Odontogenic sinusitis: a comprehensive review

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ABSTRACT

Odontogenic sinusitis (OS) is a highly prevalent, underappreciated and underdiagnosed disease that has been known for over 100 years. Apical periodontitis, periodontal disease and iatrogenic extrusion of foreign bodies into the sinus are the main causes of OS. Although the prevalence of sinus pathosis of dental origin is still controversial, otolaryngologists recognize that in the presence of recalcitrant sinusitis, a dental origin should be considered and properly treated. Currently, cone-beam computed tomography is the gold-standard imaging technique to assess the relationship between dental conditions, especially apical periodontitis and sinus diseases, and whenever this association is detected, patients should be seen by both a dentist and an otolaryngologist in order to achieve complete recovery. This article reviews the current concepts regarding the definitions, diagnosis and management of OS from a clinical point of view.

ARTICLE HISTORY
Received 20 April 2017
Revised 9 August 2017
Accepted 18 August 2017

KEYWORDS
Odontogenic sinusitis; maxillary sinus; sinusitis; periapical periodontitis

Introduction

Sinusitis is the inflammation of the mucosal lining of the paranasal sinuses caused mostly by allergies or respiratory infections. Less frequently, other conditions such as odontogenic infections may be associated with sinus alterations [1]. Maxillary dental infections have been known to cause sinusitis for over 100 years [2] and recently published data show that the number of cases seems to have increased over the last decades [3].

Computed tomography (CT) and cone-beam CT (CBCT) are the most reliable tools for the evaluation of structures within and adjacent to the maxillary sinuses, mainly due to the fact that these techniques allow tridimensional imaging and, in some cases, evaluation of the soft tissues [4–7].

Endodontic and periodontal infections are recognized as potential causes for maxillary sinusitis. In such cases, the terms odontogenic sinusitis (OS) or maxillary sinusitis of dental origin are preferred. Although dental implants and endodontic material can also impinge on maxillary sinuses, these are considered rare causes of sinusitis [1].

OS plays a relevant, yet underappreciated, role in paranasal sinus infections [8] and often requires an interdisciplinary approach [9]. Although it is rare, OS may evolve into more severe complications [10] and even life-threatening conditions [11,12]. Currently, the relationship between dental infections and maxillary sinusitis is well established [13] and otolaryngologists recognize OS as a common but often misdiagnosed condition [14]. Therefore, it is important that dentists are aware of the clinical and radiologic/tomographic features of this condition, in order to provide the correct diagnosis and management of this infection.

Odontogenic sinusitis

Definition

Sinusitis is the chronic or acute inflammation of the mucosal lining of the paranasal sinuses. Currently, rhinosinusitis (RS) is the term most commonly used to refer to sinusitis [1]. Chronic rhinosinusitis (CRS) is a multifactorial chronic inflammatory disorder in which allergic, bacterial and fungal infections may be involved [15]. Recently, the pathophysiological role of biofilms and bacterial LPS has been recognized as an important factor related to the development and persistence of CRS [16].

The diagnostic criteria are rather complex and somewhat controversial and must be based on clinical and imaging evaluation. In terms of imaging characteristics, initially, authors [17] considered that a normal sinus is found when no MT can be detected or an uniform MT <2 mm is observed (Figure 1) and that, OS can be defined when there is a soft tissue density mass within the sinus, where the MT is limited to the area of a tooth presenting one or more of the following conditions: caries, defective restoration, periapical lesion or an extraction site. Although this definition is not a consensus, and the diagnosis of OS relies strongly on clinical symptoms, a recently published study, using CBCT as diagnostic tool [18] reinforced the association between maxillary mucosal thickening ≥ 2 mm and CRS.

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Figure 1. CBCT image showing a normal sinus.

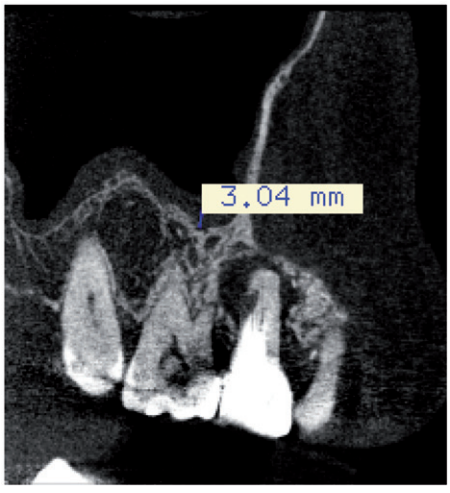

Figure 2. CBCT image showing a mucositis case.

According to the European position paper on rhinosinusitis and nasal polyps, [19] chronic rhinosinusitis (CRS) is defined as the inflammation of the nose and paranasal sinuses characterized by two or more symptoms, one of which should be either nasal blockage/obstruction/congestion or nasal discharge associated to facial pain/pressure and/or reduction/loss of smell for 12 weeks or longer. The same position paper recognizes that CRS of dental origin (also called odontogenic sinusitis) is a condition that should not be overlooked when considering the aetiology of CRS.

Although OS is a well-accepted condition in both the dental and otolaryngology communities, the definition is still debated. Most authors agree that OS occurs when the Schneiderian membrane is violated by conditions arising from dentoalveolar unit. These conditions may be due to advanced dental disease such as caries, apical periodontitis and periodontitis; iatrogenic causes or surgical manipulation [1,2,13–15,17,19,20] (Figure 2).

The initial response to such conditions is usually the thickening of the mucosal lining of the maxillary sinuses. However, there are still disagreements regarding how thick the mucosal lining should be, in order to be considered

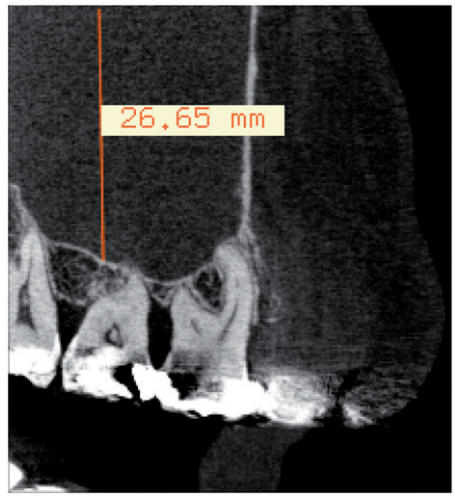

Figure 3. CBCT image showing a sinusitis case.

pathological. Initially it was accepted that MT >6 mm was indicative of disease, [21] but currently, many authors accept MT >2 mm as a sign of sinus pathology, especially when associated with clinical symptoms [18,22].

It is important to differentiate OS from CRS, which is, more frequently a condition that affects both the sinuses (Figure 3). Unilateral imaging of sinus alterations usually suggests the existence of local causes and requires dental evaluation. Consequently, a diagnostic suspicion of OS or another sinusopathy diagnosis should be considered in case of unilateral alteration in the sinus [9] (Figure 4).

Other sinus alterations that are also frequently described and should be carefully differentiated from OS are mucous cysts and retention cysts. Mucous cysts, also called pseudocysts are derived from the accumulation of exudates with a dome-shaped elevation of the sinus membrane while retention cysts are caused by the blockade of the ducts of mucous glands (Figure 5).

Even though these conditions may interfere with dental procedures such as, sinus lifting, they are usually benign and, in most cases, do not require intervention [4].

Whenever there is the suspicion that more serious conditions, such as tumours, may be present (e.g. unilateral epistaxis, nasal obstruction, severe intractable headache, visual disturbance, or cranial neuropathy) the patient should be referred to a specialist in order to confirm or discard the diagnostic with a biopsy [1].

Anatomic conditions related to OS

Periapical lesions in teeth where the root apexes are close to, or extending into, the maxillary sinuses can elicit inflammatory changes in the mucosal lining and, subsequently cause sinusitis [2,17,19,20,23]. Bauer [24] showed, in a cadaver study, that periapical inflammation was capable of affecting the sinus mucosa with or without the perforation of the cortical bone of the sinus floor. Such causes of sinusitis and OS have been known and accepted for at least 50 years.

The continuous expansion and pneumatization that occurs in some patients through life may, sometimes, lead to an

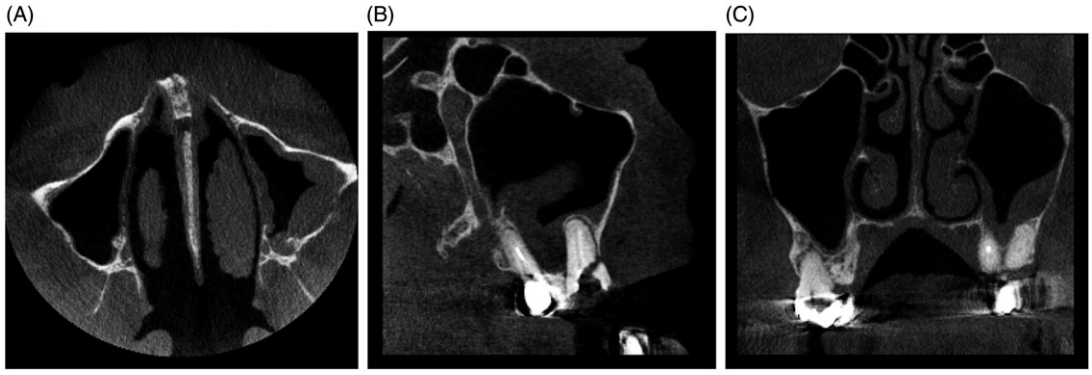

Figure 4. Unilateral imaging of sinus alterations. (A) Axial, (B) sagittal, (C) coronal.

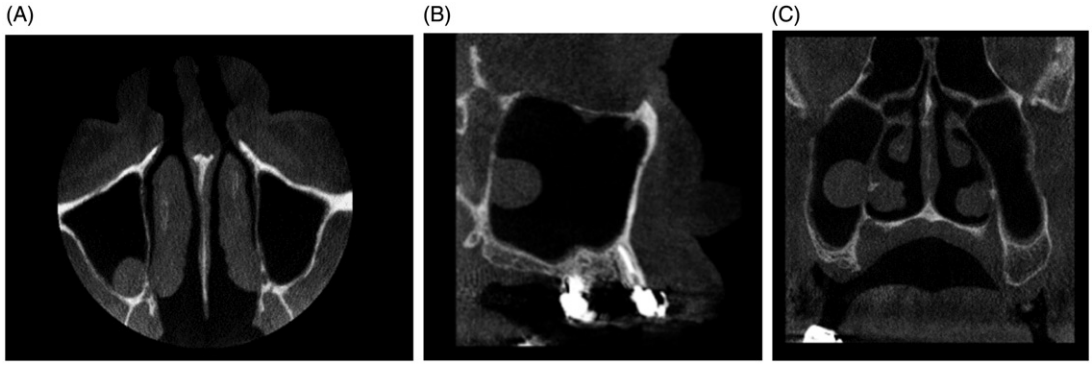

Figure 5. Mucous cyst. (A) Axial, (B) sagittal, (C) coronal.

anatomic condition where only the sinus mucoperiosteum separates teeth apexes from the sinus. This condition can favour the dissemination of odontogenic infections into the sinus [17,20].

Most studies agree that the first molars are the teeth most frequently associated with OS, followed by second molars [25–27]. Maillet et al. [28] reported that 1st and 2nd molars were 11 times more likely to be involved with OS than premolars.

The palatal roots from 1st molars are the roots most frequently associated with OS, followed by the mesio-buccal roots from the 2nd molars. However, Eberhardt et al. [29], in an anatomic study using CT showed that the apex of the mesio-buccal root of the maxillary 2nd molar was closest to the sinus floor with a mean distance of 1.97 mm and the first pre-molars were the furthest with a mean distance of 7.5 mm.

In reality, the roots of posterior maxillary teeth, in many cases, may disrupt the contours of the antral floor, thus increasing the chances of dental infections leading to sinus pathosis [1]. Since there is great variation between individuals and any maxillary posterior tooth can be closely related to the sinuses, a scrupulous examination and individualized approaches are mandatory.

Another interesting finding is that mucosal biopsies of patients that underwent sinus surgery for recurrent OS showed that the epithelial cells were degenerated, shrunken and with desquamation. Patients also presented inhibition of cell proliferation, damages to the protection and shielding effects and predominance of macrophages and lymphocytes in the infiltrate [30]. Also, Kondrashev et al. [31] found that mucociliary transport time in OS is greater than in RS, indicating there is an impaired function of the ciliary epithelium in cases of OS. These findings support the hypothesis that alterations in the protective function of the mucosal lining of the sinuses might increase the risk of proliferation of OS and should be investigated.

Aetiology and prevalence of MT and OS

The relationship between dental infections and maxillary sinusitis is well established [13]. The presence of MT >2 mm is indicative of mucosal pathological alteration [18,22] and the potential causes are infection and mucosal irritations. Sinusitis is considered the major cause of MT in symptomatic individuals [13] and it has been reported that in the presence of inflammation, sinus mucous membrane thickness can increase up to 15 times [32].

Sinus MT is a common radiographic finding which is more likely to be observed in males (2x) and is related to teeth with periapical lesions (9.75x) [22]. The prevalence described in older studies varied from 8 to 29% [33–35]. However, these frequencies seem underestimated, since newer studies, using CBCT scans, found that MT >2 mm was observed in 42–60.5% of the patients and in 29–44.6% of the sinuses [4,18,22].

Other findings from CBCT studies showed that most MT were of the flat type, therefore, not indicative of pseudocysts or retention cysts [22] and that MT >10 mm was not common [4].

Previously published studies, using radiographs, estimated that 10–12% of the maxillary sinusitis had a dental aetiology [36–38]. However, recently, a review of CT and CBCT based studies estimated that OS can account for up to 40% of all cases of sinusitis [1]. Similarly, a recently published retrospective study considered OS an underappreciated diagnosis, reporting an incidence of at least 8% in patients submitted to sinus surgery and suggesting that OS could be resistant to medication-based treatment only [39]. Most authors agree that complete unilateral opacity is uncommon (2.5–6%), and is usually inflammatory in origin and strongly related to OS [40,41].

Endodontic and periodontal infections are frequently considered the main causes of OS, followed by iatrogenic displacement of roots or dental materials into a sinus cavity [1]. However, there is no consensus among authors and each study seems to suggest different aetiologies for OS. For instance, Chen et al. [42], using CT, described the pathological conditions and clinical aspects of patients with unilateral opacity in a maxillary sinus. Out of 830 patients who had sinus surgery, 116 presented unilateral opacity in the preoperatory CT. CRS (52.6%) was the most frequent diagnosis and OS was recognized in 8.2% of the cases. These findings are supported by Phothikhun et al. [4] who found that severe periodontal bone loss was the main cause of OS.

Differently, Chemil et al. [43] reported that OS accounted for 16% of the sinusitis cases that required surgery and more than 50% of the cases were because of periapical lesions. Also, in a retrospective study with 82 CBCTs previously showing maxillary sinus pathosis, more than 50% of the cases were associated with periapical pathology [28].

Fuelling the controversy, Troeltzsch et al. [44] analyzed the causative disease associated with symptomatic unilateral maxillary sinusitis requiring surgical treatment and concluded that 75% of the cases were triggered by odontogenic infections. In their study, 64% of the cases followed dentoalveolar surgical interventions. Other etiological factors for unilateral OS were: periapical lesion (18%) and periodontal disease (10%).

Last but not least, a recently published systematic review [45] that included 19 articles, found that oroantral fistula was the most common aetiology of OS.

Although there is no consensus among authors regarding the main cause of OS, it is well accepted that unilateral sinusitis is strongly associated with a dental origin and, that in order to overcome this pathology both dental and medical assistance should be sought [1].

A study by Matsumoto et al. [9] strongly suggests that dental treatment is mandatory in order to treat OS. The authors evaluated the possible causes of unilateral paranasal sinusitis in a retrospective study that analyzed 190 patients previously treated for unilateral sinusitis and observed that the most common cause of the disease was odontogenic infections (72.6%). The potential causes of dental infection included caries, periodontal disease and dental trauma.

OS is still a therapeutic dilemma and until present, evidence that dental treatment alone is enough to achieve total remission of the disease is lacking [13,15,19,36,37,38,45,46].

Recently, Mattos et al. [47] found that 48% of the patients who presented OS needed to undergo endoscopic sinus surgery (ESS) to control their symptoms and prevent complications. In the study sample, factors such as: prior dental treatment and ostiomeatal complex involvement were strongly related to the need for surgery. All the patients with oral-antral fistula needed to undergo ESS.

Although most studies failed to find difference between genders on the prevalence of MT and OS [1,9], there are two studies that found gender-related differences. One retrospective study that included 346 patients reported that OS was more frequent in females [26]. On the other hand, Shanbag et al. [19] observed that males had higher risk for MT (1.98 times).

The findings of such studies may, in the future, allow us to identify patients with higher risk of OS and OS-related complications and provide these patients with a more individualized interdisciplinary approach.

Iatrogenic causes of OS

Sometimes dental implants; residual roots/teeth or endodontic material may be accidentally pushed into a maxillary sinus and lead to sinus alterations. Literature is filled with reports of sinus alterations following iatrogenic dental procedures and the knowledge that endodontic materials displaced into the maxillary sinus can cause sinusitis has been well documented. Thus, caution is recommended whenever areas close to the sinuses are being treated [48–50]. However, there is no consensus for treatment in cases without signs or symptoms of maxillary sinusitis.

Fortunately, according to recent reviews [1,2], iatrogenic extrusion of teeth is not a common event, thus, should not be held responsible for OS in the majority of the cases.

The risk of developing sinusitis after sinus lift and bone grafting procedures is also a controversial subject. Some authors suggest that such occurrences are not common, especially when there are no complications during surgery, such as perforation of the sinus membrane [17]. Troeltzsch et al. [44] found that no more than 5.2% of the cases of OS were associated with dental implants.

In disagreement with their peers, Puglisi et al. [51] alleged that 20% of the cases of chronic sinusitis were associated with a dental origin, and sinus lift procedures were the main etiological factor. Their conclusion is also supported by the findings of a retrospective study that analyzed the charts of patients presenting OS, and found that 37% of the cases had implant related complications and 29.6% of the cases had dental extraction-related complications [52].

Even though the relationship between implant-related procedures and the development of sinusitis is still unclear, it should be mentioned that, whenever this kind of complication occurs, the consequences are medically relevant. A prospective single-centre study with 19 patients treated for dental-implant-related sinusitis found that 79% of the patients did not respond to medical treatment and had to undergo endoscopic sinus surgery. After 2 years of follow-up, all the patients had a full recovery of the sinus pathosis and the implant survival rates were not affected

by the sinus condition [53]. Felisati et al. [54] evaluated 257 patients treated with functional endoscopic sinus surgery and observed that sinus pathosis derived from complications of implants and sinus lifting showed longer recovery times.

Fortunately, complications in cases of implants placed without sinus lifting seem to be rare, even when the cortical bone of the sinus floor is surgically disrupted. A retrospective cohort study evaluated patients who underwent implant surgery and whose implants were protruded into the sinus; however, the study failed to find any clinical or radiological signs of sinusitis in any of the patients. Long-term follow-up (up to 20 years) indicated that no sinus complications were observed following implant placement penetrating into the sinuses. The estimated implant penetration was $\leq$3 mm for all implants and it is reasonable to believe that, in such cases, the risk of mucosal perforation is small. Deeper protrusions are probably more prone to cause repercussions in the sinuses [55].

Dental infections as the origin of sinusitis

The fairly well-accepted main cause of OS is usually to be periapical or periodontal infection of a maxillary posterior tooth, where the inflammatory exudate has eroded through the bone to drain into the sinus [1]. Hoskinson [3] observed that periapical lesions were responsible for 73% of the cases of OS, oroantral fistulae for 23% and retained teeth for 4%.

In a study using CBCT to determine the relationship between dental findings and mucosal abnormalities of the maxillary sinuses, MT was present in 42% of the patients and 29.2% of the sinuses studied even without related symptoms. The same study observed that severe periodontal bone loss was associated with MT, whereas periapical lesions and root canal fillings were not [4]. These findings were similar to the ones of Chen et al. [42].

Odontogenic infections and periapical lesions are strongly associated to sinus alterations. In a study using CT, Obayashi et al. [56] found that over 70% of the patients diagnosed with maxillary dental infection showed changes in the maxillary sinuses. Acute dental infections, especially periapical abscesses seem to offer higher risk of sinusitis [57].

The initial sinus response to an infectious/inflammatory stimulus is usually the thickening of the sinus mucosa. Sinus MT is almost 10$\times$ more common in individuals with periapical lesions [22]. These findings are similar to the ones of Vallo et al. [35] that showed that periapical lesions increased the risk of having MT, but the same was not true for endodontic treatment.

In a retrospective study with 82 CBCTs previously showing maxillary sinus pathosis, more than 50% of the cases were associated with periapical lesions [28]. Another CBCT based study, with 180 individuals, found that MT was present in 39.4% of the patients. Linear regression showed association of periodontal bone loss with pulpo-periapical status and MT but the influence of periodontal bone loss was four times stronger [32].

In a study with 321 patients, Nunes et al. [58] found that most sinus abnormalities were associated with at least 1 maxillary posterior tooth with a periapical lesion and that the most frequent sinus pathosis in the presence of periapical lesion was MT. Other interesting findings were that all teeth with a CBCT periapical index score of 5 were associated with sinus abnormalities and that the highest frequency of sinus disease was found when the radiolucent area was closely subjacent to the sinus floor.

Another possible cause of MT and sinusitis is peri-implantitis. Although the literature regarding this topic is still scarce, it is reasonable to consider that, as well as in periodontitis, advanced peri-implant infection could lead to sinus abnormalities. In fact, there are already studies reporting sinus infection secondary to peri-implantitis [59,60].

Microbiological aspects

There are significant differences in the microbiology of OS and non-OS. In OS, there is a predominance of oral commensals while in non-OS, nasal commensals are dominant [1].

The microbiota also seems to vary depending on the main cause of infection. OS caused by endodontic infections present different bacteria than the ones found in OS arising from advanced periodontal infection. Anaerobic bacteria are responsible for infectious inflammation in 66.7% of the OS cases [31] and correlation between bacteria present in pathological teeth and the ones found in infected sinus has been described [61].

According to Puglisi et al. [51], all samples of chronic OS are polymicrobial. These authors isolated 15 aerobes and 25 anaerobes and the most prevalent species were: *Staphyloccoccus aureus*; *Streptococcus pneumoniae* (aerobes); *Peptostreptococcus* spp and *Prevotella* spp (anaerobes). Microorganisms strongly associated with CRS like *Haemophilus influenza* and *Moraxella catarrhalis* were not found in OS. Like most polymicrobial infections, there is great variation among samples and frequently, new putative pathogens are found [62].

Recently, a systematic review [45] found that α-haemolytic streptococcus was the most common microbiota in OS and studies on antibiotic resistance showed that OS presents high rates of penicillin-resistant bacteria [8,51,52,53]. Therefore, a different approach should be followed when treating OS.

Due to the high microbiological diversity described and technical limitations from previously published studies, there are still some gaps to be filled regarding the microbiology and the ideal antibiotic protocol in cases of OS. So far, amoxicillin-clavulanate has been the first choice, but newer drugs, such as, levofloxacin, teicoplanin and vancomycin seem to be associated with smaller chances of bacterial resistance and offer better clinical results [8].

Dimorphic fungus of the *Aspergillus* Family can be associated with OS manly in immuno-compromised patient, as diabetes mellitus, HIV infection and chemotherapy, extending to

the orbit, temporal fossa or oral cavity and, sometimes, to the brain [63,64].

Diagnosis (clinical and imaging findings)

OS presents clinical features that are similar to non-odontogenic sinusitis but is usually unilateral and not necessarily associated to obstructions of the ostium [2]. In a retrospective review of maxillary sinusitis cases, unilateral opacification was present in 57% of the cases, suggesting a dental origin, and the duration of the symptoms lasted from 1 month to 15 years [65].

The main symptoms related to OS are: facial pain; toothache; nasal pain; nasal discharge; postnasal drip; nasal obstruction; discomfort of the face and gums and bad odour. However, symptoms may vary and many cases can even be asymptomatic [9]. No difference regarding symptoms was noticed when odontogenic and non-odontogenic sinusitis were compared, and purulent nasal discharge was the most common symptom, affecting 66.7% of the patients [66].

Sinus alterations are frequently detected during imaging evaluations, especially when computed tomography is used. A cone-beam computed tomography (CBCT) based study showed that mucosal thickening (MT), for instance, was present in 42% of the patients and 29.2% of the sinuses studied even without related symptoms [4], but only mucosal thicknesses >2 mm are considered pathological [18,19] and not necessarily define the diagnostic of sinusitis. Although MT can be found in young, asymptomatic individuals [67], it is more prevalent in adults and the elderly and is closely associated with dental infections [68].

About 25% of the patients referred to orthodontic treatment (mean age of 17.5 years old) showed mild MT (mean 1.58 mm) without any clinical signs or symptoms [67]. Meanwhile, an investigation on the prevalence of maxillary findings in the elderly through panoramic radiographs showed MT in 42.26% of the patients. Authors of these studies recommended that, in the elderly, clinical findings should always be assessed because these patients are more susceptible to acute sinusitis due to their decreased host resistance [69].

Seventy-seven percent of the patients seen by both an otolaryngologist and an endodontist had unilateral sinus disease [69]. These authors suggest that regardless of negative CT evidence of dental infection, whenever unilateral maxillary sinus disease is seen, OS is a possible diagnosis and an endodontic evaluation should be performed.

Since 11% of the patients with sinusitis report toothache [70], the correct diagnosis is very important in order to avoid unnecessary dental treatment [1]. Wang et al. [71] reported that 20% of the patients with OS were not properly diagnosed and only 38% recovered from the disease after initial treatment.

Nair and Nair [72] reported a series of cases of failed endodontic therapy presenting confounding clinical signs and symptoms and images of sinus pathosis. The authors suggest that in such cases, 3D imaging with CBCT is an important diagnostic tool to aid clinicians. Even after having had adequate endodontic treatment patients should be referred to an otolaryngologist when there is a persistence of symptoms and the CBCT images suggest sinus pathosis.

Two-dimensional imaging techniques are limited in their ability to detect initial periapical and sinus alterations. A panoramic radiograph may show obvious alterations such as MT or fluid accumulation, but it does not show perfect images of the sinuses. In general, plain dental films and clinical dental evaluations fail to detect maxillary dental infection that can cause OS [2].

Although periapical radiographs are the standard radiographs used in endodontics, they are not adequate to reveal the anatomical relationships between maxillary molars and the sinus floor. Periapical radiographs can only spot approximately 40% of apical periodontitis on posterior maxilla and 3% of all infections extending to the sinuses as shown by CBCT [73].

CT is considered the gold-standard in medicine for visualization of the sinuses and has been used in dentistry because it allows the clinicians to evaluate axial and coronal views, thus, assessing the relationship of a periapical lesion to the sinus floor and any resultant change in the soft tissue of the sinus [5,6,7,74]. However, it has well-documented disadvantages when compared to CBCT, such as: higher exposure to radiation (making the technique more costly, time-consuming and less comfortable to patients); less accurate to visualize details like endodontic and periodontal pathologies, due to the larger field of view and more prone to create artifacts (like beam hardening) when hyperdense materials are close to the area of interest. Thus, currently, CT should be used for dental purposes only in cases where CBCT is not available [5–7].

Fortunately, in the last decade, CBCTs have become more widely available for clinicians and, when compared to CT, show advantages such as: lower radiation dose; chairside process and well tolerated by patients. CBCT is a reliable tool for the evaluation of structures within and adjacent to the maxillary sinuses [5–7] and diagnosing odontogenic infections [63]. CBCT must be acquired with thin slices and have at least two sections from different angles for effective sinus evaluations [9].

Longhini and Ferguson [65], observed that dental infections were not noticed in 86% of the initial radiographs and in 67% of the initial CTs despite being present. The authors reinforce the importance of assessing patients with CBCT and recommending that medical radiologists look for dental pathologies more carefully.

A recently published systematic review [74] demonstrated greater precision for detections of periapical lesions using CBCT when compared to 2D techniques. However, the authors argue that no study justifies the standard use of CBCT in the diagnosis of periapical lesions, although it is a better diagnostic imaging test and currently presents the possibility of using reduced FOV CBCT, directly reflecting the radiation dose, but still higher than that used in conventional periapical radiographs. Thus, this tool should be used in cases where there is evidence to suspect sinus involvement, a need for a surgical approach in areas adjacent to the sinus or endodontic failure, that through conventional periapical

radiography a complete imaging diagnosis is not feasible, despite the radiographic evidence of adequate endodontic treatment [74].

These studies reinforce the position of the American Association of Endodontists (2016) that state that CBCT should not be used routinely for endodontic diagnosis or screening purposes, and is recommended to be used for periapical pathosis only when there is non-specific/contradictory signs and symptoms [75].

Management of OS

Successful treatment of OS requires management of the odontogenic source and may require sinus surgery, since it is frequently recalcitrant to medical therapy [2]. OS is usually restricted to the paranasal sinuses. However, in rare occasions, life-threatening complications may occur, especially in immunocompromised patients. Therefore, dentists should always be alert to these conditions and consider the possible diagnosis of OS-related complications during their initial interviews and clinical examinations [2].

In cases where elective procedures involving the maxillary sinuses are needed (such as sinus lift procedures) and the patient shows major MT or images suggestive of sinus pathosis, an otolaryngologist should be consulted to discard or treat the sinus infection prior to the dental intervention [76].

A thorough dental examination is necessary to confirm the association between an odontogenic condition and maxillary sinusitis [77]. It is very important to make a correct diagnose in order to avoid unnecessary dental treatment [1] and provide the correct management of the condition, especially when recently published evidence highlights that 20% of the patients with OS are not properly diagnosed and only 38% had a full recovery of the disease after initial treatment [69].

Patel and Matsumoto [2] recommend that the evaluation of all patients with persistent CRS should include an inspection of the maxillary teeth on CT scan for evidence of any periapical lucencies. However, in such cases these patients should be referred for a dental appointment with proper imaging techniques such as periapical radiographs or CBCT that can be used to detect apical periodontitis, instead of CT scans.

There is a consensus that an interdisciplinary approach is mandatory [9] for OS, as it may be resistant to conventional sinusitis therapy [77]. The antibiotic therapy associated with dental treatment is usually the initial treatment for pathologies of the maxillary sinus of dental origin, however, when the conservative therapy fails, an endoscopic surgical approach is necessary. The endoscopic approach of the sinus is the treatment of choice due to lower complication rates and lower morbidity [59]. Only in some cases is an external surgical approach necessary [77].

A study in the UK found that 81% of the cases of OS required sinus surgery and that OS accounted for 8% of all cases requiring sinus surgery [3] and the aperture of the ostiomeatal complex may be a significant predictor of the effectiveness of initial treatment [78]. Dental treatment alone is rarely sufficient to treat OS [2,79].

In some cases, OS may evolve to extramaxillary extension, requiring a combined oral and endonasal approach. Up to 41% of the patients treated with surgery for OS had unilateral extramaxillary involvement [80]. A retrospective cohort study on 55 patients diagnosed with OS, and treated surgically by endoscopic surgery, showed that in 52.7% of the cases the sinusitis spread to the anterior ethmoid sinus. However, ethmoid involvement did not worsen the result of the surgery and patients showed high frequency of recovery after surgery [81].

Longhini et al. [82] reported that unrecognized periapical abscesses were the cause of endoscopic sinus surgery failures in five patients that had been submitted to, on average, 2.8 surgeries and remained with persistence of the disease and symptoms until the dental infection was treated.

Although it is rare, in some cases, OS may evolve into more severe complications such as orbital abscess [10] and even life-threatening conditions such as parietal subdural empyema [12] and other central nervous system infections [11]. Due to the differences in the etiopathogenesis, when compared to CRS, treating OS patients requires individualized medical and surgical approaches in order to achieve acceptable success rates [8].

Antibiotics treatment (resistance)

In OS, bacterial resistance to antibiotics should be an important concern. Saibene et al [8] found that in 70% of the OS cases, bacteria were susceptible to amoxicillin/clavulanate, while in all cases they were susceptible to levofloxacin, teicoplanin and vancomycin.

The same study found that 80% of the *Staphyloccocci* spp present were capable of producing β-lactamase. This finding reinforces the ones from Puglisi et al. [51] that reported a high prevalence of antibiotic resistance in bacteria from OS patients. In their study, 22% of the *S. aureus* were resistant to oxacillin; 75% of the *S. pneumonia* were penicillin-resistant and/or erythromycin-resistant; 21% of the anaerobic Gram-positive bacteria were penicillin-resistant and 44% of the anaerobic bacteria were β-lactamase-positive. Amoxicillin-clavulanate showed the highest *in vitro* activity against aerobic Gram-negative bacteria [51].

Therefore, whenever approaching infections that might be involving the sinuses, dentists should use a different antibiotic therapy protocol, targeting β-lactamase producing bacteria.

Dental treatment

Although in the past Nenzén and Wellander [36] reported on the recovery from MT after endodontic treatment, nowadays it is generally accepted that, in most cases, this does not happen, and an interdisciplinary approach is needed [2,8]. Nurbakhsh et al. [83], in a pilot study involving 30 sinus infections in 29 patients, found that only 30% of the patients full recovered from the sinus pathosis (mucositis) after endodontic treatment, despite the fact that the periapical index scores were reduced. When mucositis was detected, the resolution was assessed with CBCT scanning 3 months

after treatment and periapical healing was assessed using the periapical index (PAI) after 6 months. Only 30% of the patients had fully resolved mucositis; 30% had it partially resolved; 30% unchanged and 10% worsened.

Unquestionably the correct identification and treatment of the underlying dental disease is mandatory in order to achieve the ideal conditions for sinus intervention [28], especially in cases of endodontic and periodontal infections.

Consensus is still lacking on how to approach a foreign body inside the sinus. Surgical removal of the material is indicated in cases where the presence of the foreign body leads to sinusitis. However, a no-treatment consensus exists for cases without signs or symptoms of maxillary sinusitis [53]. In cases like these, all treatment options should be discussed with the patients and the case should be approached taking into consideration the dentist's experience and the patient's best interests.

Final comments

Maxillary dental infections have, for over 100 years, been known to cause sinusitis. However, this insight has been largely overlooked by physicians, with a tendency to focus on the ostiomeatal complex instead [2].

Overall, otolaryngologists recognize OS as a common sinus pathosis and perceive that radiologists never or rarely describe dental conditions in their sinus CT interpretations [14]. The same group suggests that otolaryngologists should suspect an odontogenic etiology whenever CRS does not respond to antibiotics, especially when a recent dental examination is lacking, and that an unrecognized dental infection may lead to sinus surgery failure and cause patients to be submitted to unnecessary surgical procedures [82].

First molars are the teeth most frequently associated with OS, followed by second molars [25–27]. However, there is a large variation among patients and each case should be evaluated individually.

In a study using CBCT to determine the relationship between dental findings and mucosal abnormalities of the maxillary sinuses, MT was present in 42% of the patients and 29.2% of the sinuses studied even without related symptoms and was more frequent in males. The authors also observed that severe periodontal bone loss was associated with MT whereas periapical lesions and root canal fillings were not [4].

Prevalence of MT varied from 8 to 29% [33–35] in older studies. This difference is probably due to technical limitations of the methods used and to different definitions of what is a normal or thickened mucosa. Initially, MT >6 mm was considered indicative of mucosal disease [21] but currently, thicknesses >2 mm are already considered pathological [22,23]. There is still some disagreement regarding the implications of increased mucosal thicknesses, especially in non-symptomatic patients.

A couple of studies found that periodontal bone loss had a stronger association to MT than periapical pathosis [4,32]. Since it seems unlikely that periodontal disease alone (not combined endodontic-periodontal lesions) could have a stronger influence on sinus mucosa, this topic should be investigated further in order to determine the real strength of each association.

One study reported sinus abnormalities in 55% of the patients referred for dental implants [84]. Since sinusitis decreases the success rates of implants [85], this should be taken into consideration whenever sinus lifting/grafting procedures are planned or implants are planned to be placed in close relation to the sinus and an otolaryngologist should be consulted prior to the surgical procedure.

Older studies estimated that 10–12% of the maxillary sinusitis had a dental aetiology [35–38]. However, this number is probably underestimated due to the limitations of the diagnostic tools available back at that time when these studies were conducted. Currently, odontogenic causes must be considered, especially in unilateral cases.

More recently, new diagnostic tools, such as CT and CBCT, together with an interdisciplinary approach, showed that OS is a highly prevalent condition, which usually goes undiagnosed [9,58].

The fact that complete unilateral opacity is uncommon (2.5–6%) should be emphasized and it is usually inflammatory in origin [40,41] while bilateral opacity is usually a consequence of allergic problems [42]. Although there are a few studies on unilateral sinus opacity, only two studies had a significant number of patients (>50) and used CT [2,86]. Thus, further investigations are needed.

There are reports that 77% of the patients seen by both an otolaryngologist and an endodontist had unilateral sinus disease. These authors suggest that regardless of negative CT evidence of dental pathology, OS should be suspected whenever unilateral maxillary sinus disease is seen and, in these cases, an endodontic evaluation should be carried out [68]. Related to this, Longhini and Ferguson [65] recommend that in cases of refractory maxillary sinusitis, otolaryngologists must seriously suspect odontogenic causes.

Since the main symptoms of unilateral sinusitis are similar to the ones found in bilateral sinusitis and there is great variation between cases, the correct diagnosis is a difficult task that usually involves medical and dental evaluations.

Although it is rare, in some cases, OS may evolve into more severe complications. Possible life-threatening complications are very rare and still a controversial topic.

Although authors consider that the relationship between dental infections and maxillary sinusitis is well established [2,9,13], it should be noted that, there is significant disagreement between studies regarding the main cause of OS depending on the study sample and the diagnostic criteria. More cohort and longitudinal multi-centred studies using the most accurate up-to-date diagnostic tools and standardized definitions of the diagnostic criteria should help clear up this matter. Prospective studies and larger multicentric epidemiological data, conducted following a strict study design, and case definitions, are still needed to better understand the prevalence, aetiology and possible repercussions of OS.

Conclusions

OS is a highly prevalent, frequently underestimated condition in which periapical lesions, periodontal disease and iatrogenic intrusion of foreign bodies into the sinus may play an important role in its aetiology. This association is more prone to happen in teeth more closely related to the sinus floor, such as the maxillary first molars but there is great anatomical variation between individuals.

Since signs and symptoms of OS are similar to those of CRS, the correct diagnosis is based on medical history, a thorough dental examination and imaging evaluation, preferably with CBCT. The first tomographic sign of sinus alterations of dental origin is MT of the flat type.

Management of OS should be interdisciplinary and dental interventions are required prior to the medical approach (usually endoscopic sinus surgery associated to antibiotic therapy targeting β-lactamase producing bacteria). Although OS is a chronic condition that can go undiagnosed for years, treatment shows high success rates and the risk of more medically relevant complications is very low.

Further research is needed and should help clear up the controversial topics regarding OS.

Disclosure statement

The authors declare that they have no competing interests.

Funding

The present study was funded with resources provided by the Estácio de Sá University productivity grant.

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