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The maxillary sinus and its endodontic implications: clinical study and review

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Abstract. *The maxillary sinus and its endodontic implications: clinical study and review. Objectives*: Endodontic infections of posterior maxillary teeth sometimes spread to the maxillary sinus, generating severe complications. The aim of this study is to present the various problems encountered during endodontic treatment of these teeth.
Methods: The files of 125 cases of odontogenic chronic maxillary sinusitis were reviewed retrospectively.
Results: Chronic apical periodontitis was the cause in 99 cases and traumatising endodontic treatment in 26 cases. Foreign intrasinusal bodies were occasionally seen as a consequence of different endodontic treatments of posterior maxillary teeth.
Conclusions: A knowledge of dento-antral relationships is particularly important in the prevention of sinal accidents and complications during various therapeutic manoeuvres, which should be performed according to and depending on the regional morphology.

Introduction

The close anatomical relationship of the maxillary sinus with the roots of maxillary molars, premolars and, occasionally, canines renders this anatomical region susceptible to morbid situations resulting from damage to, and therapeutic intervention in, the dento-alveolar environment (Figure 1). Stafne[1] estimated that 15-75% of sinusitis cases have a dental cause, although the true incidence is difficult to determine accurately. The dental literature contains several references to the extension of periapical inflammation to the maxillary sinus.[2-7] Several reports have also been published describing serious complications resulting from the extension of these inflammations, including periorbital cellulitis, blindness, and even life-threatening cavernous sinus thrombosis.[8-9]

The introduction of bacteria and their products into the pulp chamber can result in inflammation of the pulp tissue and subsequently, in its devitalisation. The necrotic and infected pulp affects the periapical tissue. The purpose of root canal or endodontic treatment is to maintain the healthy status of the tissues that surround a tooth's root, despite the fact that the tooth's pulp has undergone degenerative changes. Specifically, our goal is to protect the tissues surrounding a tooth's root from bacterial infection and/or irritating substances leaking from those inner surfaces of the tooth originally occupied by the tooth's nerve tissue. To accomplish this task during endodontic treatment, the infected pulp tissue should be removed, together with part of the dentin surrounding the root canal, with the help of mechanical instruments and chemicals. Files and reamers are used to remove the remnants of the pulp tissue and to scrape off the infected dentin, and antiseptics such as sodium hypochlorite and calcium hydroxide are used to maintain an aseptic environment. Antibiotics have not been found useful. In this way, the infection is eliminated inside the root canal. The expansion of the root canal infection to the periapical tissues can lead to a periapical pathological situation such as a periapical cyst, a granuloma or an abscess.

Maxillary sinus involvement may occur during endodontic procedures because of the extension of periapical infections into the sinus, the introduction of endodontic instruments and materials beyond the apices of teeth in close proximity to the sinus and the risks and complications associated with endodontic surgery.

The pathological disruption of both periapical and adjacent antral tissues resulting from endodontic infection has been well documented.[2-5] Selden coined the term

Figure 1
Maxillary molars in close proximity to the sinus. The arrow shows the lamina dura.

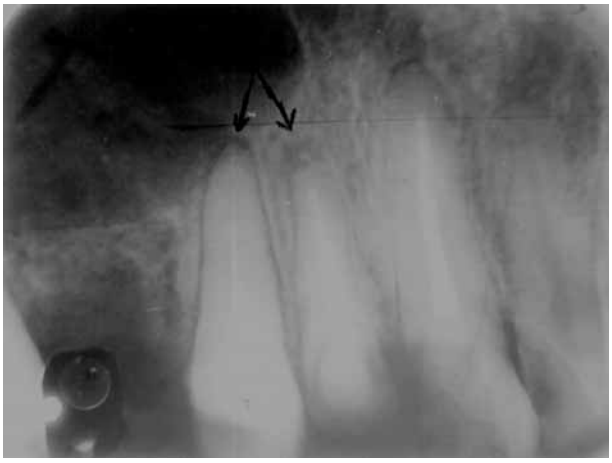

Figure 2
Thickened sinus mucous membrane as a result of chronic apical periodontitis at 25.

"endo-antral syndrome" (EAS) for the spread of pulpal disease beyond the confines of the dental supporting tissues into the sinus.[4,5] The characteristics of EAS are: (1) pulpal disease in a tooth of which the apex approximates the floor of the maxillary sinus; (2) periapical radiolucencies on pulpally involved teeth; (3) radiographic loss of the lamina dura defining the inferior border of the maxillary sinus over the pulpally involved tooth; (4) a faintly radiopaque mass bulging into the sinus space above the apex of the involved tooth, connected neither to the tooth nor the lamina dura of the tooth socket (representing a localised swelling and thickening of the sinus mucosa); and (5) varying degrees of radiopacity of the surrounding sinus space (comparison of the contralateral sinus is often helpful).[4,5] The variable presentation of EAS can create diagnostic and therapeutic difficulties, because all five features are not always evident.

The aim of this study was to examine the relation between the teeth and the maxillary sinuses, and therefore to prevent damage during the various stages of endodontic therapy.

Materials and methods

The study included 309 patients referred for endodontic treatment to the Oral Maxillary and Facial Surgery Clinic of the Carol Davila University of Medicine and Pharmacy of Bucharest over a period of 2 years. One hundred and twenty-five of them suffered from chronic maxillary sinusitis caused by various odontogenic problems and the consequences of endodontic treatment. The inclusion criteria were:

- chronic maxillary sinusitis diagnosed on clinical and radiological grounds;
- lack of response to medical or surgical treatment;
- presence of various related problems in posterior maxillary teeth;
- cure after appropriate endodontic treatment.

The files of these 125 patients were reviewed retrospectively.

Results

The patients ranged in age from 12 to 81 years (mean 46.5 years). The age range of 66 patients was 30-60 years. Sixty-nine (55.3%) of them were female and 56 (44.7%) were male. In 99 patients (79.2%), the cause of sinusitis was chronic apical periodontitis and, in another 26 cases (20.8%), traumatising endodontic treatment was probably implicated (syndrome EAS). All patients had received medical treatment, including antibiotics and anticongestants, without success. Twelve patients had been operated with Caldwell-Luc procedures, but the symptoms of maxillary sinusitis remained unchanged or had slightly improved.

Among the 99 cases of chronic periapical periodontitis (Figure 2), 12 patients presented periapical cysts, which had either gradually destroyed the alveolo-sinusal bone plate (9 cases) or showed intrasinusal invasion (3 cases) (Figures 3, 4). In the group of 26 cases with traumatising endodontic treatment, 16 presented

Figure 3
Large periapical cyst in the left maxillary area with extension into the maxillary sinus.

Figure 4a
Large cyst in the periapical area of 16 after failure of endodontic treatment (panoramic X-ray).

with foreign intrasinusal bodies from various endodontic treatments of posterior maxillary teeth (Figure 5).

In the present study we found the presence of *Selden endo-antral syndrome* as an endodontic complication in 35.9% of the patients.

Mucosal thickening was observed in 115 patients, fluid accumulation in 7 patients, and bony wall thickening in 3 patients. Severe symptoms such as pain and nasal obstruction were limited to the 7 patients who had fluid accumulations on CT images.

Figure 4b
CT scan, axial view

Figure 4c
CT scan, coronal view

Figure 4d
CT scan, lateral view

Figure 5
Root overfilled with paste in the maxillary sinus, leading to chronic maxillary sinusitis (teeth 14, 15, 16).

The following causal teeth were identified: M_2 (32.4%); M_1 (30.6%); PM_2 (23.7%); M_3 (6.8%); PM_1 (5.6%); C (0.9%). Conventional endodontic treatment was performed in 77 cases, endodontic re-treatment in 26 cases and apicectomy in 22 cases. After appropriate endodontic treatment, complete remission of the disease occurred in all 7 patients with severe sinusitis, and improvement of the symptoms and the radiological findings was observed in the other patients.

Discussion

The maxillary sinus is the first of the paranasal sinuses to develop in human foetal life. During the fifth foetal month, secondary pneumatisation starts as the maxillary sinus grows beyond the nasal capsule into the maxilla. At birth, the sinus is approximately $10 \times 3 \times 4$ mm in dimension and continues to grow slowly until the age of 7 years when expansion occurs more rapidly until permanent teeth have erupted. The average dimensions of the maxillary sinus of the adult are $40 \times 26 \times 28$ mm with an average volume of 15 mL.[10,11]

The maxillary sinus is typically pyramidal in shape, with the base of the pyramid forming the lateral nasal wall and the apex extending into the zygoma.[11] The anatomical relation between the maxillary sinus and maxillary teeth is a complex one, owing to the variable extension of the sinus. In about 50% of the population, it may expand into the process of the maxilla, forming an alveolar recess. In these cases, the maxillary sinus is in close relation to the roots of the maxillary molar and premolar teeth, particularly the second premolar and the first and second permanent molars. In rare cases the sinus floor can extend as far as the region of the canine root.[12] The sinus floor exhibits recesses extending between adjacent teeth or between individual roots of teeth. The alveolar bone can become thinner with increasing age, particularly in the areas surrounding the apices of teeth, so that root tips projecting into the sinus are covered only by an extremely thin (sometimes absent) bony lamella and the sinus membrane. The deepest point of the maxillary sinus is normally located in the region of the molar roots, with the first and second molars being the two most commonly dehiscent teeth in the maxillary sinus at 2.2% and 2% respectively.[13] However, with extensive pneumatisation, the third molar, premolars and canine teeth may all be exposed into the sinus.[11] Several studies have reported the relative positions of the roots with respect to the sinus.[14,15] According to these studies, the frequency of close proximity (0.5 mm or less) of roots of posterior maxillary teeth to the sinus floor is: second molars 45.5%, first molars 30.4%, second premolars 19.7% and first premolars 0%.[15]

Two radiographic studies classified the relationship between the roots of the maxillary teeth and the sinus inferior wall. Freisfeld *et al.*[16] described 3 types of vertical relationships and, more recently, Kwak *et al.*[17] used the Dentascann reformatted cross-sectioned images and suggested 5 vertical relationships: Type I, inferior wall of the sinus located above the level connecting the buccal and palatal root apices; Type II, inferior wall of the sinus located below the level connecting the buccal and palatal root apices, without an apical protrusion over the inferior wall of the sinus; Type III, apical protrusion of the buccal root apex observed over the inferior wall of the sinus; Type IV, apical protrusion of the palatal root apex observed over the inferior wall of the sinus; and Type V, apical protrusions of the buccal and palatal root apices observed over the inferior wall of the sinus. In addition, the horizontal relationships between the inferior wall of the maxillary sinus and the roots of the maxillary molars were allocated to 3 categories: Type 1, alveolar recess of the inferior wall of the sinus located more towards the buccal side than towards the buccal root; Type 2, alveolar recess of the inferior wall of the sinus located between the buccal and palatal roots; and Type 3, alveolar recess of the inferior wall of the sinus located more towards the palatal side than towards the palatal root. The authors found that the most frequent vertical relationship was a sinus floor that did not contact the dental roots and that the most frequent horizontal relationship was sinus recess located between the buccal and palatal roots.

The patient with suspected maxillary sinus disease of odontogenic origin should be examined clinically. The affected sinus may be markedly tender to tapping or palpation.[18] The teeth affected by sinusitis will be moderately or extremely sensitive to palpation and/or percussion, but will respond within normal limits to conventional pulp sensitivity tests. Pain typically radiates to all the posterior teeth of the quadrant, so that all the teeth usually become tender to percussion. The nasal passage of the affected side may be partially or completely blocked. Nasal discharge is considered to be a significant sign of the sinus infection. Severe acute or subacute sinusitis rarely produces fever, but a severe fulminating sinusitis will produce a high temperature and some degree of malaise. If only one tooth demonstrates tenderness to percussion, this may be the source of the difficulty and sinusitis may be excluded. Radman[19] suggested the placement of a cotton swab saturated with 5% lidocaine in the nostril of the affected side as a differential diagnostic test. The swab should be placed posterior to the area of the middle meatus and left in place for 20-30 seconds. If the pain is of sinusal origin it will be modified or eliminated within 1-2 minutes and therefore lead to the presumptive diagnosis of maxillary sinusitis. Similarly, the use of a topical nasal decongestant may help in differentiating between pain caused by sinusitis and pain of dental origin. In contrast to pain of sinusal origin, pain of dental origin is much more variable and ranges from thermal sensitivities to spontaneous episodes of sharp and unrelenting severe pain and may be associated with regional swelling and cellulitis. In advanced dental disease, radiographic involvement is usually apparent.

Diagnostic evaluation of the maxillary sinus may be obtained by radiographic examination. A wide variety of exposures readily available in the dental surgery, otolaryngology, or radiology clinic are available.[20,21] These include periapical, panoramic and facial views, which may provide adequate information to either confirm or rule out pathology. On periapical radiographs, the border of the maxillary sinus appears as a thin, delicate tenuous radiopaque line and is seen as a fusion of the lamina dura and the floor of the sinus.[22] This view may fail to show lamina dura covering the root apex in areas with defective bony covering.

The lamina dura is the thin hard layer of bone that lines the socket of a tooth and that appears as a dark line in radiography (Figure 1). It surrounds the periodontal ligament and consists of bundle bone. This type of bone usually forms attachments of tendons and ligaments in different parts of the human bone structure, and it is usually more calcified than other types of bone. The disruption of the continuity of the lamina dura in the periapical area is the first sign of periapical pathology resulting from dental root canal infection. This fact is of great clinical importance as it can lead to the early diagnosis of endodontic infections.

Panoramic radiography provides an extensive overview of the sinus floor and its relationship with the dental roots. It allows for the determination of the size of periapical lesions and cysts as well as radio-dense foreign bodies. Furthermore, local swelling of the sinus membrane and opacities can be diagnosed.[12,21]

Periapical and panoramic radiography are routinely used for the diagnosis, treatment, and monitoring of the healing process of periapical lesions. These techniques compress three-dimensional anatomic structures into two-dimensional images, resulting in the superimposition of anatomic structures onto the features of diagnostic interest, sometimes to the extent of concealing the latter. It is well known that, under certain conditions, periapical lesions may not be seen in intra-oral radiographs. These limitations become particularly evident in the maxillary molar region with its complex anatomy. Other disadvantages are horizontal and vertical magnification (10-33%) and a lack of cross-sectional information.[22,23]

Additional information can be obtained with the help of specialised skull views.[22] The occipito-mental or Water's projection is optimal for the visualisation of the paranasal sinuses, including the maxillary sinuses. With varying angles (15°, 30°, and 35°), it is possible to compare internal anatomy, bony continuity and defects, as well as sinus pathology or foreign objects.[23] Other images that may be included are submentovertex, posteroanterior and lateral skull views. Unfortunately, the sensitivity of conventional radiological skull views is low and they have been replaced recently by computerized tomography (CT) that has become increasingly important for the evaluation of sinus disease.[22] This modality provides multiple sections through the sinuses at different planes and therefore contributes to the final diagnosis and determination of the extent of the disease.[9,22] CT surpasses the limitations of conventional views owing to uniform low magnifications, but its disadvantages include limited availability, expense and the high radiation dose.[24] Dentascan is a CT dental reformatting program that allows reconstruction of the mandibular or maxillary alveolar ridges in direct coronal and panoramic planes (Figure 6). This software was developed as a more accurate and sophisticated method of evaluating the mandible and the maxilla for the purposes of dental implant technology. The images predominantly show the osseous anatomy of the jaw. However, this software is not yet established in the routine evaluation of the maxillary sinuses.[21]

New approaches to evaluating the maxillary sinuses with magnetic resonance imaging (MRI) continue to develop rapidly. However, standard T1-weighted and T2-weighted images still provide the basis of imaging. Advantages include better soft-tissue discrimination than with CT and easier multi-planar image acquisition. The limitation of MRI is its inability to image bone due to the lack of signal for cortical bone. In addition, the air within the sinus does not produce a signal. This makes evaluation of the bony anatomy and pathology difficult. Currently, MRI is mainly useful in determining the spread of disease, especially intracranially and intraorbitally. Distinguishing between neoplastic and inflammatory tissue is an additional advantage.[19,21]

The radiographic appearance of EAS usually varies consistently from normal appearance. The typical radiographic pathological EAS changes are: development of a periapical radiolucent area; loss of the osseous lamina dura characteristically defining the inferior border of the maxillary sinus; the appearance of a faintly radiopaque rounded mass bulging into the sinus space above the apex of the involved tooth; and varying degrees of radiopacity of the contiguous sinus space.[4,5] Radiographically, changes in the lower part of the sinus strongly indicate odontogenic involvement, and this is a notable finding representing the initial sign of dental infection that leads to severe sinusitis.[20] Other signs include fluid accumulation and maxillary sinus wall thickening.[7] In our cases, the most frequent radiographic sign was mucosal thickening of the maxillary sinus. Other investigators agree with this finding.[7,22]

Microscopically, the involved areas showed the destruction of the bone separating the sinus from the teeth, with particular loss of the cortical bone normally found on the sinus floor. In addition, the sinus mucosa was seriously altered in many ways, such as swelling with inflammation, granulation tissue, hypertrophy, fibrous changes, hyalinisation or complete necrosis.[4] In the past these mucosal changes in the sinus led to the belief that the involved teeth should be extracted.[25] By contrast, newer studies seem to indicate that most cases of EAS will respond satisfactorily to non-surgical root canal treatment. A surgical approach has been recommended for cases refractory to routine conservative management.[2,4]

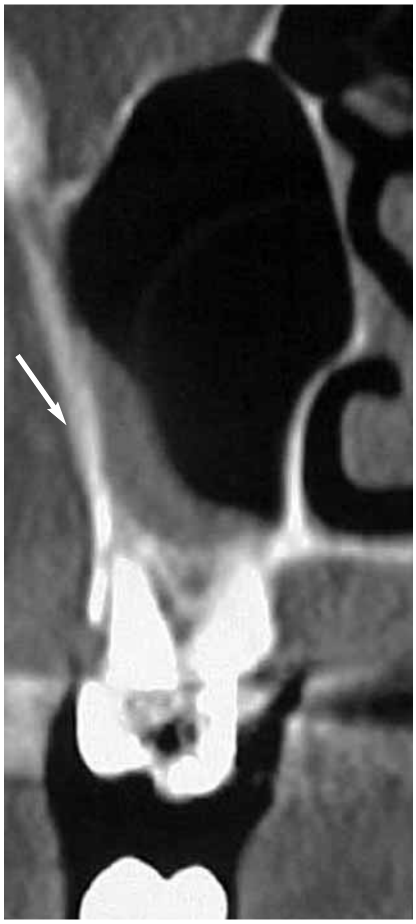

Figure 6
Dentascann view

Root filling materials have, occasionally, been reported as causative agents of maxillary sinus fungus ball.[26,27] Kopp *et al*.[28] and Stammberger *et al*.[29] found that the typical radiopaque maxillary sinus concretions seen in more than 50% of the cases with diagnosed sinus fungus ball consisted of iatrogenically placed endodontic materials. These findings were confirmed in a study by Legent *et al*.[30] who reported that 85% of 85 reported cases of fungus ball of the maxillary sinus were related to overextended root canal sealer in maxillary teeth. Stammberger *et al*.[29] and Kopp *et al*.[28] described the influence of root-filling materials containing zinc oxide-eugenol on the pathogenesis of sinus fungus ball. According to this “dental” hypothesis, sinus fungus ball is caused by overfilling of the root canal, with the zinc oxide in the root filling material inducing the infection. However, Odell and Pertl[31] found that zinc oxide eugenol sealers showed antifungal activity against *Aspergillus*. The cross-correlation of endodontic therapy and fungus ball continues to be controversial.

Pathological exposure of the sinus floor predisposes many surgical endodontic procedures to maxillary sinus communication.[4,32] The thickness of bone separating the apices of the teeth in the lateral segments of the maxilla from the sinus is shown to range from 0.8 to 7 mm.[14] Perforations of the maxillary sinus following apicectomy of premolar and molar teeth in the maxilla have been reported.[33,34] Ericson *et al*.[35] found oro-antral communications in 7.7% of canines, 8.8% of first premolars, 26.1% of second premolars and 40% in molars, whereas Freedman and Horowitz[34] found a rate of 23% for perforations in molars, 13% in second premolars and 2% in first premolars.

Invasion of the maxillary sinus does not seem to result in the permanent alteration of either the sinus membrane or its physiological function. Selden[3] and Benninger *et al*.[36] observed that the mucous membrane, complete with cilia, regenerate in about five months after total surgical removal. There is also agreement that the sinus membrane will recover from sinusitis, once proper ventilation is restored. Watzek *et al*.[37] found no significant difference in the healing rate between patients with and without intraoperative sinus exposure in 146 apicectomies. These findings were consistent with those of Ericson *et al*.,[35] who found no difference between the results regarding treatment outcome of apicectomies obtained in the groups without, and with, oro-antral communications. In the same study, the results of the operation in the oro-antral communication group with ruptured sinus mucosa did not differ from those in the group with intact mucosa. Surgical treatment of maxillary teeth with periapical periodontitis refractory to conventional endodontic treatment is therefore recommended, regardless of the anatomical relationship of the teeth to the maxillary sinus.[4] However, it should be noted that, in these cases, there is only limited involvement of the maxillary mucosa, by contrast with extensive mucosal stripping of the maxillary sinuses, as seen in the Caldwell-Luc sinus operations, which may be followed by extensive fibrosis and occasionally, massive osteitis. Even after functional endoscopic sinus surgery, sinus mucosa repairs slowly and many pathological findings are evident in the mucosa six months postoperatively, some of which may even be irreversible.[38,39]

In the present study we found EAS as an endodontic complication in a significant percentage of the patients, owing to dental sinus morpho-pathological correlations. The knowledge of dento-antral relationships is particularly important in the prevention of sinusal accidents and complications during various therapeutic manoeuvres, which should be performed according to and depending on the regional morphology.[40,41] To minimise the risk of odontogenic sinus complications, it should be assumed that anything introduced in the root channels of the sinus teeth could create an access path to the sinus tissues. This fact requires a re-assessment of drainage procedures, of endodontic medication and of known biologically compatible materials. Additionally, it is compulsory to determine in advance the length of the root channel as accurately as possible.

Conclusions

The close anatomical relationship of the maxillary sinus and the roots of maxillary molars, premolars, and, in some instances, canines, can lead to several endodontic complications. Periapical periodontitis may result in maxillary sinusitis of dental origin, with resultant inflammation and thickening of the mucosal lining of the sinus in areas adjacent to the involved teeth. In cases of sinusitis of dental origin, conventional endodontic treatment or retreatment is the treatment of choice, with surgical intervention only indicated in refractory cases. Conventional root canal treatment may result in the perforation of the sinus floor in one or more treatment stages, with resultant irritation and inflammation of the maxillary sinus mucosa. This inflammation may be due to over-instrumentation and/or inadvertent injection or extrusion of irrigating intracanal medicaments, sealers, or solid obturation materials. Furthermore, endodontic surgery performed on maxillary teeth may result in sinus perforation. Perforation caused during endodontic surgery constitutes a low risk for the maxillary sinus, provided that there is a good knowledge of the specific anatomic conditions and an appropriate surgical procedure is applied. Root ends and/or materials may enter the sinus during conventional or surgical endodontic therapy, with the need for subsequent surgical approach for their removal.

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