IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 8 Ser. 2 (August. 2024), PP 49-52
www.iosrjournals.org

Harnessing Innovative Perspectives On The Maxillary Sinus: Clinical Implications And Consequences For Endodontic Procedures

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Abstract:
The intricate anatomical relationship between the maxillary sinus and the roots of maxillary teeth poses significant challenges and presents unique opportunities in endodontic practice. This article examines the latest advancements in diagnostic imaging technologies and their transformative impact on managing complications associated with the maxillary sinus in endodontics. Traditional imaging methods, such as periapical and panoramic radiography, often lack the necessary detail and accuracy for optimal diagnosis. In contrast, cutting-edge techniques like computed tomography (CT) and emerging magnetic resonance imaging (MRI) provide superior visualization and a more detailed understanding of sinus pathology. These innovations enable precise diagnosis and informed treatment planning. This review underscores the critical clinical relevance of these advanced imaging perspectives, highlighting their role in enhancing procedural outcomes, minimizing complications, and refining endodontic practices. By incorporating these novel diagnostic approaches, dental professionals can achieve more accurate assessments and effective management of maxillary sinus issues, significantly improving patient care and treatment success.

Keywords: *Maxillary sinus, Endodontic procedures, Imaging technology, Sinus perforation, Root canal treatment*

Date of Submission: 28-07-2024 | Date of Acceptance: 08-08-2024

I. Introduction:

Sinus perforation is a rare but serious complication that can occur during endodontic treatment of posterior maxillary teeth. This problem occurs when errors or anatomical irregularities made during surgery cause the sinus floor to rupture and cause many problems. Understanding the causes, consequences, and treatment mechanisms of maxillary sinus perforation is important to improve patient outcomes and minimize complications.[1]Maxillary sinus perforation can be caused by many factors, including proximity of anatomical structures, improper surgery, and past medical history.[2]The roots of maxillary molars and premolars are often close to or associated with the maxillary sinuses, and changes in the roots may increase the risk of perforation.[3]Procedural errors such as radiation failure, excessive irradiation, or excessive water can also cause perforation of the wound. Preexisting conditions such as chronic sinusitis or previous surgery can also weaken the nasal walls, making them more susceptible to perforation. [4]The clinical effects of maxillary sinus perforation range from mild discomfort to serious complications. Perforation can allow bacteria into the sinuses, causing an existing infection, or worsening an existing infection, causing sinusitis.[5] It can also cause local infection and pain, and the infection can complicate endodontic treatment and require additional treatment. In addition, open communication between the root canal and the sinuses can allow oral fluid to continue into the sinuses, affecting the teeth and nose. The physical relationship between the maxillary sinuses and the roots of the maxillary molars, premolars, and sometimes canines makes this area a dental problem.[6] Stafne estimates that 15 to 75 percent of sinusitis may be caused by dental problems, but the cause is difficult to determine.[7] The dental literature describes several cases of periapical inflammation extending into the maxillary sinus. Several studies have shown that this condition can cause serious problems, including periorbital cellulitis, vision loss, and the possibility of nasal obstruction.The penetration of bacteria and their by-products into the cavity can cause inflammation and necrosis, thus affecting the periapical tissue.[8]The aim of root canal treatment is to preserve the health of the tissue around the tooth root by protecting it from bacteria and viruses despite degenerative changes in the pulp.[9] To achieve this during endodontic treatment, mechanical and chemical instruments must be used to remove the tissue and some of the surrounding areas. [10]Files and reamers are used to remove tissue and clean the dentin, while disinfectants such as sodium hypochlorite and calcium hydroxide are used to maintain a sterile environment.[11] Antibiotics have proven ineffective. This procedure eliminates bacteria in the root canal. If the root canal penetrates the periapical tissue, infections such as periapical cysts, granulomas, or abscesses may occur. [12] Sinus involvements may occur during endodontic surgery due to periapical infection in the nose, placement of endodontic materials and materials beyond the apex and close to the nose, and the risks brought by endodontic surgery.[13]The pathological effects of endodontic disease on periapical and adjacent tissues have been documented.[14] The main features of Endodontic-Antral Syndrome include pulp lesions in teeth near the maxillary sinus floor, periapical radiolucency of the affected tooth, loss of the dura mater of the affected tooth on X-ray, and detection of changes in the maxillary sinus margin.[15]Additionally, a small radiopaque mass may be present in the sinus cavity above the alveolar ridge separating from the dural plate of the tooth and the alveolus, indicating localized inflammation and thickening of the sinus wall.[16] Changes in the radiopacity of the surrounding area compared to the nasal cavity can be detected. The variable presentation of Endodontic-Antral Syndromecan lead to diagnostic and treatment problems as not all five features are fixed. The aim of this study is to evaluate the relationship of teeth with the maxillary sinus in order to reduce problems at every stage of endodontic treatment.[17]

II. Discussion:

The maxillary sinus is the first of the paranasal sinuses to develop during fetal growth, beginning its expansion from the nasal capsule into the maxilla by the fifth month of gestation. [18]At birth, it measures approximately 3-4 mm and grows steadily until about age 7. After this period, its growth accelerates until the permanent teeth erupt.[19] In adults, the sinus typically measures 26-28 mm with an average volume of 15 mL and has a pyramidal shape, with its base forming the lateral nasal wall and its apex extending towards the zygomatic bone.[20]The relationship between the sinus and the maxillary teeth can be complex due to its varying enlargement.[21] In about 50% of individuals, the sinus extends into the maxillary alveolar process, nearing the roots of the second premolar and the first and second molars, and occasionally reaching the canine root.[22]The sinus floor may have recesses around the tooth roots, and as one ages, the surrounding bone may thin, sometimes leaving only a thin bony layer over the sinus membrane.[23]The deepest part of the maxillary sinus is typically near the molar roots, with the first and second molars most likely to extend into the sinus, occurring in 2.2% and 2% of individuals, respectively.[24]Significant sinus expansion can also involve other teeth, such as third molars, premolars, and canines. Radiographic classifications of the relationship between tooth roots and the sinus floor include: Type I, where the sinus floor is positioned above the level connecting the buccal and palatal root apices; Type II, where the sinus floor is below this level without any apical protrusion; Type III, where the buccal root apex extends into the sinus; Type IV, where the palatal root apex extends into the sinus; and Type V, where both the buccal and palatal root apices extend into the sinus. [25]Additionally, horizontal relationships between the inferior wall of the maxillary sinus and the roots of the maxillary molars are classified as: Type 1, where the alveolar recess of the sinus's inferior wall is positioned more towards the buccal side than the buccal root; Type 2, where the recess is located between the buccal and palatal roots; and Type 3, where the recess is situated more towards the palatal side than the palatal root.[26] The most prevalent vertical relationship is where the sinus floor does not make contact with the dental roots, while the most common horizontal relationship is a sinus recess situated between the buccal and palatal roots.[27]Patients suspected of having maxillary sinus issues of dental origin should receive a comprehensive clinical and radiographic assessment.[28]The affected sinus may show considerable tenderness to tapping or palpation. Teeth associated with sinusitis often exhibit moderate to intense sensitivity to palpation and/or percussion but typically respond normally to standard pulp sensitivity tests.[29]Pain commonly radiates to all posterior teeth in the affected quadrant, causing tenderness to percussion across all involved teeth. The nasal passage on the affected side might be partially or completely obstructed, with nasal discharge being a notable indicator of sinus infection.[30] Severe acute or subacute sinusitis seldom causes fever, although severe acute sinusitis may result in a high fever and some level of malaise.If only one tooth demonstrates tenderness to percussion, it could be the primary source of the issue, potentially excluding sinusitis. [31]Radman suggested using a cotton swab soaked in 5% lidocaine in the nostril of the affected side as a diagnostic test.[32] The swab should be placed posterior to the middle meatus and left for 20-30 seconds.[33] If the pain is sinus-related, it will typically be alleviated or diminished within 1-2 minutes, indicating maxillary sinusitis. Similarly, applying a topical nasal decongestant may assist in distinguishing between sinusitis-related pain and dental pain.[34] Unlike sinusitis pain, dental pain is often more inconsistent, ranging from thermal sensitivities to spontaneous, severe discomfort, and may be accompanied by regional swelling and cellulitis.[35] Advanced dental disease generally exhibits clear radiographic changes.[36]Diagnostic assessment of the maxillary sinus involves various radiographic techniques and diagnostic imaging methods.[37] These include periapical, panoramic, and facial views, available indental, otolaryngological, or radiological settings.[38] Each method provides valuable information to confirm or rule out pathology. Periapical Radiographs: On periapical radiographs, the boundary of the maxillary sinus appears as a thin, delicate radiopaque line, blending with the lamina dura and the sinus floor. [39]However, this view may not always show the lamina dura over the root apex in areas with insufficient bony coverage.[40] The lamina dura, a thin, dense bone layer lining the tooth socket, appears as a dark line on radiographs and surrounds the periodontal ligament.[41] Disruption of the lamina dura's continuity in the periapical region is an early indicator of periapical pathology due to dental root infection and is crucial for diagnosing endodontic infections.[42] Panoramic radiography provides a comprehensive view of the sinus floor and its relation to the dental roots. It helps in assessing periapical lesions, cysts, radiopaque foreign bodies, and localized swelling and opacities.[43]While periapical and panoramic X-rays are commonly used for diagnosing, treating, and monitoring periapical lesions, these techniques compress three-dimensional anatomical structures into two-dimensional images. This can lead to overlap of anatomical features and obscure diagnostic details.[44] Periapical lesions may be missed on intraoral radiographs, especially in complex anatomical areas like the maxillary molar region.[45]Limitations also include horizontal and vertical magnification (10-33%) and lack of cross-sectional detail. Specialized skull views, such as the occipito-mental (Water's projection), provide more detailed visualization of the paranasal sinuses, including the maxillary sinuses.[46] These views use various angles (15°, 30°, and 35°) to assess internal anatomy, bone continuity, defects, and sinus pathology or foreign objects. [47]Other imaging options include submentovertex, posteroanterior, and lateral skull views. However, conventional radiological skull views have limited sensitivity and are increasingly being replaced by computed tomography.[48] CT scans are important in evaluating sinus disease because they provide many different images of different planes of the sinuses.[49] Currently, MRI is the most crucial tool for assessing disease spread, particularly intracranial and intraorbital, and for differentiating between neoplastic and normal tissue. This enables more precise diagnoses and a better understanding of the disease. CT scans address many limitations of traditional imaging techniques by reducing magnification and offering detailed images.[50] However, CT has drawbacks, including limited availability, high cost, and increased power consumption. While Dentascan effectively demonstrates jaw anatomy, it is not widely used for routine evaluation of the maxillary sinuses. MRI, however, cannot visualize bone due to the absence of signal from cortical bone and nasal air, which limits its effectiveness in assessing bony structures and complex diseases.[51]Endo-Sinus Syndrome (EAS) often appears abnormal on radiographs. Typical radiological changes include a periapical radiolucent area, loss of the bony lamina dura defining the lower border of the maxillary sinus, a rounded pale radiopaque mass in the sinus above the apex of the affected teeth, and varying degrees of radiopacity in the surrounding sinus space. These changes in the lower sinuses indicate odontogenic involvement and are early signs of dental disease leading to severe sinusitis.[52] Additional indicators include fluid accumulation and thickening of the sinus wall. In our cases, thickening of the maxillary sinus mucosa was a common finding, consistent with other studies. Microscopic examination reveals destruction of the bone separating the sinus from the tooth and loss of cortical bone normally present on the sinus floor.[53] The sinus mucosa often exhibits severe changes, such as swelling, inflammation, granulation tissue, hypertrophy, fibrous variation, hyaline degeneration, and even necrosis. Historically, these mucosal changes led to the belief that extraction of the affected tooth was necessary. However, recent studies indicate that most Endo Antral Syndrome cases respond well to nonsurgical root canal treatment, with surgery recommended only for cases resistant to conventional treatment.[54]

Root filling materials have been associated with maxillary sinus fungus balls. Studies by Kopp et al. and Steinberg et al. have shown that overextension of root canal material is linked to sinus fungus balls in over 50% of diagnosed cases. [55]Efsane et al. found that 85% of reported maxillary sinus fungus balls were associated with excessive root canal sealer. The impact of root-filling materials, especially those containing zinc oxide-eugenol, on fungal ball formation remains controversial.[56]Some studies suggest these sealers may induce fungal infections, while others highlight their antifungal properties against Aspergillus.[57]The connection between endodontic treatment and sinus fungus balls continues to be debated.Maxillary sinus perforation diagnosis typically involves clinical examination and radiographic imaging. [58]Clinical evaluation includes checking for symptoms like persistent pain, swelling, or rhinorrhea, which may indicate perforation.[59] Radiographic imaging, including preoperative and postoperative X-rays or cone-beam computed tomography (CBCT), can confirm the presence of a perforation and assess its location. Treatment strategies for sinus perforation include sealing the perforation with materials such as gutta-percha or mineral trioxide aggregate (MTA) as soon as it is detected. Antibiotic therapy may be prescribed to prevent or address infections. Careful sinus irrigation with saline and avoidance of invasive procedures help manage and monitor the perforation. In some cases, surgery may be necessary to close the perforation and restore sinus integrity. Regular follow-up is crucial to monitor healing and prevent complications.[60] A thorough radiological evaluation, including preoperative imaging to assess root proximity to the sinus floor and ensure no complications, is essential. This requires careful technique, precise methods, and appropriate irrigation to minimize perforation risk. Anatomical knowledge is also crucial for identifying variations and potential risks during endodontic treatment, ensuring greater control and safety in procedures.[61]Pathological exposure of the sinus floor during endodontic surgery often leads to maxillary sinus communication. The thickness of the bone separating the tooth ridge from the sinus ranges from 0.8 to 7 mm. Reports of maxillary sinus perforations following apicoectomy of premolars and molars show varying rates of oroantral communication, with some studies noting perforation rates as high as 40% in molars.[62] Despite these issues, wound infection and function typically improve with mucosal reconstruction about five months after surgery. Proper ventilation can aid sinus mucosa in healing from sinusitis. Studies show no significant difference in healing rates between patients with and without intraoperative sinus exposure. [63]Therefore, surgical treatment of maxillary teeth with periapical inflammation is recommended regardless of their anatomical relationship to the maxillary sinus. However, involvement of the maxillary mucosa in these cases is less compared to the extensive mucosal dissection seen in Caldwell-Luc procedures, which can lead to severe fibrosis and occasionally osteitis. Postoperative sinus mucosal healing can be slow, with persistent findings even six months after surgery. In our study, EAS was identified as an endodontic complication.[64]

III. Conclusion:

The close anatomical proximity of the maxillary sinus to the roots of maxillary molars, premolars, and occasionally canines can lead to various endodontic complications. Periapical inflammation in these teeth may cause maxillary sinusitis of dental origin, leading to inflammation and thickening of the sinus mucosa adjacent to the affected teeth. For sinusitis of dental origin, conventional endodontic treatment or retreatment is typically preferred, with surgical intervention reserved for cases resistant to these methods. However, conventional root canal treatment can sometimes result in perforation of the sinus floor, causing irritation and inflammation of the sinus mucosa. This inflammation may arise from over-instrumentation or accidental extrusion of irrigants, sealers, or obturation materials. Endodontic surgery on maxillary teeth also carries a risk of sinus perforation. Nevertheless, this risk is relatively low when the procedure is performed with a comprehensive understanding of anatomical conditions and the application of appropriate surgical techniques. If root ends or materials enter the sinus during treatment, subsequent surgical intervention may be necessary to remove them. Preventive measures, meticulous procedural techniques, and effective management of complications are crucial in reducing risks associated with maxillary sinus perforation. Ongoing education and research are essential for refining techniques and enhancing outcomes in managing this complex condition.

Financial support and sponsorship Nil
Conflicts of interest There are no conflicts of interest

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