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Review Article

The Relationship Between Maxillary Roots And The Maxillary Sinus.

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Abstract

The anatomical relationship between the maxillary roots and maxillary sinus is a critical consideration in dental practice owing to its implications for diagnosis, treatment planning, and surgical interventions. This review explored the developmental, anatomical, and clinical aspects of this relationship, emphasizing its impact on oral health and associated pathologies. The maxillary sinus, the largest of the paranasal sinuses, develops during the third month of fetal life and continues to expand until early adulthood. Its growth occurs concurrently with the eruption of maxillary teeth, resulting in varying degrees of proximity between the sinus floor and apices of the posterior teeth. In many cases, the roots of the premolars and molars lie in proximity to or even penetrate the sinus cavity, separated only by the Schneiderian membrane and a thin cortical plate. These anatomical variations increase the risk of complications, such as oroantral communication, sinus membrane perforation, and odontogenic sinusitis, during dental procedures, including extraction, root canal treatment, and implant placement. Furthermore, periapical infections, root resorption, and alveolar bone loss can compromise the sinus integrity, leading to pathological conditions. Advanced imaging modalities, particularly cone-beam computed tomography (CBCT), have enhanced the accuracy of assessing root–sinus proximity, thereby improving surgical safety and reducing postoperative complications. The review also highlights classifications of root–sinus relationships, radiographic evaluation methods, and surgical considerations, such as sinus lift procedures and their potential complications. Understanding the anatomical variability of the maxillary sinus in relation to the tooth roots is crucial for minimizing iatrogenic risks, optimizing treatment outcomes, and informing future research. Further longitudinal studies and technological advancements in imaging are recommended to refine the clinical protocols and improve patient safety in procedures involving the posterior maxilla.

Keywords : *maxillary sinus, maxillary root.*

INTRODUCTION

The anatomical relation between maxillary roots (MR) and maxillary sinus (MS) is clinically important. The juxtaposition of the roots to the sinus floor can vary, with some roots located very close to or even extending into the sinus cavity. (1). This anatomical variation may lead to complications such as odontogenic sinusitis, sloughing or resorption of the maxillary sinus floor by the apices of the maxillary root tips, and altered radiographic appearances that can obscure normal sinus features, including the lower border. (2).

Advancements in radiographic imaging have revealed closeness between the maxillary permanent teeth roots to the base of the MS (3). Clinically, for patients requiring tooth extraction, root canal treatment, or implant assignment in the posterior maxilla, precise knowledge of this relationship is essential for appropriate case selection, treatment planning, and counseling. Surgical measures in this anatomical area must be performed with caution to mitigate the risks associated with the intimate association between the floor and the roots of the MS (4).

ANATOMY OF THE MAXILLARY REGION

The final sinus that develops is the MS, which is the biggest. It begins to form during fetal development and continues to grow until adulthood. Around the third month of pregnancy, the cells branch off from the middle nasal meatus to form ethmoidal air cells, one of which becomes the maxillary sinus. (5). This sinus increases in volume from six months of life until

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it reaches adult size between 18 and 20 years of age. Dental roots eventually come to lie very close to the sinus floor, with some roots extending into the sinus cavity and covered by the Schneiderian membrane (**Fig. 1**). Changes in the sinus associated with tooth loss and alveolar bone resorption considerably reduce the maxillary bone volume, limiting the proper placement of dental implants. (6).

Figure 1. Sagittal section of maxillary sinus illustrating the normal anatomy in relation to the roots of maxillary premolars and molars.

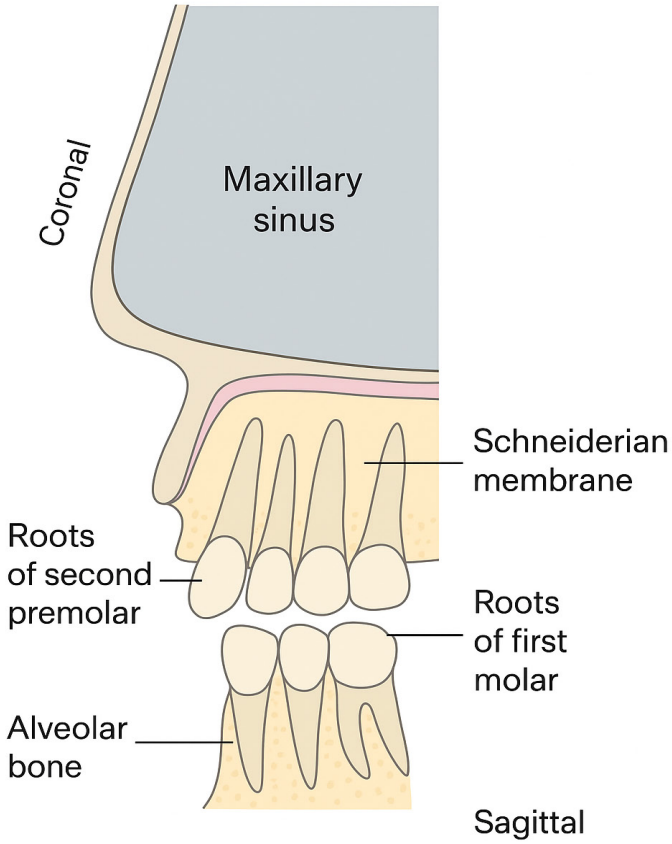


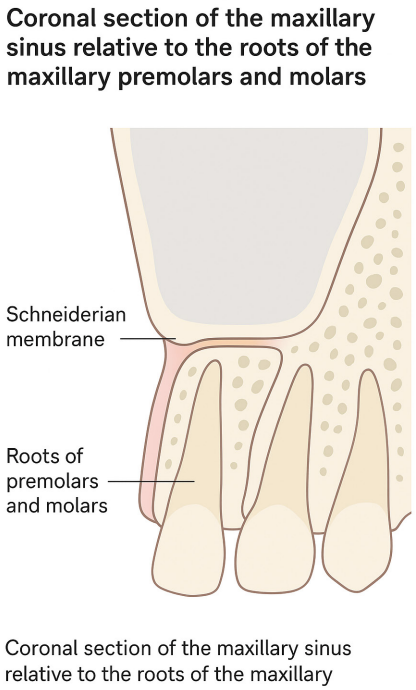
Figure X. Sagittal section illustrating the normal anatomy of the maxillary sinus in relation to the roots of the maxillary premolars and molars

Maxillary human teeth consisted of 16 permanent teeth (five molars, four premolars, one canine, and two incisors on each side) and 20 deciduous teeth (five on each side of the upper jaw). Root resorption may result from trauma, orthodontic treatment, osteoclastic activity, cysts, tumors, periapical inflammatory processes, or idiopathic causes. (7). Arising from inflammation and located at the apex of the tooth root, periapical lesions may extend to the maxillary sinus and remain undetected, especially when they develop asymptomatically (8, 9).

Maxillary Sinus Anatomy

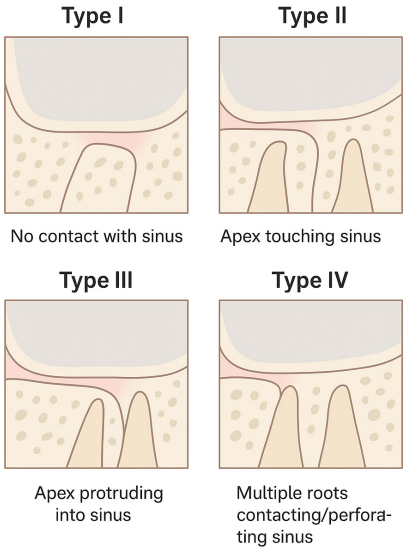
The MS has a pyramid-shaped hollow in the maxillary bone (**Fig. 2**). Owing to the anatomical proximity of the MS and the maxillary roots of posterior teeth, odontogenic infection can easily spread to the sinus area. The maxillary sinus is a peri apical radiolucent area that appears as a peripheral radiolucency on a radiograph and can obscure the appearance of the apex of the maxillary posterior tooth. On the same note, the apices of the maxillary posterior teeth may also appear to encroach on the margins of the maxillary sinuses. But, in such cases, diagnosis of periapical pathosis cannot be confirmed unless additional clinical symptoms are present. The close anatomical relation between the maxillary sinus and posterior tooth roots is of clinical importance, especially when performing apical curettage of the maxillary molars or premolars, which may result in the creation of a pathological communication between the oral cavity and the maxillary sinus (9, 10).

Figure 2. Coronal section of the maxillary roots of premolar and molar teeth relative to the maxillary sinus.



Kwak et al. classified the relation between the maxillary sinus floor and the maxillary posterior teeth roots into three groups in 2004 (11). These groups are as follows: Type I, in which the root apex is located beneath the lower MS wall; Type II, with the root apex situated just in contact with the MS floor; and Type III, in which the root apex protrudes laterally into the sinus cavity (see **Fig. 3**). A similar classification, but with an additional group, was conducted by Wan et al. in 2019: Type I, with no contact of the root apex with the inferior wall of the MS; Type II, with the root apex in contact with the inferior wall of the MS; Type III, with the superior root apex extending into the MS; and Type IV, with two or more roots either in close contact or perforating the inferior wall of the maxillary sinus (11).

Figure 3. Classification of Root–Sinus Relationships.



MAXILLARY TOOTH ROOTS ANATOMY

The maxillary teeth include eight incisors and canines, four premolars, and six molars. The roots are situated inside the alveoli of the alveolar processes.

The morphology of the roots of the upper teeth presents variations related not only to the individual but also to the specific type of tooth. These differences constitute an important anatomical aspect and have special relevance in clinical practice (12).

DEVELOPMENT OF THE MAXILLARY SINUS

Embryology

The maxillary sinuses are small but present at birth. Large sinuses appear only after three years of age. At birth, the maxillary sinus had spread beyond the outer border of the nostril. Along with the frontal sinuses, the maxillary sinuses are the least well-developed at birth. They expand alongside the jaws down to the level of the primary teeth, and subsequently into the alveolar processes around the permanent premolars and first molars. Fetal radiographs show the progression of the maxillary sinuses from the fourth to the eighth month of development. (13, 14).

Growth

The maxillary sinus pneumatization proceeds postnatally from the nasal floor. Vertical growth of the cranium, fracture of the pneumatized cranium, and physiological processes of growth postnatally extend the pneumatization. The frontal bone was the first to grow cranially. The growth of the maxilla and expansion of the maxillary air sinus joints also contribute to vertical displacement of the maxillary teeth. Pneumatisation is significantly influenced by pressure. The sinus has an extremely thin wall, and tooth development and eruption exert great pressure on the wall, resulting in thinning, bulging, and occasional perforation. (15, 16).

Embryological Development

The maxillary sinus forms as a result of invagination of the ethmoid infundibulum during fetal development. The fetal maxillary sinus is intubated, and the ethmoid infundibulum elongates into the nasoethmoidal fossa. Maxillary sinus development begins during the third month of intrauterine life and continues gradually throughout the first 12 years of life. The maxillary sinus is usually radiographically visible at birth. The maxillary sinus is relatively small early in life, with the eruption of permanent teeth, and pneumatization is an important factor for its enlargement. Sinus size is larger, specifically in children aged 7–12 years, followed by a reduction in older age groups (13) (**Fig.4**).

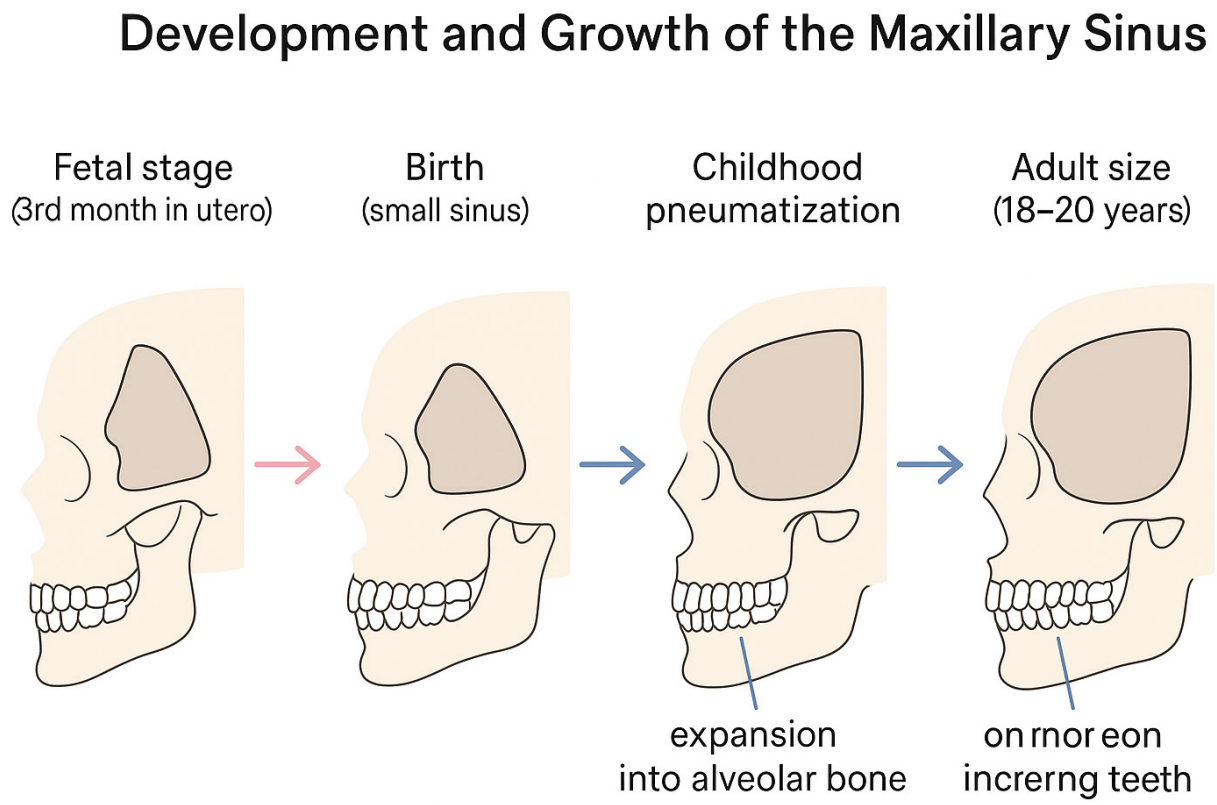
The close anatomical relation between the maxillary teeth and sinus can result in several pathological conditions, such as odontogenic sinusitis, root resorption, and periapical lesions. Maxillary teeth, especially the first and second molars, often have root apices in proximity to or even projecting into the floor of the MS. Furthermore, the degree of root protrusion into the MS varies among individuals. (1, 2). These anatomical variations highlight that the maxillary roots of posterior teeth are situated in proximity to the sinus and that during extraction or root canal dental treatment, the risk of oroantral communication increases (**Fig.4**).

Growth Patterns

Upon reaching its final position in the skull facial part, the maxillary sinus develops then grows in close relation to anatomical structures such as the orbits of the eye, the roof of oral cavity, the maxillary alveolar process, and the maxillary teeth roots (Fig.4). This close association results in marked morphological variability, with the MS floor sometimes reaching the alveolar maxillary process and being close to the maxillary tooth roots. The associated alveolar bone also tends to become thinner during this growth phase. (13, 17).

Because the growth of the maxillary sinus occurs asynchronously with that of the maxillary roots, the extent of its growth influences the positional relationship with the roots. These variations in vertical dimension are significant because they create an intimate relation between some roots of posterior maxillary teeth and the MS flour (**Fig. 4**), which can affect the diagnosis and performance of surgical procedures involving these structures (18).

Figure 4. Maxillary Sinus Development and Growth.



MAXILLARY TOOTH ROOTS OVERVIEW

The teeth within the maxilla consist of maxillary anterior and posterior teeth. The maxillary anterior teeth included the lateral and central incisor teeth in addition to the canines. Maxillary posterior teeth included the 1st and 2nd premolar teeth, besides the first, second, and third molar teeth. Although the posterior teeth are thicker and bigger than the anterior ones, the anterior teeth roots are generally longer than those of the posterior teeth. (19, 20).

Several teeth exhibit a close, sometimes intimate, relation with the maxillary sinus floor in an axial plane. These include the maxillary canines and the 1st and 2nd premolar teeth in the anterior maxilla and palate, as well as the 1st, 2nd, and 3rd maxillary molars. Among molars, the mesiobuccal root of the 1st molar tooth is frequently closely associated with the maxillary sinus floor. Similarly, the mesiobuccal and distobuccal roots of the 2nd molar tend to approximate the MS floor more closely than the palatal root (20, 21).

Types of Maxillary Teeth

Maxillary teeth are classified into three main types based on their morphology and function: incisors, canines, and premolars. These teeth are located in the maxilla or upper jawbone. The maxillary tooth roots may closely approximate the MS floor. The close relation between the roots of these teeth and the MS can potentially result in several clinical complications and variations. The floor of the MS represents a barrier between the oral cavity and nose and is in proximity to multiple roots of the maxillary molars and premolars (22).

The maxillary canine was located between the incisors and the premolars. The root tends to be quite long and is usually the longest in the mouth, along with the mandibular canine tooth. The buccal roots of maxillary premolars can become extremely close to the maxillary sinus, with some roots protruding into the sinus. Given the proximity of the floor of the MS to the maxillary premolars and molars' roots, any surgical or pathological problems related to these teeth can have a direct impact on the maxillary sinus. The MS floor is composed of very thin bone, which may be readily perforated by the roots of the teeth. (23, 24).

Root Morphology

The root morphology of maxillary teeth encompasses several anatomical variations. The number of roots per tooth varies, with some teeth bearing single roots, others double or triple roots, and even teeth such as the maxillary second molars exhibiting diverse root patterns. Similarly, the number of root canals can also differ (25). Moreover, the relation between the maxillary tooth roots and MS is highly individualized, exhibiting considerable variation not only between different tooth types but also among individuals possessing the same

tooth. This diversity is of critical importance to dentists. For example, proximity or even direct contact between a maxillary root and the maxillary sinus mucosa can elevate the risk of MS perforation during extraction or endodontic treatment (25, 26). Calcification or resorption of the roots can further modify root morphology, especially in individuals presenting with pathologies or systemic diseases. As dental implantation procedures become increasingly commonplace, a thorough understanding of the anatomical structures of the maxillary posterior teeth and their spatial intimacy with the maxillary sinus has gained heightened clinical significance (25).

PATHOLOGICAL CONSIDERATIONS

Several pathologies can be associated with the maxillary roots and sinus when these structures are very close to each other. For example, trauma to the maxillary sinus floor can lead to maxillary sinusitis. Apical infection of maxillary posterior teeth can also induce maxillary sinusitis. Atrophic changes in the maxillary posterior region may result in resorption of the MS floor and roots of the posterior teeth, increasing the perforation risk during surgical procedures. (27). Root resorption adjacent to the maxillary sinus may be caused by pressure from ectopic teeth, odontomas, aneurysmal bone cysts, calcifying odontogenic cysts, dentigerous cysts, or tumors. Untreated dental pathological conditions, such as periodontitis or periapical lesions of the posterior maxillary teeth, may lead to maxillary sinusitis. (28, 29).

Owing to these pathological conditions, radiographic evaluation of the MS and roots is required before any intervention. Diagnosis relies heavily on radiographs. Computed tomography (CT) provides additional information beyond that of traditional conventional radiography in the analysis of the MS and the maxillary teeth roots. It also aids treatment planning and assessment of postoperative complications in the maxillary posterior region. (30, 31).

Sinusitis and Dental Implications

The anatomical proximity of the maxillary sinus to the maxillary molars apices and premolars has significant clinical implications, especially in the context of sinusitis. This close anatomical relationship allows infection to be transported from the teeth roots of the maxillary sinus and vice versa. Maxillary sinusitis can result from a secondary odontogenic infection, such as apical periodontitis (32). Radiographically, inflammation of the sinus appears as an opacification of the maxillary antrum. Occasionally, periapical abscesses can cause changes in the maxillary sinus epithelial lining. One of the most important aspects of the close relationship between the roots of the maxillary molars and/or premolars and the sinus during the extraction of these teeth is that the maxillary sinus floor can be perforated by their removal (33).

Resorption of the maxillary Roots

Root resorption is described as the loss of dentin, cementum, or bone, and its relationship with the maxillary sinus, when caused by the sinus itself, must be considered. Although rare, root resorption of maxillary molars can result from maxillary sinus mucosal inflammation, whether associated with upper respiratory tract infections such as rhinitis or sino-zonitis or with inflammatory, allergic, or infectious processes originating in the maxillary sinus itself (34).

Usually, asymptomatic apical root resorption is detected during routine radiographic examinations. Symptoms depend on the degree of bone resorption in the molar and its relationship with the maxillary sinus. Radiographically, a radio-opaque mass was observed in the antrum, with cupuliform areas of radiolucency in contact with the maxillary teeth root apices. Detection of the pathological process in the maxillary sinus requires cautious clinical inspection and interpretation of the patient's symptomatology based on radiographic findings (34).

Periapical Lesions

The intimate spatial relation between maxillary roots and the MS is highly variable; some roots are situated at a distance from or beneath the MS floor, whereas the apices of other roots may protrude into the maxillary sinus. This anatomical variability holds significant clinical relevance, as any pathological condition affecting the roots or periradicular area of these teeth can propagate to involve the maxillary sinus, resulting in odontogenic sinusitis (35, 36). Despite numerous case reports documenting the extension of odontogenic sinusitis to the orbit, a review of the odontogenic origins of orbital complications remains essential (36, 37).

Interpretation of periapical radiographs requires an understanding of the potential loss of lamina dura of the adjacent teeth. The normal ciliated respiratory mucosa lining the maxillary sinus and the thin layer of cortical bone forming the floor of the MS can become compromised in the presence of periapical granulomas of the posterior upper teeth. Resorption of the sinus floor with subsequent protrusion of the granuloma into the sinus was evident. As the size of the periapical lesion and extent of alveolar bone destruction increase, so does the probability of the lesions reaching and involving the mucous lining of the MS (36, 37).

RADIOGRAPHIC EVALUATION

Imaging Techniques

Imaging techniques play a significant role in evaluating the relationship between the maxillary roots and the MS. The selection of technique depends on the required three-dimensional depiction and resolution. For routine visualization, panoramic radiographs provide a useful overview and

information for the posterior-anterior dimension, but can be affected by distortions (38, 39). Periapical radiographs generally represent the best two-dimensional imaging technique for maxillary tooth roots and the adjacent sinus floor, allowing dimensional analysis with minimal distortion. However, the methods used to determine the vertical or horizontal distance from the tooth root to the MS floor can be prone to bias, as the root is compressed in one plane; in particular, the third dimension is not depicted. The methods described allow a study of the anatomical conditions in three dimensions as well as virtual dissection (38).

Approach

The approach to the correct depiction of the intimate relationships between the maxillary roots and the MS depends on the clinical question, the imaging technique applied, and the sufficient three-dimensional depiction together with the necessary resolution. Despite the widespread use of CBCT, periapical and panoramic radiograms are commonly used, either alone or in combination with the three-dimensional technique (30, 37). The sinuses represent critical anatomical structures, as the floor can be close to the alveolar crest in some cases, thereby strongly influencing tooth eruption. Moreover, dental roots protruding into the sinus cavity may impede tooth eruption and may be associated with root resorption. Sinusitis of dental origin may also be related to root position. However, periapical conditions represent a possible etiological factor for sinuses without dental roots protruding into the cavity. Finally, the position of the alveolar crest and sinus floor can limit the height available for implantation (40).

IMAGING TECHNIQUES

The close anatomical relation between the maxillary roots and sinus can be demonstrated both radiologically and anatomically. A widened periradicular space around the root apex of the maxillary molar or premolar indicates inflammation and periapical pathology. The proximity of the sinus floor to the maxillary root is not always the cause of oroantral fistulas, but it does increase the risk of occurrence, especially following the extraction of molars or premolars, which in some patients are closely related to the floor of the MS (41). Several surgical procedures have been described for the reconstruction of oroantral fistulas. Maxillary molars or premolars may be responsible for damage to the maxillary sinus and its lining (39).

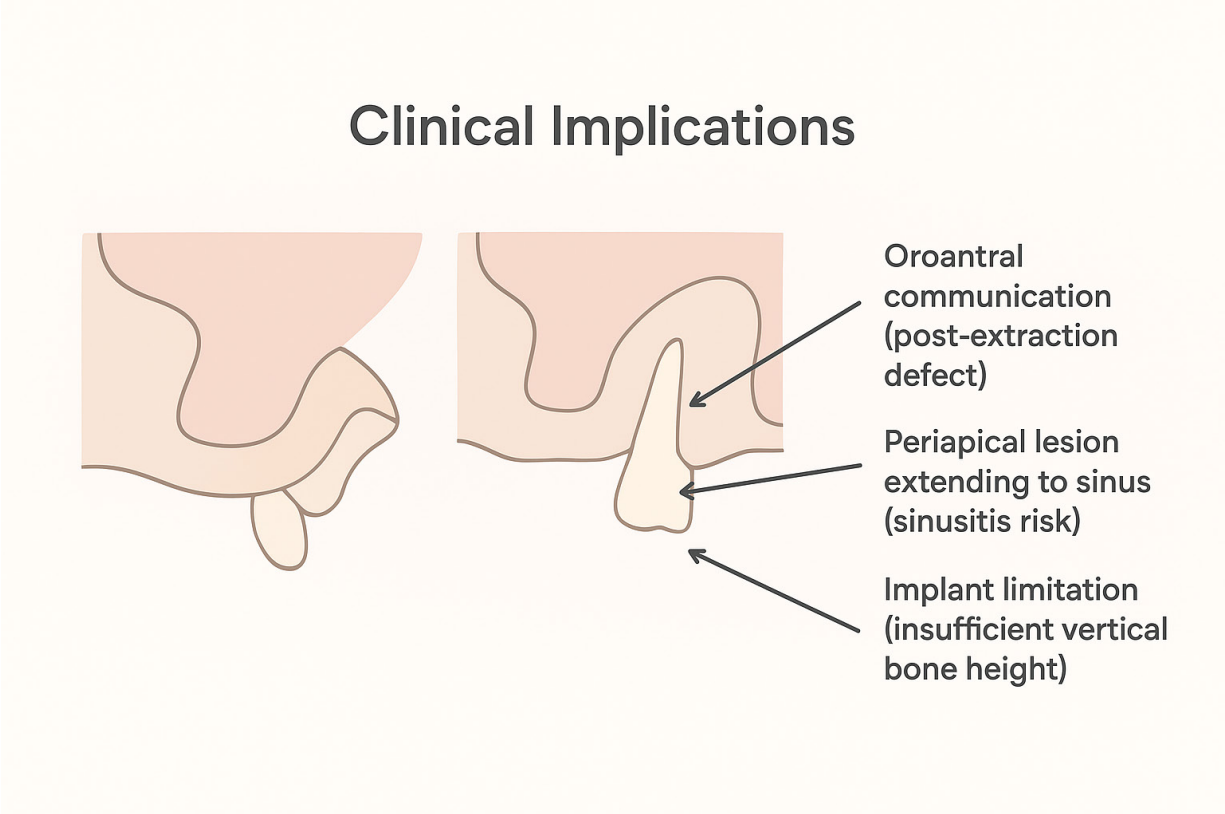
Imaging techniques capable of revealing pathological conditions in this region include conventional radiological evaluation, trans sinuses direct examination, and surgical exploration. The eruption of the permanent teeth and the relationship between the roots and the floor of the maxillary sinus can be studied radiologically during development. Variations in age and bone thickness can be determined from radiographs of different individuals. Finally, the steady increase in the number of implant surgeries has resulted in a corresponding increase in cases of maxillary sinus lift, and the ratio between the length of the dental root and height of the alveolar bone has also become an important factor influencing bone resorption (31).

CLINICAL IMPLICATIONS

Closeness of the maxillary roots to the MS is of paramount clinical importance. If the sinus is very close to the root of the maxillary molars and premolars, dental procedures such as tooth extraction, implant placement, and root canal treatment may damage the sinus membrane and subsequently cause infection. Infection originating from the teeth may also cause sinus issues, such as bone grafting in this area. Implants placed at the working length beyond the bone may cause injury to the sinus membrane. (29). The close anatomy between the roots of maxillary posterior teeth and the MS and periapical inflammations can lead to several clinical problems, including the formation of oroantral fistulas, oroantral communications, and sinus infections. (42, 43).

Common clinical observations associated with alterations in the anatomical proximity of the roots to the MS floor (i.e., root resorption and sinus floor resorption) are discussed. A periapical lesion of the maxillary tooth with roots in proximity to the maxillary sinus may lead to maxillary sinusitis. A gradual increase in the volume of teeth requires adequate tooth preparation during root canal treatment to avoid perforation beyond the working length of the root canal. (32). When this working length is extended beyond the bone matrix, structural and functional damage to the maxillary sinus membrane may occur, warranting pathological consideration of the root–sinus relationship. Infections that originate from the maxillary teeth have the potential to be transmitted into the sinus and cause pathological changes. Therefore, a clear understanding of the clinical features associated with the relationships between the maxillary roots and MS is essential to provide effective medical and surgical care for maxillary sinusitis. (44).

Figure 4. Clinical Implications of Maxillary Root–Sinus Relationship.



Dental Procedures and Sinus Risk

As the molars and premolars' roots are located close to its base or project into the maxillary sinus, operations involving extraction, endodontic diagnostics, and endodontic therapy of these teeth may sometimes present the risk of affecting the maxillary sinuses. The nearness of molars and premolars to the sinus plays an important role in the fragmentation of dental roots, the creation of oroantral fistulas, and the pushing of tooth roots into the sinus cavity (45).

Six types of relations between the apexes of the MSs and tooth roots have been outlined, and a classification of roots according to the chance of perforation of the MS floor has been proposed. The risk of periapical tooth inflammation should also be considered, as the maxillary sinus is more frequently a site of inflammation, especially when the (periapical) bone destruction is located near the wall or the floor of the MS cavity. The proximity between the roots and sinus is an important factor when planning the placement of implants in the alveolar processes of the posterior regions of the maxilla (46).

Implant Placement Considerations

Radiographic evaluation of implant placement in the posterior maxilla remains a critical part of implant treatment planning because of the close structural relationships between the sinus and alveolar antral artery. Loss of a tooth and its alveolus causes varying degrees of remodeling in the adjacent maxilla, with the distribution and amount of bone with respect to the antrum of particular concern when planning any procedure. The reduction in the vertical and/or horizontal dimensions of the alveolar process necessary for implant placement could require augmentation of the residual bone with either bone augmentation techniques or elevation of the sinus floor (47), (Fig. 5). The close anatomical relationship and associated pathology could present a problem during the placement of abutment teeth or prostheses, as in cases such as mucositis or malpositioning of the teeth with periapical or periodontal lesions, which might be the cause of maxillary sinus pathology. The resulting infections could complicate treatment and lead to implant failure. However, the proximity of the roots to the lining of the sinus often makes it difficult to perform surgery or root canal treatment without causing trauma to the sinus membrane, which frequently causes maxillary sinus disease. (48).

SURGICAL INTERVENTIONS

Numerous dental and oral surgical interventions, such as root canal treatment, extraction, apical resection, cystectomy, and dental implantation, when performed in maxillary molars and premolars, may cause complications within the MS. Occasionally, the roots of these teeth project into the MS, elevating the probability of the maxillary sinus being affected during such procedures. Maxillary sinus complications can also result from periapical or periodontal infections, trauma, iatrogenic events, odontogenic tumors, benign cysts, or oral malignant neoplasms (49).

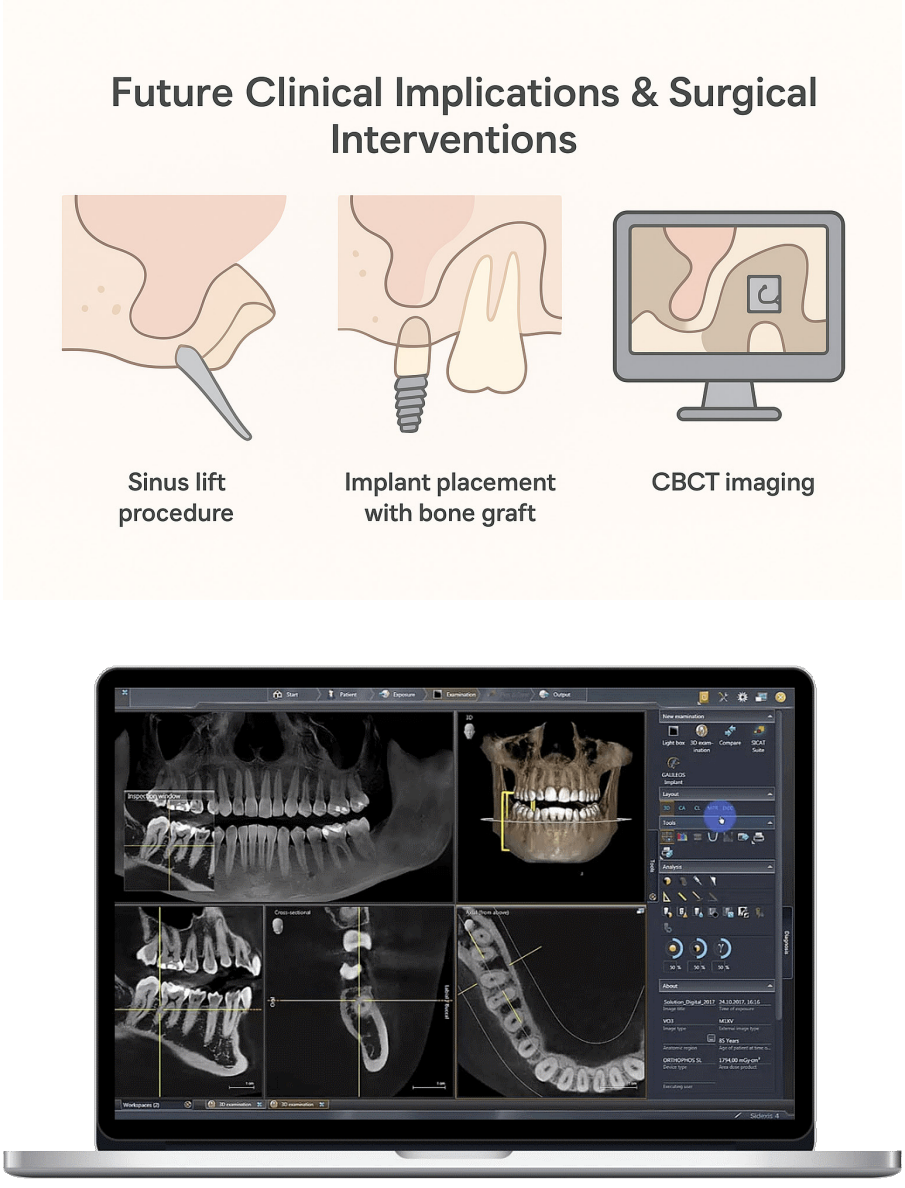
A sinus lift procedure is typically indicated for patients requiring teeth implants in the posterior upper jaw and those with insufficient bony height for implant placement. If the maxillary MS floor is situated too close to the alveolar crest in the molar or premolar region, guaranteeing the stability and osseointegration of the implants becomes challenging. Consequently, the sinus floor must be elevated to produce adequate space for implant insertion. The sinus lift procedure entails elevating the sinus membrane by inserting a graft beneath it, thereby increasing the bone volume and facilitating the placement of implants that can effectively bear occlusal forces and restore chewing function (49) (**Fig. 5**).

Sinus Lift Procedures

The close structural relationship between the maxillary tooth roots and the MS is of considerable clinical importance because its proximity can lead to pathological or clinical complications. The increasing use of dental implants in recent decades has also focused on the limited bone volume that may be available. In such cases, sinus lift procedures for the maxillary sinus floor represent a practical solution (50).

The MS is the major human paranasal sinus and lies between the roots of the maxillary teeth. Its continual growth can result in thin sinus floors with roots that are closely approximated to, or even protruding into, the sinus, which may affect root canal treatment or implant placement. The intimate relationship between the MS and roots of maxillary teeth complicates dental treatment. When a sinus lift is planned, information on root proximity to or intrusion into the sinus must be confirmed to avoid complications, such as sinus membrane perforation. Various radiographic techniques have been proposed to determine whether the maxillary molar root projects into the MS (51) (**Fig. 5**).

Figure 5. future clinical implications and surgical interventions.



Root Canal Treatments

The position of the root apex in relation to the MS may lead to complications during the surgical intervention of the dental roots, potentially affecting the sinus. Endodontic surgical procedures in the posterior region of the upper jaw impose specific demands on both the precise preparation of the operating area and the level of asepsis. These demands increase due to anatomical changes caused by the relation between the MS and the roots of the molars, as well as pathological processes in the root apex area (28).

Many anatomical variations in this region, such as changes in the thickness of the buccal cortical plate and the proximity and depth of the root tips relative to the maxillary sinus, can elevate the chance of perforation of the maxillary sinus membrane pocket during an invasive procedure. Understanding these anatomical nuances is essential for optimizing endodontic surgical approaches and minimizing potential complications (52).

CASE STUDIES

The intimate anatomical relationship between the maxillary roots and the MS has been a focal point in dental literature for many years. Variations in root morphology and tooth location within the maxilla are responsible for the differences in the proximity between the MS and maxillary roots.

Maxillary sinus floor augmentation is a surgical procedure that elevates the sinus floor to increase bony height in the posterior maxilla and to facilitate implant placement in the atrophic maxilla. During maxillary sinus lift, elevation, and extensive dissection, the risk of perforation of the Schneiderian membrane increases, warranting caution. Evaluating the distance between the roots of the maxillary premolars and the MS is essential. Such evaluations help to avoid complications such as Schneiderian membrane perforation and enhance the prognosis of endodontic lesions with periodontal furcation involvement. These relationships between the maxillary posterior teeth and the MS greatly influence prosthodontics, periodontics, endodontics, and maxillofacial surgery (43).

Most dental treatments involve radiographic examination for diagnosis, prognosis, and planning. The prominence of the MS floor and its relationship with the roots of the maxillary premolars and molars are important when patients report pain in the upper jaw. The rapid development of CBCT systems has opened new possibilities for examining the compound anatomy of the periapical region, including the intricate relationship between root apices and the MS (27).

Clinical Case Reports

Clinical cases demonstrating the impact of anatomical and pathological relations between the maxillary roots and the sinus have been frequently described in the literature. Any inflammatory, iatrogenic, or spontaneous process potentially involving the maxillary roots is usually associated with the risk of damaging the sinus membrane and its supporting walls. Consequently, communication between the maxillary sinus and the surrounding oral environment can induce sinusitis. Inflammatory processes, in particular, are frequently reported in maxillary root–maxillary sinus situations, especially when ROI analysis of periapical lesions is needed.

Although several pathological phenomena have been investigated with regard to the maxillary roots, their anatomical relationship with the sinus has not been systematically considered during radiological assessment. Several studies have suggested that such analyses could reduce the risk of complications due to the potential involvement of the maxillary sinus. In this context, root resorption, particularly the limitation of its progression, has been examined. Case reports have considered the closeness of the maxillary roots to the MS using root canal instrumentation to prevent damage to the sinus membrane. Clinical cases related to the implantological field and maxillary sinus lift procedures have also been documented (48, 53).

Comparative Analysis

The roots of the upper maxillary teeth may be in close anatomy to the sinus walls, which is important in cases of maxillary sinusitis caused by odontogenic origin, root resorption, or other pathological processes.

The extension of the roots of the upper teeth into the MS floor complicates many dental procedures, including tooth extraction, root canal treatment, and implant placement. Because of the anatomical relation between the root apices of the upper molars and premolars and the MS floor, periapical lesions of these teeth can extend to the sinus, potentially causing sinusitis. Evaluation of such areas on panoramic radiographs is particularly challenging (54, 55).

FUTURE RESEARCH DIRECTIONS

With the development of image processing technologies and the expansion of computer-aided surgery, more efficient and less invasive procedures have become available in sinus-related surgeries, such as sinus lifting, functional endoscopic sinus surgery, and aesthetic rejuvenation. However, the intracranial volume and morphology of the MS have rarely been studied because of its irregular shape. Research into the relationships between maxillary roots and the MS, including volumetric and surface measurements, will improve our understanding of associated pathologies.

Proximity of the maxillary roots to the sinus is an important consideration. For example, the risk of sinus perforation during tooth extraction is high when a simple extraction is

performed. The presence or absence of contact between the maxillary roots and MS also affects prognosis after surgical treatment of the lesions. Furthermore, localized severe root resorption can occur when the root apex is close to the cortex of the MS cavity. Consideration of the root-sinus relationship can help avoid complications during implant placement in the posterior maxillary regions. Many studies have reported variations in the contact ratio of the maxillary roots inside the MS. Future research analyzing the root-sinus relationship based on morphometric measurements can provide useful information for clinical evaluation.

Emerging Technologies

Recent advances in imaging technology have enhanced the definition of the anatomical relation between the maxillary roots and the MS. Orthopantomography allows the visualization of this relationship, and the introduction of computed tomography has provided more accurate images. Non-collapsed and patent maxillary sinuses can be evaluated by computed tomography images, which give dental surgeons a panoramic view of the whole sinus, allowing for the identification of asymmetries and visualization of these regions even in the presence of edema, polyps, or secretion. These aspects are difficult to observe on plain radiographs (56). Owing to the use of computed tomography images, three-dimensional reconstruction may now be used for surgical planning, improving the precision of many surgical procedures, such as the placement of dental implants (57).

Longitudinal Studies

Longitudinal studies on the relationship between maxillary roots and the MS also promise to significantly enhance our current knowledge. Such studies would ensure a larger sample size and provide more detailed age-related observations. The distance from the upper molars and premolars to the antrum maxillaris is a frequently described aspect of the temporal relationship between the teeth and the sinus. Root anatomy, in conjunction with its proximity to the antrum, plays a substantial role in the onset and progression of various pathological conditions.

More specifically, the relation of the roots to the sinus represents a crucial anatomical consideration in surgical procedures, such as sinus lift interventions employed in dental implantology, as well as in performing root canal treatments. The perforation risk of the MS membrane is particularly anticipated in cases in which the root apices are positioned near the sinus or, in certain instances, are covered by it. Variations in root morphology undoubtedly exert a considerable influence on this risk, given that roots in close vicinity to the sinus membrane or exhibiting protrusion into the sinus face heightened vulnerability to damage during surgical manipulation or subsequent inflammation.

CONCLUSION

The maxillary sinus lining is either close to the roots of the maxillary teeth or in contact with them in adult humans. Variations in the tooth root projections into the maxillary sinus can provoke pain and discomfort in some cases. These close relationships can also be the cause and source of disease, especially if a tooth becomes pathological or requires dental treatment. Pathologies, such as maxillary sinusitis of dental origin, root resorption, and periapical lesions, have been described in several studies.

An evaluation of the maxillary root protrusion inside the MS was performed using panoramic radiographs to determine the relationships before the surgical removal of some teeth or their roots, placement of implants inside the maxillary sinus, and root canal treatment. Owing to the proximity of the teeth roots to the MS, dental procedures should be performed carefully.

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