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Diagnostic Imaging Modalities of Paranasal Sinuses(normal anatomy, variations & diseases)

A Project Submitted to

The College of Dentistry, University of Baghdad, Department of Oral Diagnosis in Partial Fulfillment for the Bachelor of Dental Surgery

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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صدق الله العظيم

سورة طه الآية (١٤٤)

Certification of the Supervisor

I certify that this project entitled "Diagnostic Imaging Modalities of Paranasal Sinuses(normal anatomy, variations & diseases)" was prepared by the fifth-year students Shahad Dhiaa Hassan and Shahad Mohammad Tamkeen under my supervision at the College of Dentistry/University of Baghdad in partial fulfillment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor's name

Date

We, the members of the discussion committee, certify that we have read and examined this graduation project and that in our opinion it meets the standared of a graduation project.

Signature	**Signature**	**Signature**

Approved by the head Oral diagnosis department at the college of dentistry, University of Baghdad.

Signature

Dedication

We will be honored to dedicate this project to our parents, family, friends and all the people who stand by our side throughout this hard journey. we also would like to thank each other for being so cooperative with each other and make the team work very easy. We cannot forget to dedicate this to our teachers and doctors every single one of them. Last but not least, we would like to thank our supervisor Dr. Farah for being the best supervisor out there, we were lucky to be under her supervision.

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	Abbreviation
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
CN V1	Cranial nerve (ophthalmic nerve)
CN V2	Cranial nerve (maxillary nerve)
MDCT	Multidetector Computed Tomography
MRI	Magnetic Resonance Imaging
MPR	Multiplanar Reformat
PET	Positron Emission Tomography

Introduction

The paranasal sinuses are the four paired sets of air-filled cavities and mucosa-lined spaces within the maxillofacial region and skull centred on and communicating with the nasal cavity , teeth and oral cavity . They consist of the maxillary, frontal, and sphenoid sinuses and the ethmoid air cells. The maxillary sinuses are of particular importance to the dentist because of their proximity to the teeth and their associated structures.

Abnormalities arising from within the maxillary sinuses can cause symptoms that may mimic diseases of odontogenic origin; conversely, abnormalities that arise in and around the teeth may affect the sinuses or mimic the symptoms of sinus disease. Because the paranasal sinuses may appear on many diagnostic images used in the practice of dentistry, the dentist should be familiar with variations in the normal appearances of the sinuses and the more common diseases that may affect them. **(White & Pharoah, 2014)**

During fetal development, the paranasal sinuses originate as invagination of the nasal mucosa into the lateral nasal wall, frontal, ethmoid, maxilla and the sphenoid bones. This unique development explains the enormous amount of anatomical variation. Computed tomography (CT) is an excellent means of providing anatomical information of this region, assessing disease extent, assisting endoscopic evaluation and guiding treatment. The role of magnetic resonance imaging is limited but may provide further information on fungal infection and differentiating thickened mucosa from fluid retention. **(Dwivedi & Singh, 2010)**

The maxillary sinuses are of particular importance to dentist because of their close proximity to the teeth and their associated structures, so increased risk of maxillary sinusitis has been reported with periapical abscess, periodontal diseases, dental trauma, tooth extraction, and implant placement. **(Mudgade et al., 2018)**

Several variants of the paranasal sinuses are of primary importance in surgical planning. Also important, but less so, is that they can increase the likelihood of developing sinus disease. The most common ones are Agger nasi cells, infraorbital ethmoidal (Haller) cells, sphenoethmoidal (Onodi) cells, nasal septal deviation, and concha bullosa , which can be seen on CT scan. **(Kazmi & Shames, 2015)**

Less common anatomic variants of the paranasal sinuses include pneumatization of the uncinate process (or an uncinate bulla), large ethmoidal bullae, supraorbital cells, and pneumatized crista galli. **(Shpilberg et al., 2015)**

Imaging technology has played a significant role in the diagnosis and management of sinonasal disorders. Plain sinus films are almost exclusively replaced by CT in the work-up for inflammatory sinus disease. MRI provides complementary information to CT in cases of sinonasal and skull-base neoplasms. **(Ling & Kountakis, 2006)**

Chapter One: Literature Review

1.1 The Normal Anatomy

The paranasal sinuses are air-filled spaces located within the bones of the skull and facial bones. They are centered on the nasal cavity. **(Ameet et al., 2017)** They have several functions of which reducing the weight of the head is the most important. Other functions are air humidification and aiding in voice resonance and serving as a crumple zone to protect vital structures in the event of facial trauma. **(Sachintha, 2017)**

They are named for the facial bones in which they are located:

Maxillary sinus

Sphenoid sinus

Ethmoid sinus

Frontal sinus

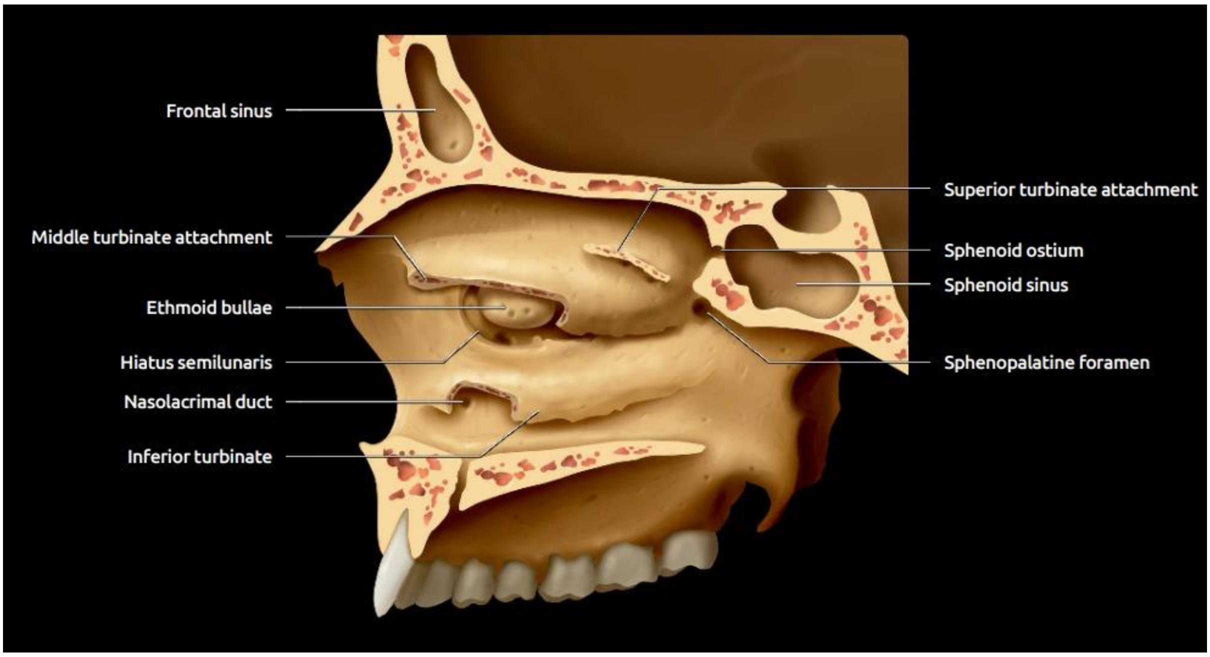

FIGURE 1_1. Sagittal graphic demonstrates the osseous anatomy of the lateral wall of the nose. The superior and middle turbinates have been resected. The ethmoid bullae and hiatus semilunaris are seen below the middle turbinate attachment. The inferior turbinate has been partially resected to reveal the nasolacrimal duct, which empties into the anterior aspect of the inferior meatus.

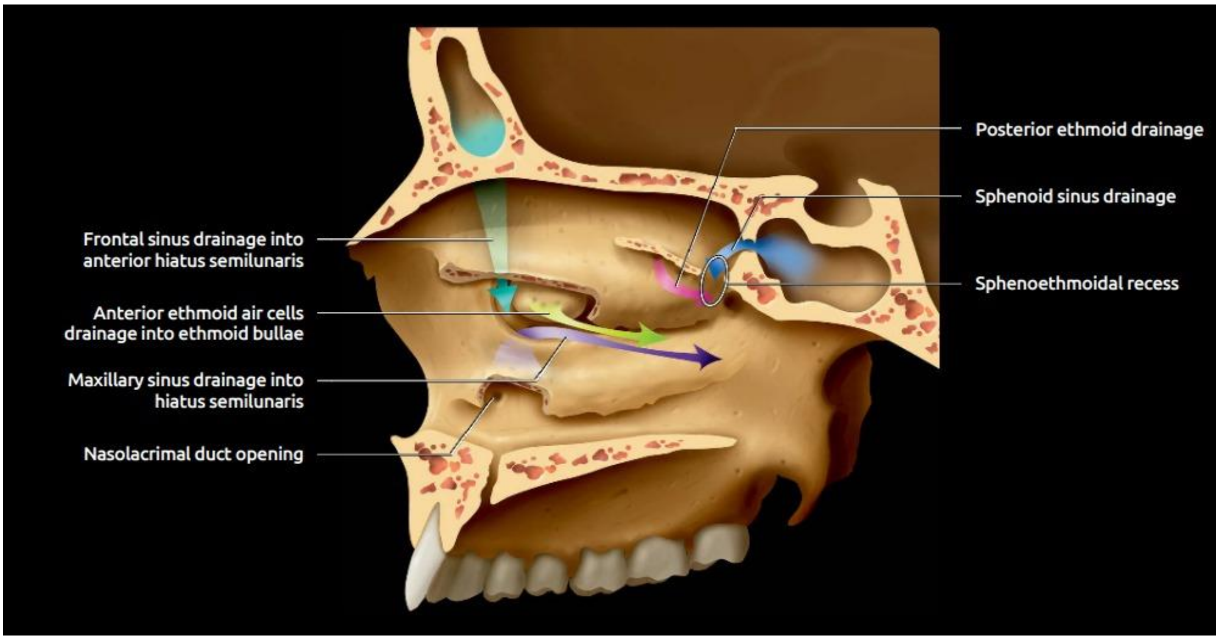

FIGURE 1_2. Sagittal graphic of the lateral wall of the nose shows the drainage pathways of the sinuses. The sphenoid and posterior ethmoid sinuses drain into the sphenoethmoidal recess in the posterior nasal cavity. The maxillary sinus drains via the maxillary infundibulum while the anterior ethmoids mostly drain through the ethmoid bullae into the ostiomeatal complex/middle meatus. The frontal sinus drains into the anterior middle meatus through the nasofrontal drainage system**. (Koenig et al., 2017)**

1.1.1 Maxillary Sinus

The maxillary sinus is the largest paranasal sinus and lies inferior to the eyes in the maxillary bone .It is the first sinus to develop and is filled with fluid at birth. It grows according to a biphasic pattern, in which the first phase occurs during years 0-3 and the second during years 6-12. The earliest phase of pneumatization is directed horizontally and posteriorly, whereas the later phase proceeds inferiorly toward the maxillary teeth. **(Dalgorf & Harvey, 2013)**

This development places the floor of the sinus well below the floor of the nasal cavity. The shape of the sinus is a pyramid, with the base along the nasal wall and the apex pointing laterally toward the zygoma. The natural ostium of the maxillary sinus is located in the superior portion of the medial wall. **(Iwanaga et al., 2019)**

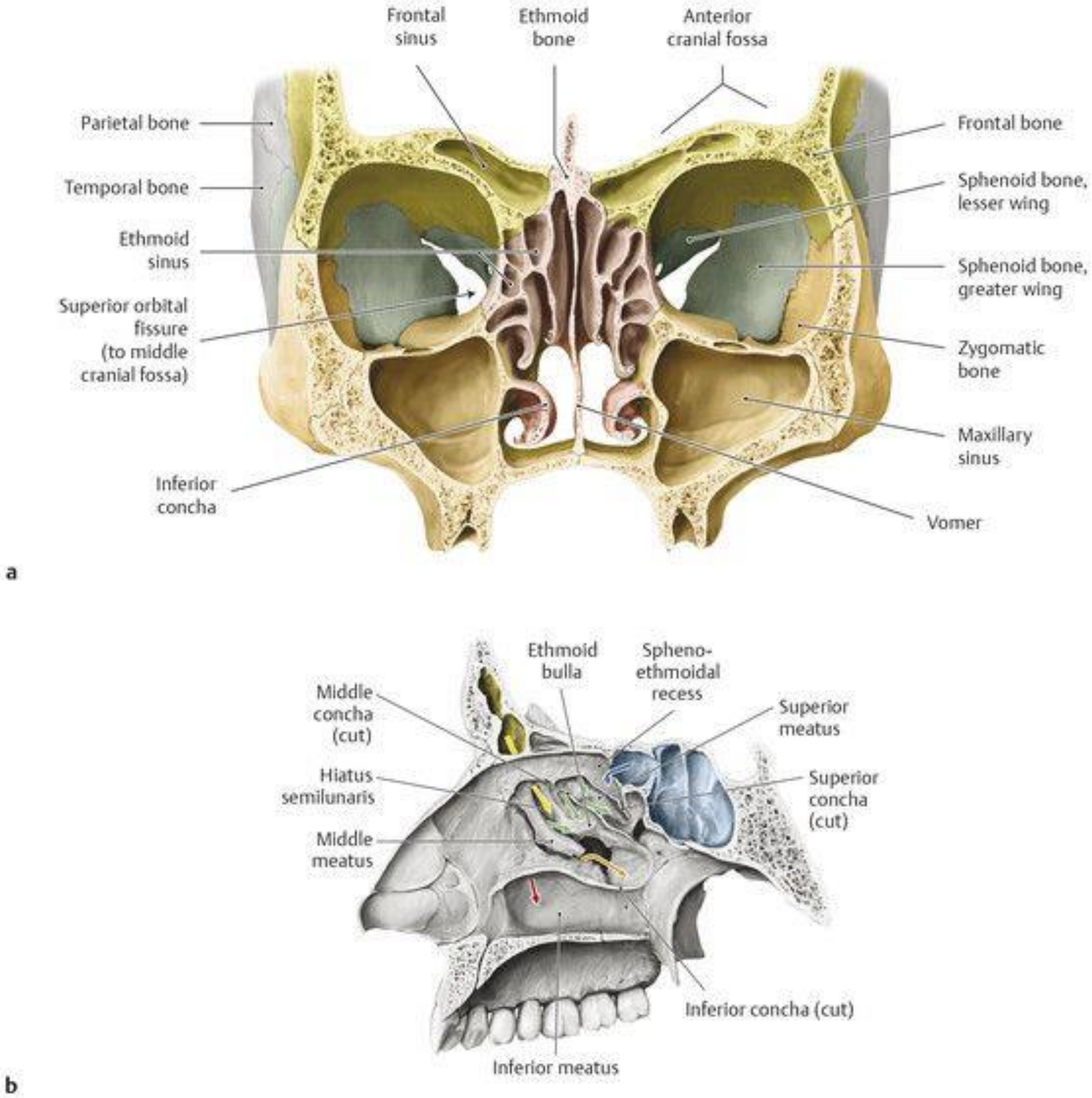

FIGURE 1_3. Anatomy of paranasal sinuses. (a) Diagram of a coronal section through the frontal, ethmoid, and maxillary sinuses showing the osseous boundaries of the sinuses and their relationship to the nasal cavity and orbits. (b) Diagram of a sagittal section through the nasal cavity, showing drainage pathways of the paranasal sinuses as they relate to the hiatus semilunaris and nasal turbinates. **(Koenig et al., 2017)**

The anterior maxillary sinus wall houses the infraorbital nerve, which runs through the infraorbital canal along the roof of the sinus and sends branches to the soft tissues of the cheek. The thinnest portion of the anterior wall is above the canine tooth, called the canine fossa, which is an ideal entry site for addressing various disease processes of the maxillary sinus. The roof of the maxillary sinus is the floor of the orbit. Behind the posteromedial wall of the maxillary sinus lies the pterygopalatine fossa, a small inverted space that houses several important neurovascular structures and communicates with several skull base foramina. The infratemporal fossa lies behind the posterolateral wall of the maxillary sinus. **(Whyte & Boeddinghaus, 2019)**

The maxillary sinus is supplied by branches of the internal maxillary artery, which include the infraorbital, alveolar, greater palatine, and sphenopalatine arteries. It is innervated by branches of the second division of the trigeminal nerve, the infraorbital nerve, and the greater palatine nerves . **(Ameet et al.,2017)**

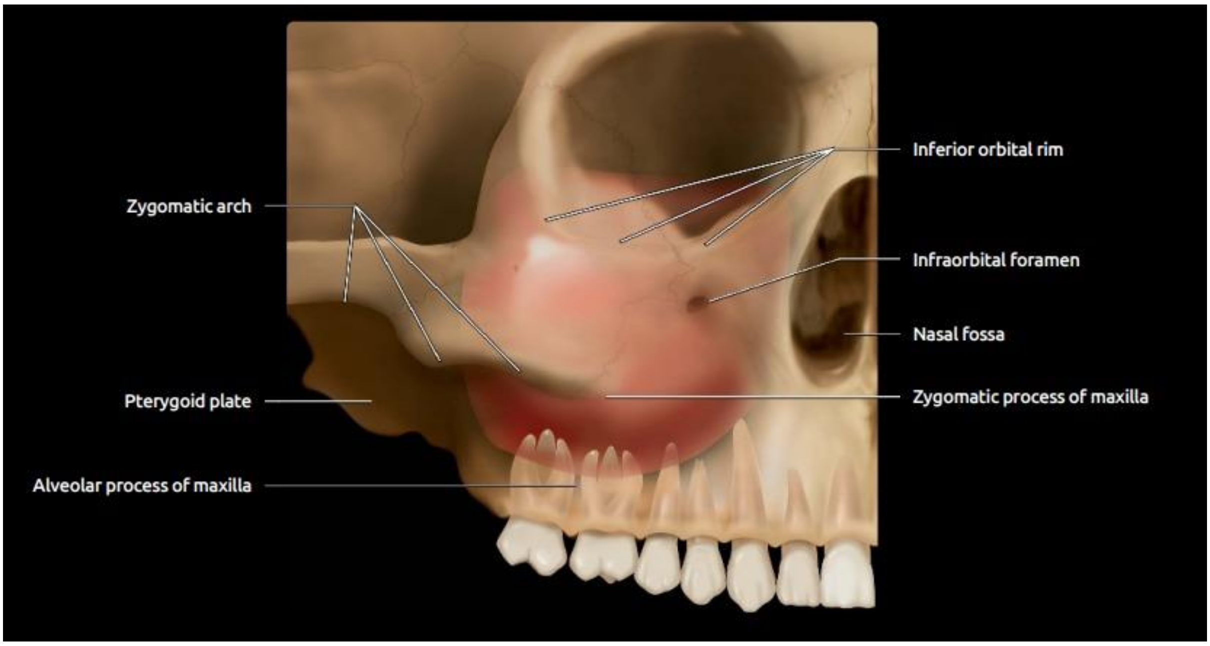

FIGURE 1_4. Graphic depicts the relationship of the maxillary sinus to the surrounding osseous structures and teeth from the perspective of a panoramic radiograph. The sinus generally extends anteroposteriorly from the lateral nasal wall to the posterolateral wall of the maxilla and superoinferiorly from the floor of the orbit to the alveolar process. The zygomatic process of the maxilla and zygomatic arch are superimposed over the sinus.

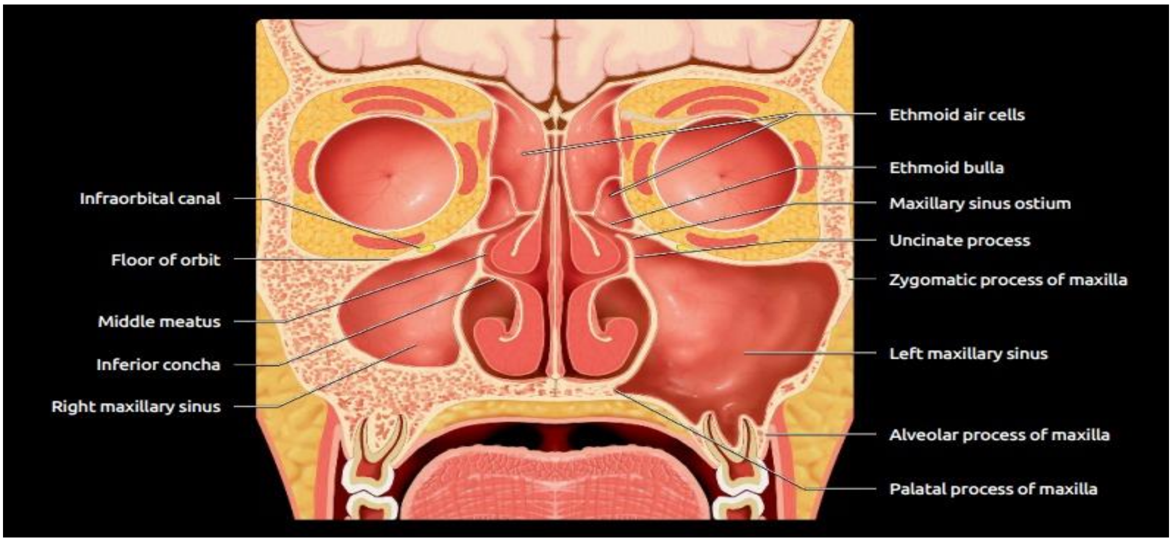

FIGURE 1_5. Coronal graphic depicts normal size variations of the maxillary sinuses. The right maxillary sinus is hypoplastic while the left sinus has pneumatized the zygomatic, palatal, and alveolar processes. Note the close relationship of the maxillary molar roots to the sinus when the sinus extends into the alveolar process. This may more easily result in the spread of dental disease to involve the sinus. Oral surgical procedures in the region are also more likely to create an oral-antral communication in this situation**. (Koenig et al., 2017)**

1.1.2 Frontal Sinus

The frontal sinus is housed in the frontal bone superior to the eyes in the forehead. It is formed by the upward movement of anterior ethmoid cells after the age of 2. Developmentally, this is the last sinus to pneumatize **(Dalgorf & Harvey, 2013).** Growth increases at age 6 years and continues until the late teenage years. The frontal sinuses are funnel-shaped structures with their ostia located in the most dependent portion of the cavities. The posterior wall of the frontal sinus, which separates the sinus from the anterior cranial fossa, is much thinner than its anterior wall. **(Reddy & Dev, 2012)**

The frontal sinus is divided into two cavities by the frontal septum. Several anatomical structures are important to frontal sinus anatomy, and they include:

1.1.2.1 Frontal Sinus Infundibulum and Ostium

The frontal infundibulum is a conically tapering constriction located in the frontal sinus floor superior to the agger nasi cells, that drains into the frontal recess. It is a transition zone between the frontal sinus and the frontal recess, and its narrowest area is known as the ostium (as shown in figure 1_6). **(Saini & Govindaraj, 2016)**

1.1.2.2 Frontal Recess

The frontal recess is the space posterior to the frontal beak into which the frontal sinus drains. It is anteriorly bounded by the posterior wall of the agger nasi cell, laterally by the lamina papyracea, and medially by the middle turbinate. **(Wormald et al., 2016)**

Several cells cover this space and influence the direction of the drainage outflow. The frontal recess is a common site of infection, and its surgical approach is known to be challenging. The recess can open into the middle meatus in more than half of individuals or into the ethmoid infundibulum in the rest. **(Reddy & Dev, 2012)**

1.1.2.3 Agger Nasi Cell

The most anterior ethmoidal cell is known as Agger nasi cell. Almost all patients have this cell, which is an ethmoturbinal remnant. It locates lateral, inferior, and anterior to the frontal recess, and elongates anteriorly into the lacrimal bone. To accurately view the frontal recess, the agger nasi cells need to be opened. **(Cappello et al., 2018)**

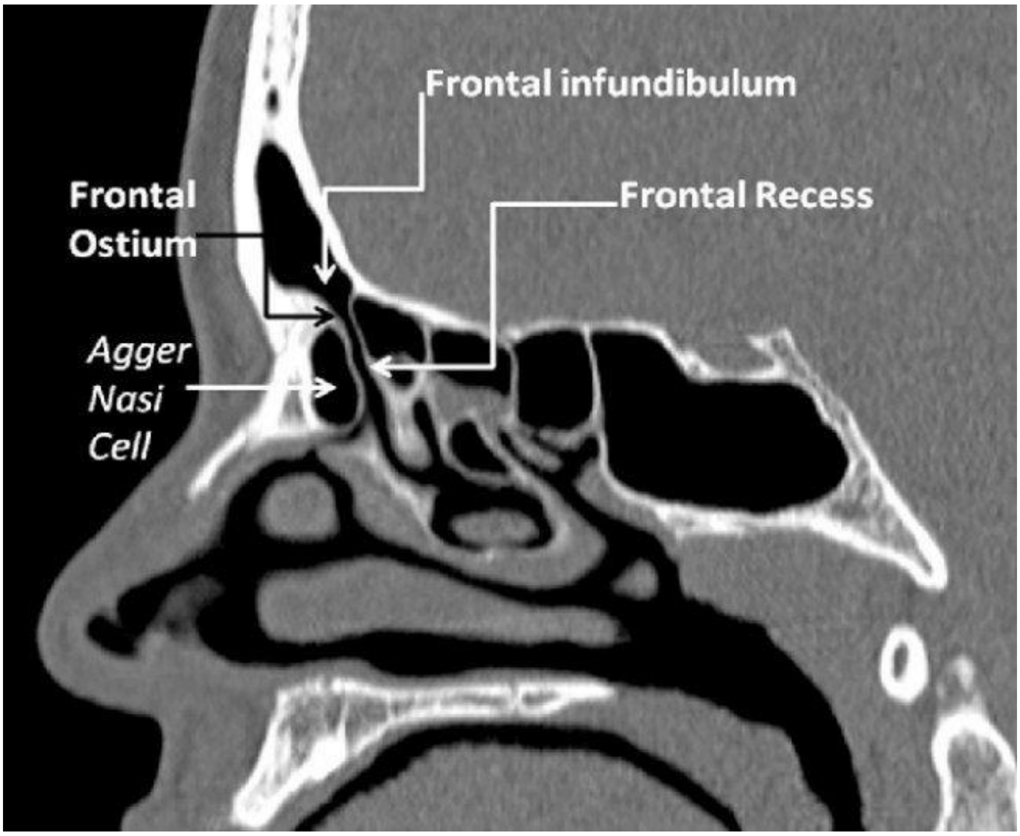

FIGURE 1_6. The frontal recess and its relation to the frontal infundibulum and ostium. **(Koenig et al., 2017)**

1.1.2.4 Frontal Cells

Frontal cells are anterior ethmoid cells that pneumatize the frontal recess. These cells may cause obstruction or persistent sinus disease **(Cappello et al., 2018)**. They are located posterior and superior to the agger nasi cell, and Bent and Kuhn classify them into four types according to their relation to the agger nasi cell and the orbit's roof

Type I: Single cell above the agger nasi cell.
Type II: Multiple cells above the agger nasi, and below the orbit's roof.
Type III: Single large cell that extends supraorbitally through the floor of the frontal sinus, attaches to the anterior table, and stays contiguous to the agger nasi cell.
Type IV: Single isolated cell that is contained within the frontal sinus**.**
(Tuncyurek et al., 2012)

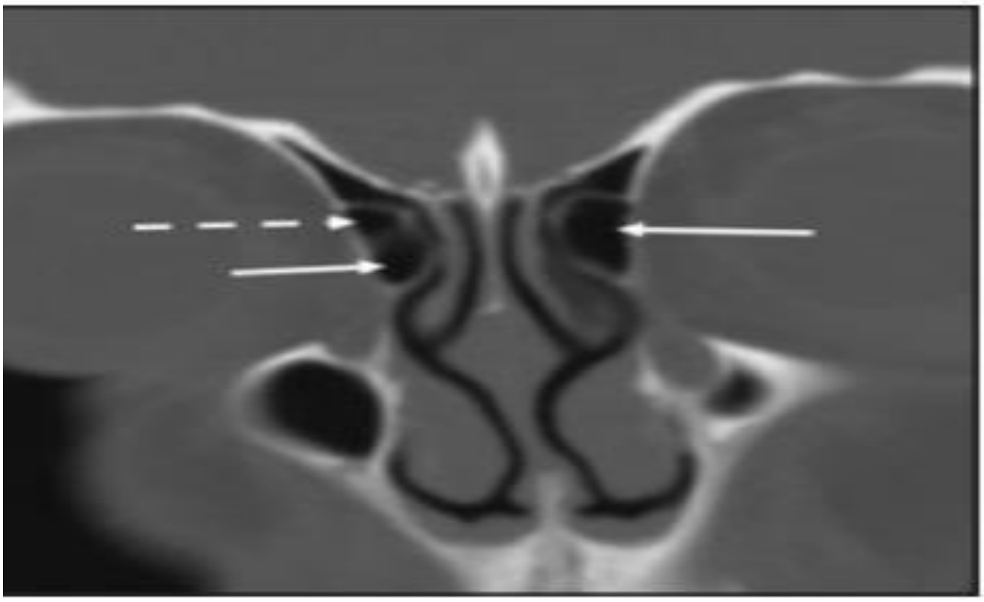

FIGURE 1_7 . Agger nasi and frontal air cells. Coronal CT image demonstrates the agger nasi cells (solid arrows) and a type 1 frontal cell (dashed arrow). **(Kazmi et al ., 2015)**

The frontal sinus is supplied by the supraorbital and supratrochlear arteries of the ophthalmic artery. It is innervated by the supraorbital and supratrochlear nerves of the first division of the trigeminal nerve**. (Langille et al., 2012)**

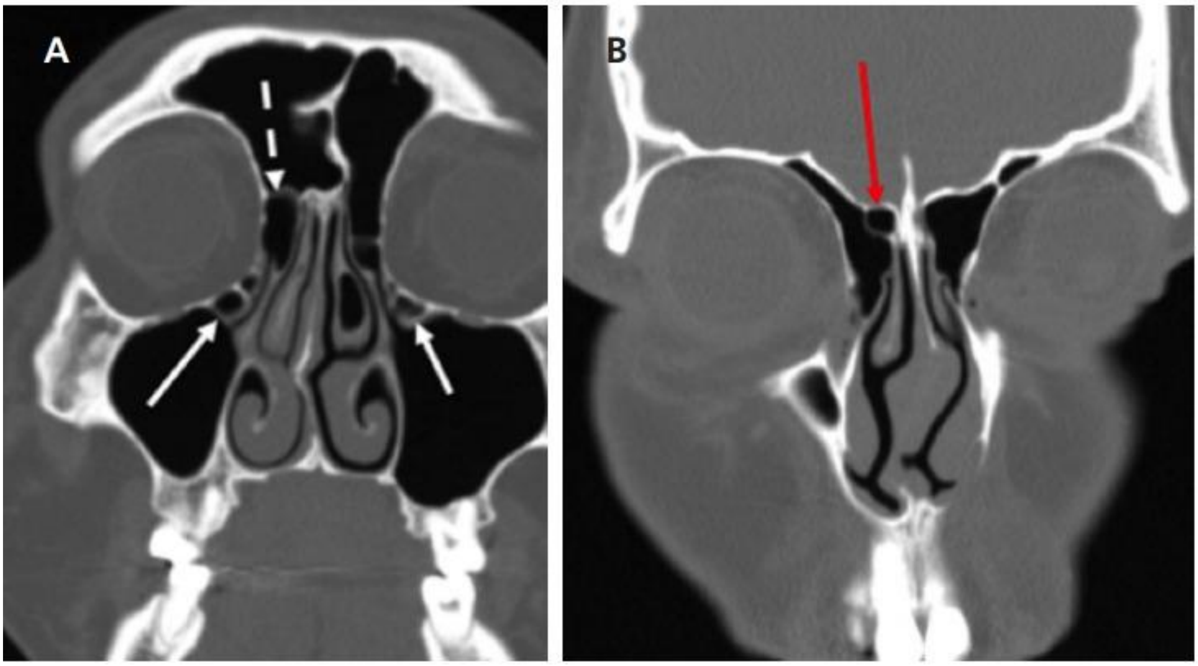

FIGURE 1_8. Haller and frontal air cells. Coronal CT images (A and B) demonstrate bilateral Haller cells (white arrows, A), and type 3 (dashed white arrow, A) and type 4 (red arrow, B) frontal air cells. **(Kazmi et al ., 2015)**

1.1.3 Sphenoid Sinus

The sphenoid sinus is located centrally and posteriorly within the body of the sphenoid bone, and it is posteriorly and superiorly bounded by the sella turcica. The sphenoid sinus, present only in humans and primates, can be identified in radiographs from the age of two. It keeps developing throughout life but matures in size at around 12 to 14 years of age. The typical adult size is 0.5 to 8 mL. **(Özer et al., 2018)**

Several important structures have a close relation to the sphenoid sinus, including the internal carotid artery and the optic nerve. The carotid artery is located adjacent to the lateral wall of the sinus, and in 25% of patients, it is dehiscent in this area. The optic nerve leaves an anteroposterior indentation on the roof of the sphenoid, and the overlying bone can be dehiscent in around 4% of individuals **(Cashman et al., 2011).** The sphenoid sinus is also adjacent to the cavernous sinus and hypophysial gland. **(Özer et al., 2018)**

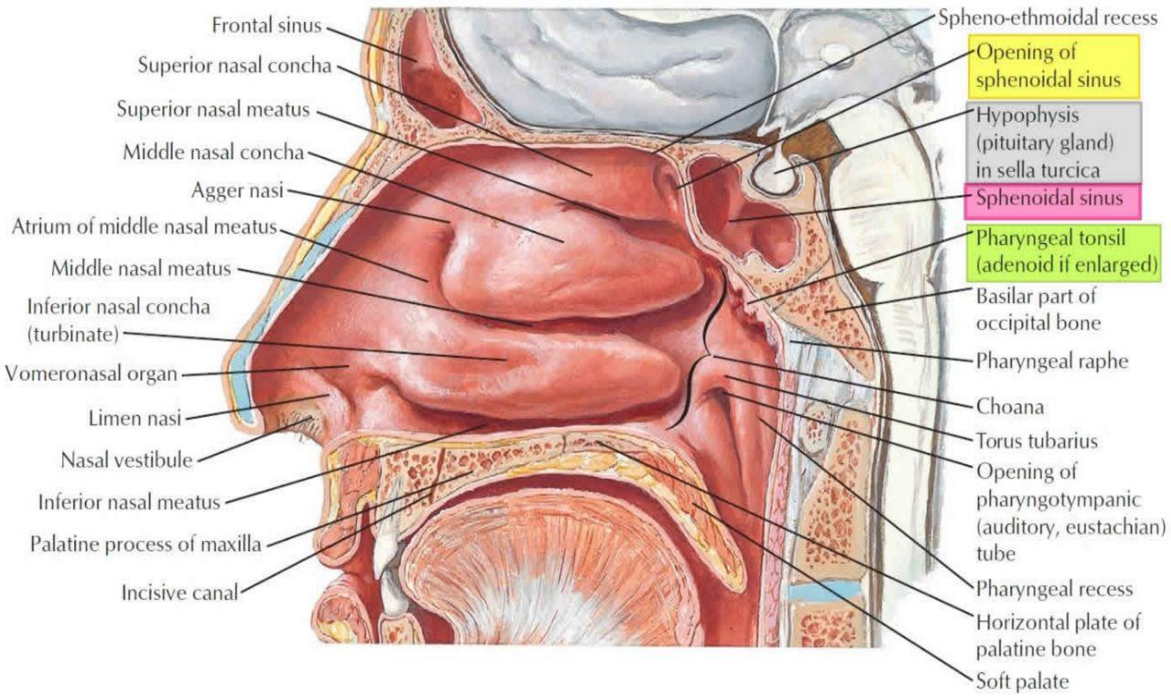

FIGURE 1_9. The sphenoid sinus is adjacent to the pituitary gland. **(Koenig et al., 2017)**

The patterns of the sphenoidal sinus pneumatization were classified into conchal, pre-sellar, and sellar, depending on the extension of pneumatization concerning the sella turcica. But, Štokovic et al. added a fourth type – post-sellar **(Štoković et al., 2016).** The sphenoid ostium drains into the sphenoethmoidal recess located within the superior meatus. **(Cappello et al., 2018)**

1.1.4 Ethmoid Sinus

The ethmoid bone is formed by a multitude of cells with an intricated structure, through which all the paranasal sinuses drain. There are 3 to 4 ethmoid air cells at birth that develop into 5 to 15 paired cells by adulthood with a total volume of 2 to 3 mL. They are located between the eyes, on either side of the septum. The anterior ethmoid cells drain into the ethmoid infundibulum, in the middle meatus. The posterior ethmoid cells drain into the sphenoethmoidal recess located in the superior meatus. **(Cappello et al., 2018)**

The complex ethmoidal labyrinth can be reduced into a series of lamellae based on embryologic precursors. These lamellae are obliquely oriented and lie parallel to each other.

1. The first lamella is the uncinate process.
2. The second lamella corresponds to the ethmoid bulla.

3. The third lamella is also known as the basal or ground lamella of the middle turbinate. It serves as the division of the anterior and posterior ethmoids. The anterior part inserts vertically into the crista ethmoidalis. The middle portion attaches obliquely into the lamina papyracea. The posterior third attaches to the lamina papyracea as well but in a horizontal fashion.
4. The fourth lamella is the superior turbinate. **(Lafci et al., 2018)**

The agger nasi cell is the most anterior of the anterior ethmoid cells. It is found anterior and superior to the middle turbinate attachment to the lateral wall. The posterior wall of the agger nasi cell forms the anterior wall of the frontal recess. **(Wormald et al., 2016)**

The ethmoid bulla is the largest of the anterior ethmoid cells that lies above the infundibulum - the anterior ethmoid artery courses over the roof of this cell. **(Cappello et al., 2018)**

1.2 Blood Supply and Lymphatics

The maxillary sinus is irrigated by branches of the maxillary artery: the infraorbital artery, the posterior superior alveolar artery, and the posterior lateral nasal artery.The infraorbital artery travels through the infraorbital groove and canal and then through the infraorbital foramen. The posterior superior alveolar artery runs along the sinus' medial wall. The posterior lateral nasal artery can also be found within the medial wall of the maxillary sinus. **(Nuñez-Castruita et al., 2012)**

The maxillary sinus' innervation is provided by branches of the maxillary nerve: middle, anterior, and posterior superior alveolar nerves, and infraorbital nerve. **(Iwanaga et al., 2019)**

The frontal sinus vasculature consists of the supraorbital and supratrochlear arteries and ophthalmic and supraorbital veins. The sphenopalatine artery supplies the sphenoid sinus, and venous drainage is via the maxillary vein.

The ethmoid sinuses are supplied by the anterior and posterior ethmoid arteries, respectively. These arteries are branches of the ophthalmic artery, a branch of the internal carotid artery. Ethmoid sinus venous drainage is done by the maxillary and ethmoid veins. **(Cappello et al., 2018)** .

1.3 Innervation

The maxillary sinus' innervation is provided by branches of the maxillary nerve: middle, anterior, and posterior superior alveolar nerves, and infraorbital nerve. The sphenoid sinus' innervation is provided by the sphenopalatine nerve, which comprises parasympathetic fibers and CN V2. The frontal sinus is innervated by the supraorbital and supratrochlear nerves (CN V1). The anterior and posterior ethmoid nerves provide innervation to ethmoid sinuses. **(Iwanaga et al., 2019)**

1.4 The Development and Anatomic Variation

The paranasal sinuses develop as invaginations from the nasal fossae into their respective bones (maxillary, frontal, sphenoid, and ethmoid) and continue to enlarge until skeletal maturity. **(White & Pharoah, 2014)**

The paranasal sinuses develop in conjunction with the palate from changes in the lateral wall of the nasal cavity. At 40 weeks' gestation, 2 horizontal grooves develop in the mesenchyme of the lateral wall of the nasal cavity. Proliferation of maxilloturbinate mesenchyme between these grooves results in an outpouching of tissue medially into the nasal lumen. This outpouching is the precursor of the middle and inferior meatus as well as the inferior turbinate. Ethmoidoturbinate folds develop superiorly to give rise to the middle and superior turbinates. Once the turbinate structures are established, sinus development begins and continues until early adult life. **(Brook ,2018)**

The sinuses open into the nose via small openings called ostia **(Seo et al., 2013)**. The mucosal lining of the paranasal sinuses is similar to the lining found in the nasal cavity but with slightly fewer mucous glands. The epithelial cilia move these sinus secretions toward their respective communications, the ostia, with the nasal fossae. **(White & Pharoah, 2014)**

1.4.1 The Maxillary Sinus

The maxillary and ethmoid sinuses form at 3-4 months' gestation. Thus, an infant is born with 3-4 ethmoid cells and tiny teardrop-shaped maxillary sinuses. By the teenage years, each maxillary sinus progressively enlarges to an adult capacity of 15 mL. **(Brook, 2018)**

The maxillary sinuses or antra are the first to develop in the second month of intrauterine life. An invagination develops in the lateral wall of the nasal fossa in the middle meatus, and the sinus cavity enlarges laterally into the body of the maxilla. At birth, each sinus is a thin, small slit, no more than 8 mm in length in its anteroposterior dimension. With time, the maxilla becomes progressively more pneumatized as the air cavity expands further into the bone both laterally under the orbits toward the zygomatic process and inferiorly into the alveolar process. Enlargement of the air space, or pneumatization, into the alveolar process superimposes the maxillary sinus and floor over the roots of the premolar or molar teeth to varying degrees on plain images. **(Scuderi et al., 1993)**

The radiographic appearance of the floor of the maxillary sinus is a thin, radiopaque line. Where the alveolar process of the maxilla is not well pneumatized, the floor of the sinus may not be visible on periapical images (as shown in Fig. 1_10, A), or it may be seen superior to the roots of the maxillary premolar or molar teeth. With greater pneumatization of the alveolar process, the floor of the sinus may appear to undulate or drape over or around the roots of the teeth or be superimposed over the roots of the adjacent teeth, giving the false impression that the tooth roots have penetrated the sinus floor (as shown in Fig. 1_10, C and D) **(White & Pharoah, 2014)**. Closer examination of the periapical areas of the teeth in such instances reveals intact laminae durae and periodontal ligament spaces. In patients with considerable pneumatization of the alveolar process of the maxilla, the lamina dura of a premolar or molar tooth may form a portion of the sinus floor. **(Bolger et al., 1991)**

FIGURE 1_10 A-D. The range of normal of the position of the maxillary sinus relative to the premolar and molar teeth is shown in periapical images. There is no apparent floor in A, with progressively more pneumatization of the alveolar process in B and C; draping of the maxillary sinus border over the apices of the teeth is particularly evident in D. **(White & Pharoah, 2014)**

Maxillary sinus pneumatization may also extend into the palatal, zygomatic, and frontal processes of the maxilla, and this can be appreciated on plain images and advanced imaging examinations such as cone-beam computed tomographic (CBCT), computed tomographic (CT), or magnetic resonance (MR) imaging (as shown in Fig. 1_11).

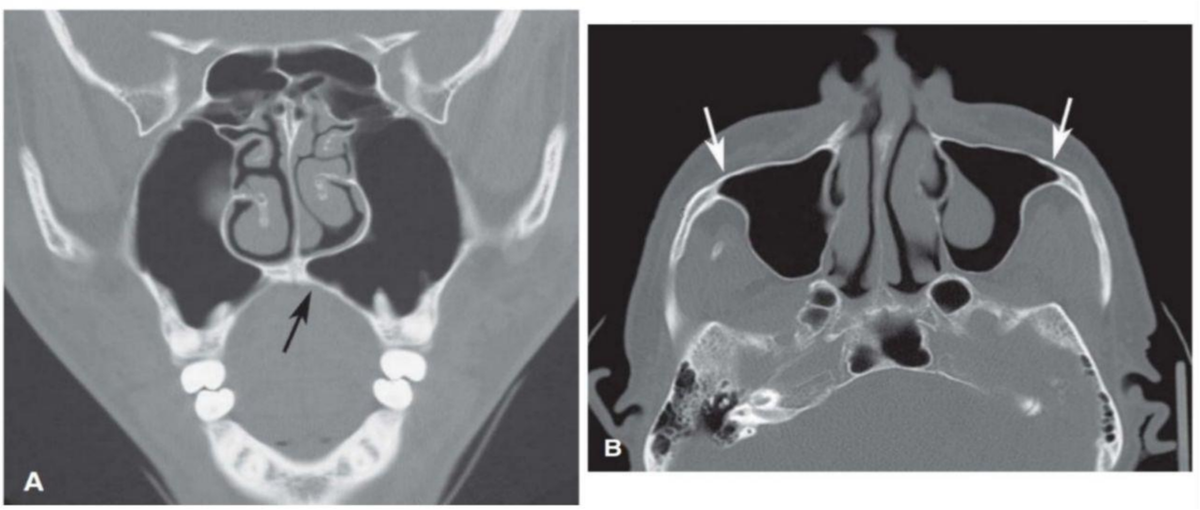

FIGURE 1_11. **A,** Example of pneumatization of the maxillary sinus into the palatal process of the maxilla (arrow) in coronal MDCT image. **B,** Examples of pneumatization of the zygomatic process of the maxilla (arrows) in axial MDCT image; also note the retention pseudocyst in the left maxillary sinus. **(White & Pharoah, 2014)**

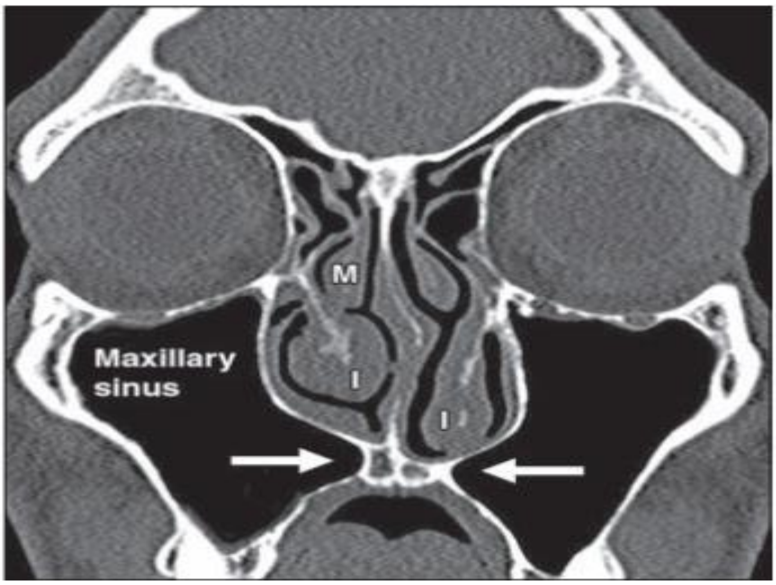

FIGURE 1_12. Coronal unenhanced CT scan of sinuses in 34-year-old woman with sinusitis shows bilateral pneumatization of hard palate (arrows), representing pneumatization from maxillary sinus into palatal process of maxilla. M = middle turbinate, I = inferior turbinate. **(Shpilberg et al., 2015)**

In some instances, the appearance of the normally pneumatized maxilla may be mistakenly confused with a benign space-occupying lesion, particularly on plain images. **(White & Pharoah, 2014)**

FIGURE 1_13. Panoramic image of a loculus (arrows) of the left maxillary sinus draping over the roots mimicking a benign spaceoccupying lesion. **(White & Pharoah, 2014)**

Hypoplasia of the maxillary sinuses occurs unilaterally in about 1.7% of patients and bilaterally in 7.2%. In these patients, the images of the affected sinus may appear more radiopaque than normal because of the relatively large amount of surrounding maxillary bone. The configuration of the maxillary sinus walls frequently helps to distinguish between a hypoplastic sinus and a sinus that is pathologically radiopaque. **(Bolger et al., 1991)**

An occipitomental (Waters) view shows an inward bowing of the sinus wall resulting in a smaller than normal air cavity. In contrast, extensive enlargement of the maxillary and other paranasal sinuses is a well-known feature of acromegaly **(Scuderi et al., 1993).** Its prevalence has been reported to be 1%-11%. Maxillary sinus may become hypoplastic during its development in the embryologic period, accompanying syndromes such as Apert, Crouzon and Treacher Collins , or later due to traumatic, iatrogenic or structural causes. **(Papadopoulou et al., 2021)**

Ozcan et al. were the first to describe that frontal sinus hypoplasia/aplasia was more common in patients with hypoplastic maxillary sinuses. On the other hand, the maxillary sinus is over-pneumatized when the longest horizontal or vertical axis of the maxillary sinus is 90% or more of the relevant orbital size. **(Ozcan et al.,2018)**

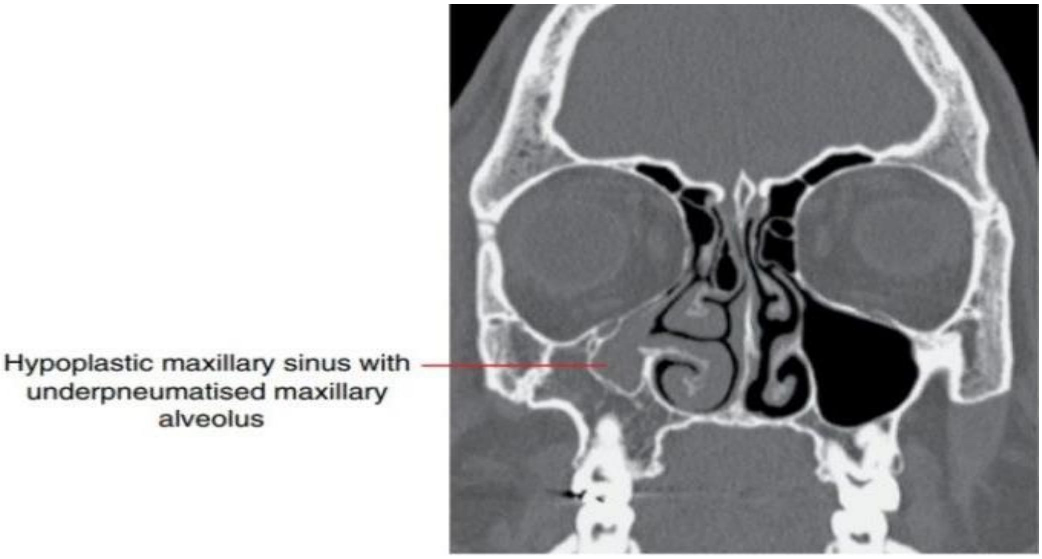

FIGURE 1_14. Maxillary sinus hypoplasia: coronal MDCT image. **(Koong, 2017)**

The widening of the posterior ethmoid cells into the maxillary sinus is known as ethmomaxillary sinus and it drains into the superior meatus. Its incidence is reported to be 0.7%-2% and is most frequently accompanied by a hypoplastic maxillary sinus. If not determined with CT prior to endoscopic sinus surgery, it may cause anatomical disorientation during the operative procedure. **(Papadopoulou et al., 2021)**

Finally, Lantos et al. have been the first to systematically describe the prevalence of infraorbital nerve protrusion into the maxillary sinus, revealing that it is not an uncommon variant (10.8%). The protrusion of this branch of the trigeminal nerve into the maxillary sinus, instead of normally traversing the orbital floor, can lead to an increased risk of injury during endoscopic sinus surgery or open surgical approaches, such as the Caldwell-Luc procedure. **(Lantos et al., 2016)**

The maxillary sinus septum divides the maxillary antrum into bony compartments and is the most frequently encountered maxillary sinus variation in the literature, with a mean prevalence of 29% **(Amine et al., 2020)**. The primary septa are assumed to be formed during the embryonic development of the midline of the face. Secondary septa, on the other hand, are assumed to be formed secondary to bone resorption in the sinus base due to alveolar ridge atrophy following tooth loss in the process of maxillary sinus pneumatization. **(Papadopoulou et al., 2021)**

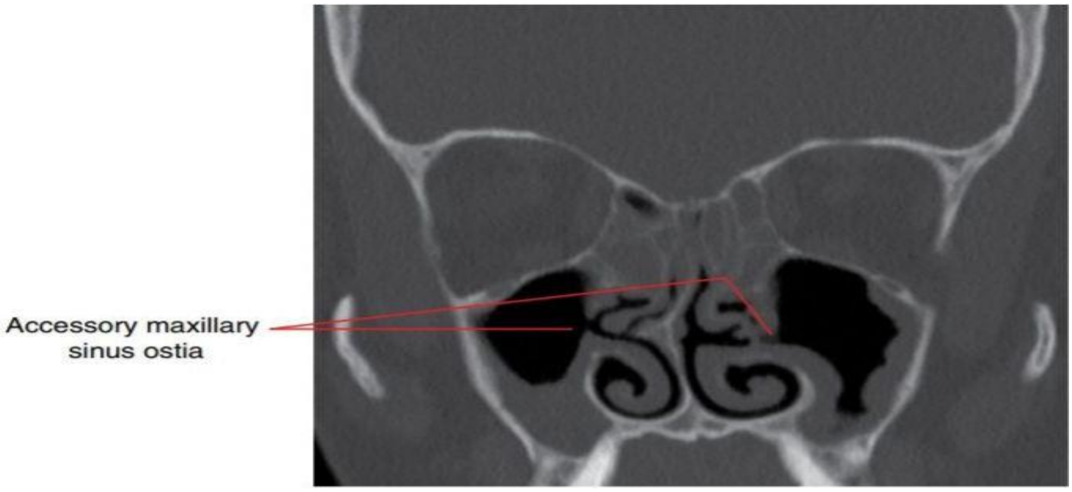

FIGURE 1_15. Accessory maxillary sinus ostia: coronal MDCT multiplanar reformat image. **(Koong, 2017)**

The ethmoid air cells extend into the developing ethmoid bones during the fifth fetal month. They consist of multiple separate or interconnected air-filled chambers that border the medial and sometimes inferior aspects of the orbital cavities. **(White & Pharoah, 2014)**

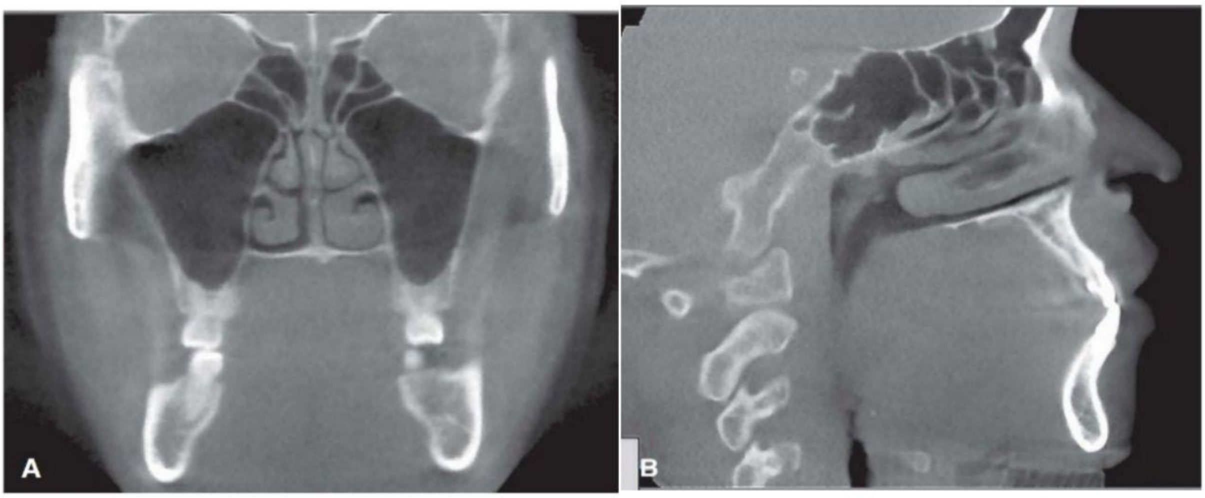

FIGURE 1_16. A, Coronal CBCT image of normal maxillary sinuses and ethmoid air cells. B, Sagittal CBCT image of normal frontal and sphenoid sinuses and ethmoid air cells. **(White & Pharoah, 2014)**

In healthy individuals, the ethmoid sinuses increase in number to 18-20, and each drains by an individual ostium that is 1-2 mm in diameter **(DelGaudio et al., 2010)**. The number of air cells varies considerably, with each ethmoid bone containing 8 to 15 cells. In some cases, the ethmoid air cells may encroach into the neighboring maxillary, lacrimal, frontal, sphenoid, and palatine bones. **(Bolger et al., 1991)**

The frontal sinus either develops directly as extensions from the nasal fossae or develops from the anterior ethmoid air cells **(White & Pharoah, 2014)**. The sinus develops from an anterior ethmoid cell and moves to its supraorbital position when the individual is aged 6-7 years. Frontal sinuses may begin to develop at this age but usually do not appear radiologically until the individual is aged approximately 12 years. The maxillary, anterior ethmoid, and frontal sinuses drain into the middle meatus; the posterior ethmoid and sphenoid sinuses drain into the superior meatus. **(Brook, 2018)**

In about 4% of the population, the frontal sinuses fail to develop. As with the other paranasal sinuses, the right and left frontal sinus cavities develop separately, and as they expand, they approach each other in the midline. In such instances, a thin bony septum may partially or completely separate the two asymmetric cavities. In adults frontal sinus pneumatization may also extend posteriorly into the orbital roofs. **(White & Pharoah, 2014)** .

1.4.2 Frontal Sinus Variations

Knowledge of the frontal sinus anatomy is important for surgeons performing endoscopic sinus surgery, frontal sinus balloon sinuplasty, craniotomy or external approaches. **(Gotlib et al., 2015)**

The frontal sinuses are essentially the only paranasal sinuses that are absent at birth, because, on average, these sinuses do not reach up into the frontal bone until the age of about six years. Because the left and right frontal sinuses develop independently, a significant asymmetry between these sinuses can arise in the same individual. **(Papadopoulou et al., 2021)**

An absence of pneumatization in the frontal bone results in frontal sinus aplasia. Although frontal sinus aplasia is not rare in the literature, its frequency is variable between different populations. More specifically, the frequency of bilateral absence of the frontal sinus has been reported in 2% to 33%, whereas the incidence of a unilateral absence has been reported to be between 0.8% and 7.4%. **(Aslier et al., 2016)**

In addition, bilateral frontal sinus aplasia is more common among female subjects. Besides, climatic conditions, local inflammations and the mechanical stress of mastication can affect the size of frontal sinus. **(Craiu et al., 2017)**

The sphenoid sinus begins growing in the fourth fetal month as invaginations from the sphenoethmoidal recesses of the nasal fossae. Located in the body of the sphenoid bone. the sinuses may be separated by a partial or complete bony septum that may result in sinus cavities that are asymmetric in size and shape. Similar to the other sinuses, the sphenoid sinuses may extend beyond the body of the bone into the dorsum sella, the clinoid processes, the greater or lesser wings, and the pterygoid processes. The ostium of the sphenoid sinus is a relatively large-diameter opening, which may explain why blockages of the sphenoid sinus ostium are uncommon. **(White & Pharoah, 2014)**

1.4.3 Sphenoid Sinus Variations

The sphenoid sinus and adjacent bony structures may show various degrees of pneumatization. Considerable variations including cavernous sinus, internal carotid artery, optic and vidian canals are intimately related to sphenoid sinuses. **(Papadopoulou et al., 2021)**

More extensively, the optic canal is the place where the optic nerve is the least nourished throughout its course; therefore, it is very susceptible to injury through direct inflammatory invasion of the sinus diseases, and additionally, there is a risk of blindness if the surgeon damages the nerve within the sinus **(Turna et al., 2014)** . The reported prevalence for optic nerve protrusion into the sphenoid sinus ranges from 7% to 35% **(Lantos et al., 2016)**. When the anterior clinoid process is pneumatized, mostly by the sphenoid or ethmoid sinus or both, the optic nerve protrudes against the superior lateral sinus wall. **(Turna et al., 2014)**

Dasar et al. found a statistically significant association between anterior clinoid process pneumatization and optic nerve protrusion into the sphenoid sinus. **(Dasar et al., 2016)**

Furthermore, a dehiscence in the bone covering internal carotid artery may lead to direct contact of the artery with sinus mucosa that may lead to infection occurring within the cavernous sinuses. On the other hand, if this variation has not been noticed by the surgeon preoperatively, carotid artery injury could result in blindness or fatal hemorrhage **(Turna et al., 2014)**. The prevalence of internal carotid artery dehiscence and protrusion varies widely from 2% to 23% and 5.2% to 67% respectively. **(Papadopoulou et al., 2021)**

Rereddy et al. found a significant association between dehiscent or protruding optic nerve and dehiscent or protruding internal carotid artery. **(Rereddy et al., 2014)**

Postsellar pneumatization from the sphenoid sinus, particularly pneumatization of the dorsum sella, may result in the penetration of the posterior wall of the sphenoid with resultant CSF leak during trans-sphenoidal pituitary surgery. **(Shpilberg et al., 2015)**

Insertion of an intersphenoid sinus septum onto the carotid canal has been reported in 4.7%. Another anatomical variant is the sphenomaxillary plate, a condition where a posteriorly over-pneumatized maxillary sinus is united with the sphenoid sinus via a bony septum. This structure should be recognized on the CT images in order to avoid orbital complications during surgery. **(Lantos et al., 2016)**

Aplasia of the sphenoid sinuses, lastly, is an extremely rare phenomenon. The diagnosis of sphenoid sinus hypoplasia is potentially important in patients in whom trans-sphenoidal hypophysectomy is contemplated. **(Turna et al., 2014)**

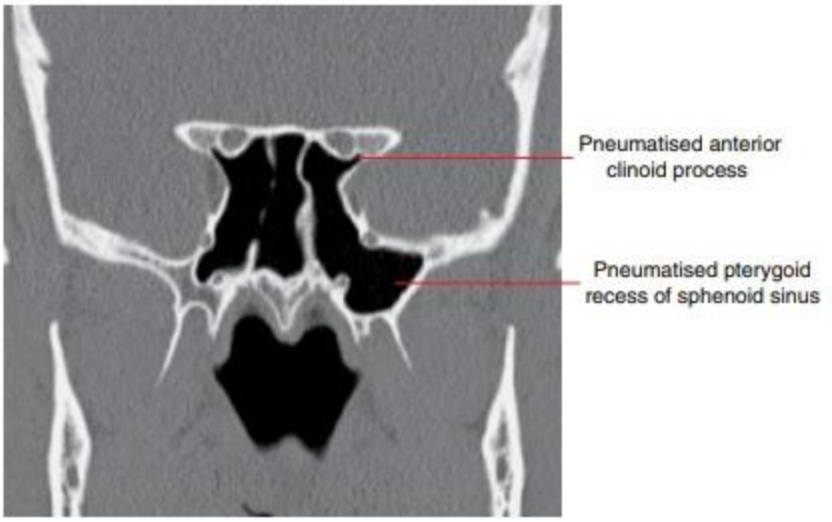

FIGURE 1_17. Sphenoid sinus variant pneumatisation: coronal MDCT image. **(Koong, 2017)**

1.4.4 Ethmoid Sinus Variation

Numerous sinonasal anatomic variants exist and are frequently seen on sinus CT scan. The most common ones are:

1. The Agger nasi cells are the most anterior ethmoidal air cells. Their location is anterior lateral, and inferior to the frontal recess. **(Shpilberg et al., 2015)**

2. Infraorbital ethmoidal (Haller) cells are ethmoidal cells that extend downward under the medial floor of the orbit adjacent to and above the maxillary sinus ostium lateral to the infundibulum. **(Mathew et al., 2013)**

3. Sphenoethmoidal (Onodi) cells are posterior ethmoidal cells that extend laterally, superiorly, and posteriorly to the sphenoid sinus and are intimately associated with the optic nerve. **(Shpilberg et al., 2015)**

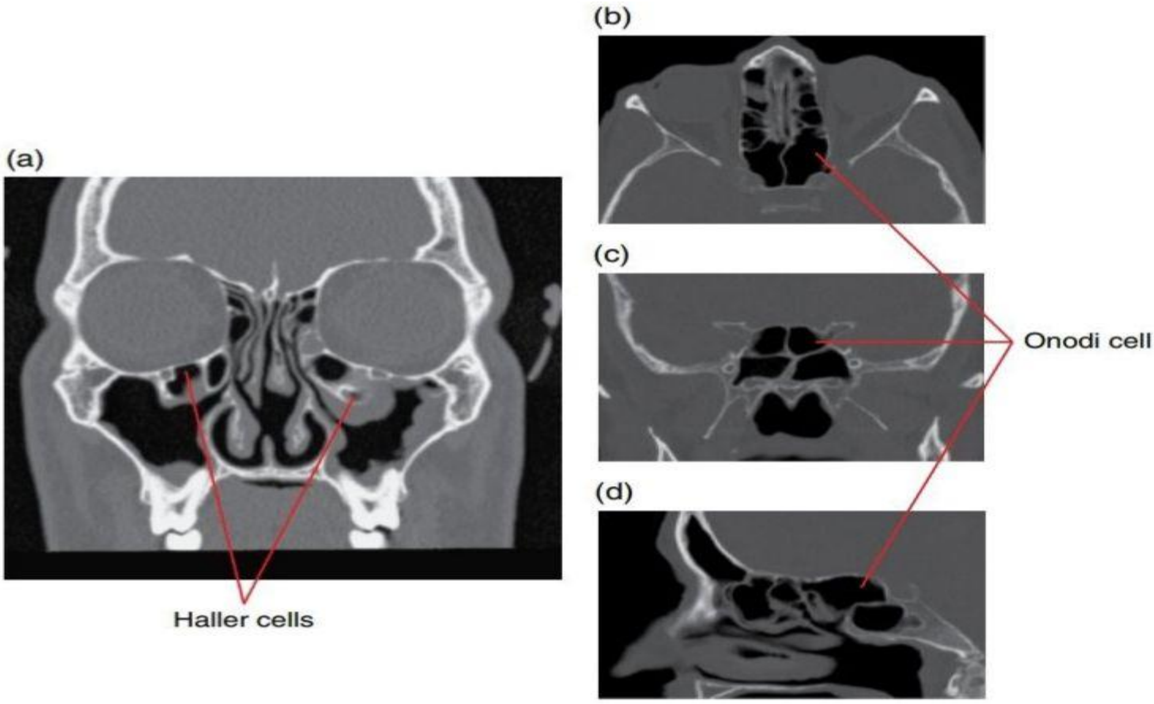

FIGURE 1_18. Ethmoid air cell variations: coronal CT (a) and axial (b), coronal (c) and sagittal (d) MDCT multiplanar reformat (MPR) images. **(Koong, 2017)**

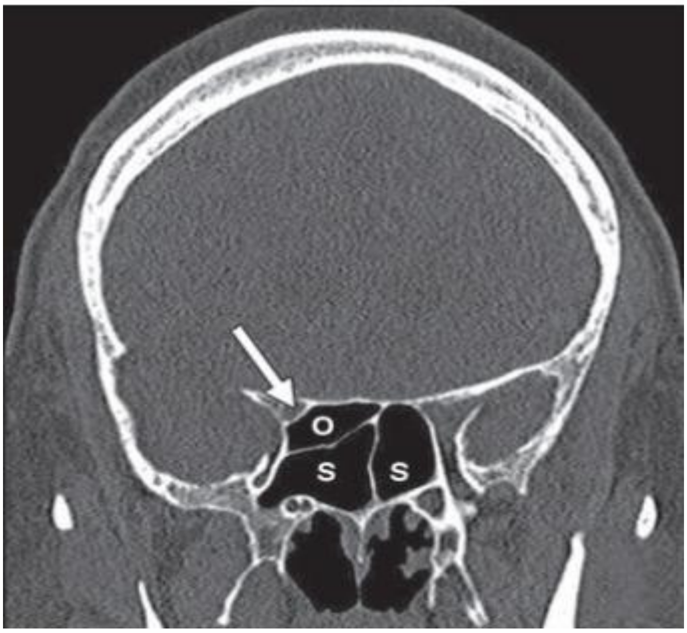

FIGURE 1_19. 22-year-old woman with chronic sinusitis. Coronal unenhanced CT scan shows right-sided sphenoethmoidal (Onodi) cell (O) in upper lateral sphenoid sinus (S). Projection of optic nerve canal into sphenoethmoidal (Onodi) cell (arrow) is evident. **(Shpilberg et al., 2015)**

4. Nasal septal deviation is defined as any bending of the septal contour on coronal CT scans and is present in more than one half of the population.

5. Concha bullosa is commonly defined as pneumatization of the middle turbinate involving its inferior bulbous portion and is usually bilateral. **(Fadda et al., 2012)**

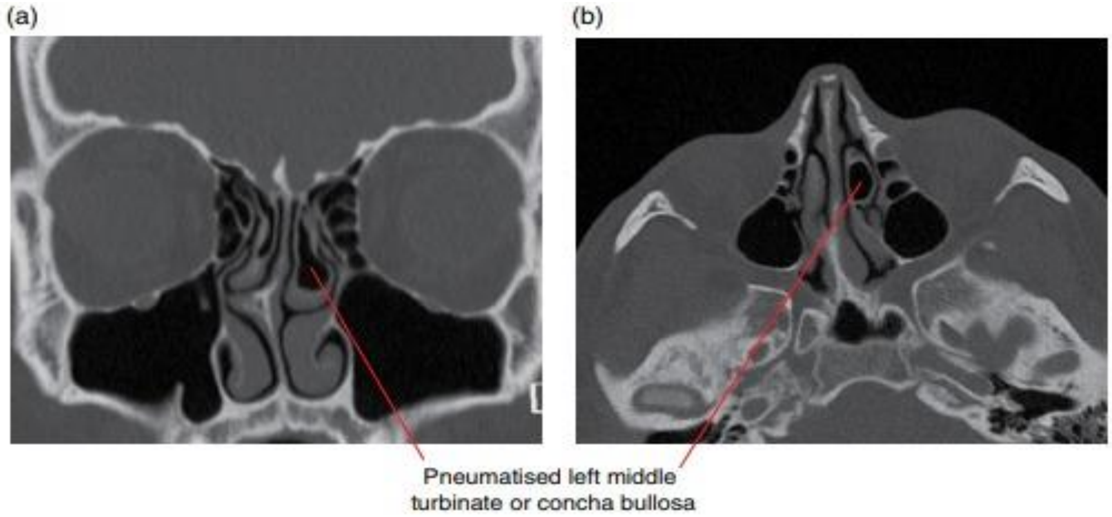

FIGURE 1_20. Concha bullosa (pneumatised middle turbinate): coronal (a) and axial (b) MDCT images. **(Koong, 2017)**

6. A paradoxically bent middle turbinate is defined as a turbinate having a scroll convexity in the lateral rather than the medial aspect. **(Fadda et al., 2012)**

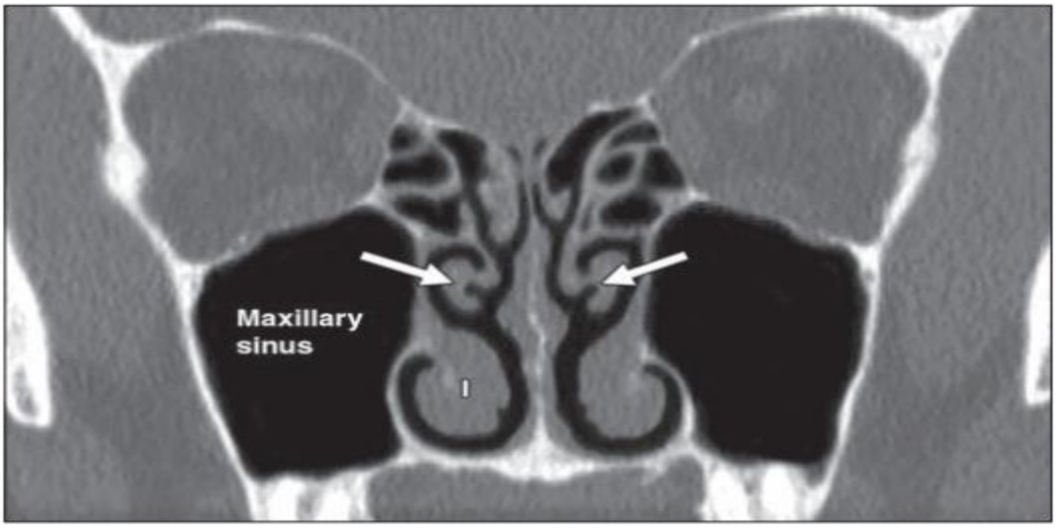

FIGURE 1_21. 49-year-old man with chronic sinusitis. Coronal unenhanced CT scan of sinuses shows bilateral paradoxically bent middle turbinates (arrows). I= inferior turbinate. **(Shpilberg et al., 2015)**

Other anatomic variants of the paranasal sinuses include pneumatization of the uncinate process (or an uncinate bulla large ethmoidal bullae, supraorbital cells and pneumatized crista galli) but they are less common. **(Comer et al., 2013)**

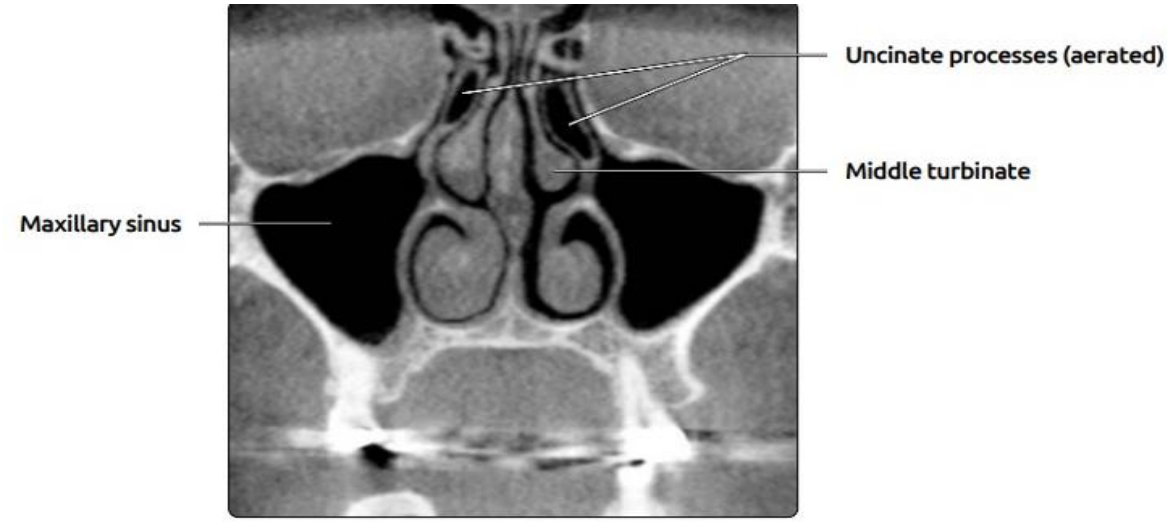

FIGURE 1_22. Coronal CBCT shows pneumatization of the uncinate processes of the ethmoid bones. This variation could also potentially obstruct maxillary sinus drainage. There is no sinus disease evident in this patien. **(Koenig et al., 2017)**

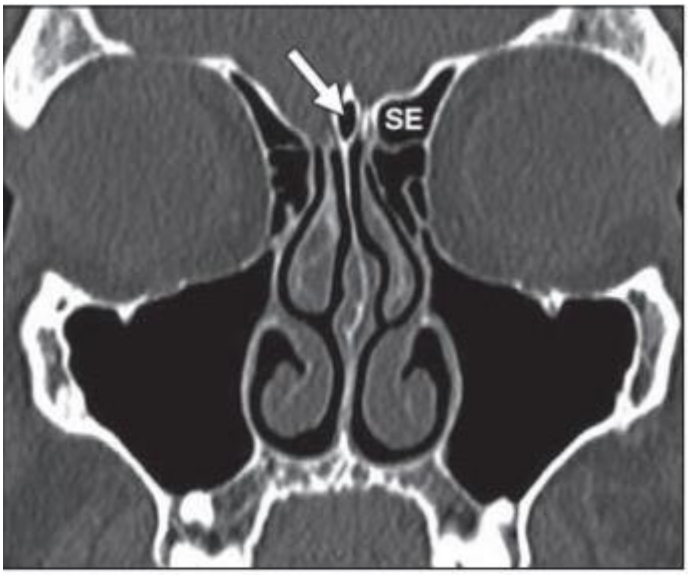

FIGURE 1_23. Coronal unenhanced CT of 50-year-old woman with chronic sinusitis shows pneumatization of crista galli (arrow), which occurs as diverticulum of frontal sinus. Left supraorbital ethmoidal cell pneumatizing roof of orbit (SE) also is evident. **(Shpilberg et al., 2015)**

1.5 Imaging of the Paranasal Sinuses

Of primary concern to the radiologist the paranasal sinuses and nasal fossae is identification of any osseous changes or variations, noting the presence of abnormal soft tissue disease and its possible extension beyond the sinonasal cavities, and the characterization of this disease. Available imaging techniques include computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography/computed tomography (PET/CT). Each of these modalities offers certain advantages, and each has disadvantages when compared with the other techniques. **(Fatterpekar et al., 2008)**

Notably, plain films are no longer considered to be apart of the primary imaging armamentarium. At best , they give only an overview of the anatomy and underlying pathology, as they are limited to displaying three-dimensional structures in a two-dimensional plane. CT and MRI imaging have the advantage of being able to show fine anatomic detail in serial tomographic sections , and thus eliminating the gross volume averaging inherent in plain films . In fact, in most cases, after a plain film study shows that disease is probably present, a CT or MR imaging study is then routinely obtained. **(Som, 2003)**

1.5.1 Computed tomography(CT Scan)

Traditionally CT imaging of the sinus has been acquired in the axial and coronal planes, using non contrast high-resolution 3-mm thick contiguous scans. Axial Images are obtained with the patient supine on the scanning table and maintaining neutral position of the scanning gantry. This differs from the coronal scans, which are enabled by extension of the patient's neck in either prone or supine position and angling of the scanning gantry to approximate the sinus coronal plane, PET/CT is used for staging and restaging of head and neck tumors. **(White & Pharoah, 2014)**

An Increasing number of institutions have abandoned the separate coronal acquisition, because the very thin overlapping sections obtained on newer multi-detector scanners can be reformatted to nearly the same quality as native coronal acquisition. The coronal imaging plane offers best visualization of the drainage pathways of the sinuses, whereas some drainage pathways (such as sphenoid sinus ostia) and sinus walls oriented close to the coronal plane are better seen on axial images. The initial scanning data are typically reconstructed with two different imaging algorithms (as shown in Figs.1-24 and 1-25). The bone, or edge, algorithm enhances the interface between tissues of substantially differing densities, so that osseous margins and intact bone are easily distinguished from demineralized or eroded bone. **(Som, 2003)**

However, this bone algorithm causes artifactual noise in structures of similar density, such as mucosal thickening of the sinus margin. Therefore, soft-tissue algorithm images are also generated to eliminate this artifactual noise in homogeneous structures and allow better visualization of soft-tissue structures and abnormalities. Because evaluation of both bone and soft tissue is crucial in the assessment of sinuses, both algorithms are scrutinized for evidence of pathology. **(Fatterpekar et al., 2008)**

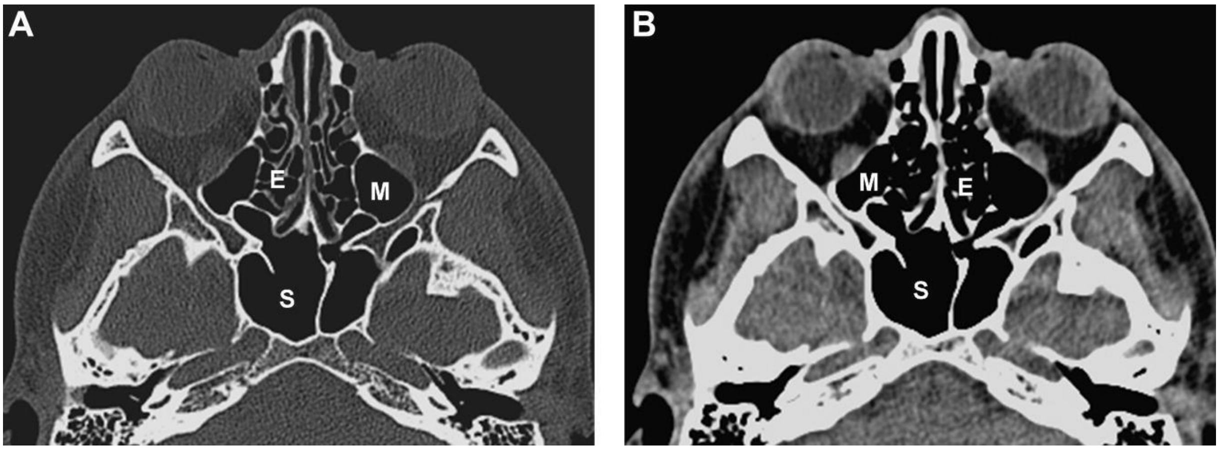

FIGURE 1-24. CT scans of the paranasal sinuses at the level of the ethmoid sinuses, (A) bone algorithm Axial and (B) soft-tissue algorithm images demonstrating the importance of visualizing paranasal scans using the two different window image processing techniques**. (Fatterpekar et al., 2008)**

The bone algorithm windowing helps to better evaluate the bony structures such as the walls of the sinuses as well as cartilage bounded by nasal or sinus lumen. The soft-tissue algorithm and windowing help to better evaluate the adjacent soft-tissue structures. Also, note that the posterior walls of the paranasal sinuses, which are oriented at or near the coronal plane, can be better assessed on the axial scans than in the coronal images. **(Fatterpekar et al., 2008)**

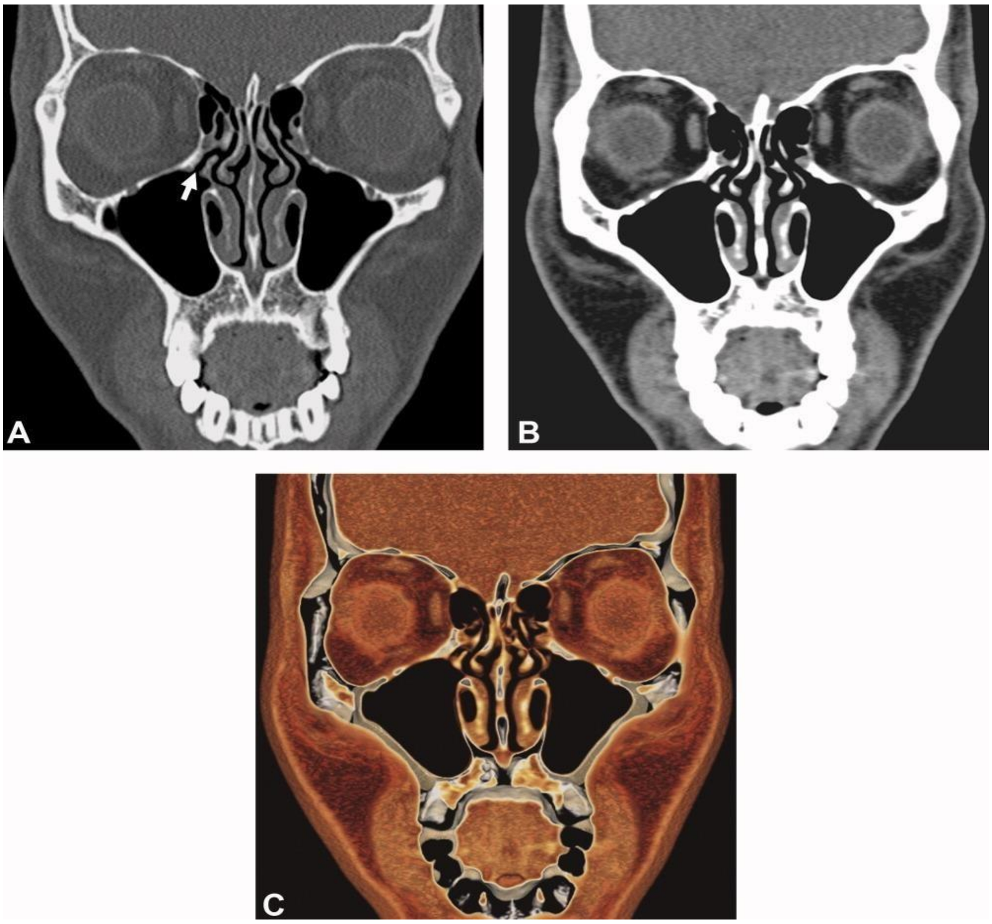

FIGURE 1-25. Coronal CT scans of the paranasal sinuses at the level of the alveolar process of the maxilla, (**A**) bone algorithm, (**B**) soft-tissue algorithm, and (**C**) 3D constructions demonstrating the importance of visualizing scans in the coronal plane. Certain structures, including important drainage pathways such as the osteomeatal units (arrow), are best demonstrated in the coronal plane. **(Fatterpekar et al., 2008)**

1.5.2 Magnetic resonance imaging (MRI)

Although CT is ideal for assessing the osseous margins of the paranasal sinuses, the inherently superior soft-tissue resolution and multi-planar capabilities render MRI superior for assessment of soft-tissue masses and extension of infectious/malignant disease processes beyond the paranasal sinuses. MR imaging of the paranasal sinuses must include high-resolution (3 mm) T1-weighted and T2-weighted images, not only of the sinonasal cavity but also of the orbit, skull base, and the adjacent intracranial compartment Images should be acquired in both the axial and coronal planes, although sagittal or arbitrary oblique planes can be added as necessary. In addition, contrast-enhanced T1-weighted images are routinely obtained as shown in (as shown in Fig1-26). **(Fatterpekar et al., 2008)**

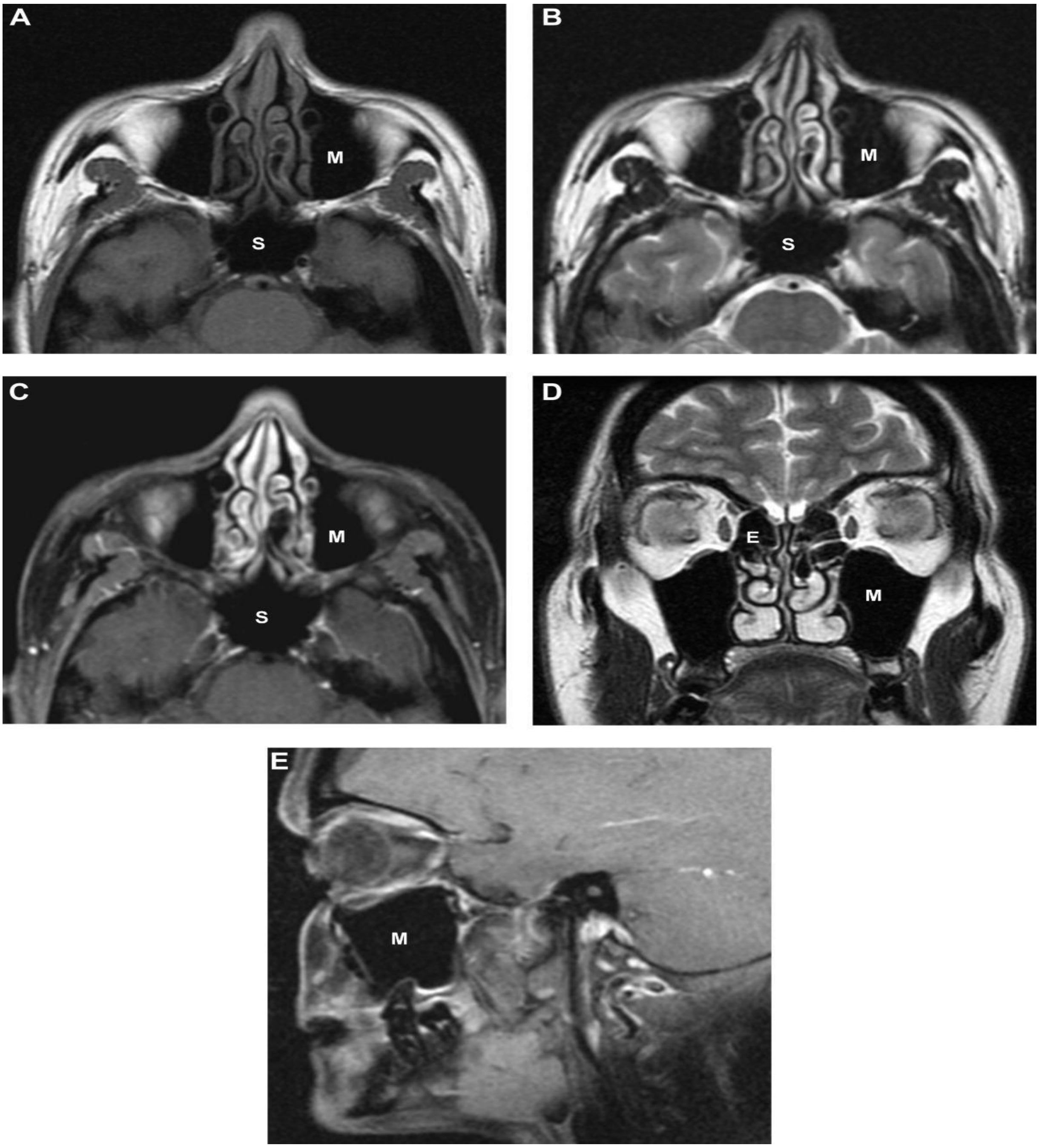

FIGURE 1-26 Normal MRI study of the paranasal sinuses. Axial and coronal scans are routinely obtained before and after intravenous gadolinium chelate administration. Demonstrated here are (A) axial T1W, (B) axial T2W, (C) axial fat-suppressed contrast-enhanced T1W, and (D) coronal T2W scans. Additionally, (E) sagittal fat-suppressed contrast-enhanced T1W scans may also be obtained. Note that on post contrast images, the mucosa enhances physiologically and should not be interpreted as abnormal**. (Fatterpekar et al., 2008)**

1.6 Diseases Assiciated With The Paranasal Sinuses

The maxillary sinuses are of greatest concern to the dentist because of their proximities to the teeth and supporting structures.

A. DEFINITION

Diseases associated with the maxillary sinuses include diseases that originate primarily from tissues within the sinus (intrinsic diseases) and diseases that originate outside the sinus (most commonly diseases arising from odontogenic tissues) that either impinge on or infiltrate the sinus (extrinsic diseases). These types of diseases include inflammatory odontogenic disease, odontogenic cysts, benign and malignant odontogenic .neoplasms, bone dysplasias, and trauma. **(White & Pharoah, 2014)**

B. General clinical features:

The clinical signs and symptoms of maxillary sinus disease include a sensation of pressure, altered voice characteristics, pain on head movement, percussion sensitivity of the teeth, regional dysesthesia, paresthesia or anesthesia, and swelling and tenderness of the facial structures adjacent to the maxilla.

1.6.1 Intrinsic Diseases of the Paranasal Sinuses :

The following are abnormalities that originate from tissues within the sinuses. **(White & Pharoah, 2014)**

Inflammation may result from a variety of causes such as infection, chemical irritation, allergy, introduction of a foreign body, or facial trauma. The radiographic changes associated with inflammation include thickened sinus mucosa, air-fluid levels in the sinuses, polyps, empyema, and retention pseudocysts. Viral infections may, however, not cause any radiographic change in a sinus. **(Nurbakhsh et al., 2011)**

1.6.1.1 Mucositis

A. synonym

Thickened sinus mucosa

B. Definition

The mucosal lining of the paranasal sinuses is composed of respiratory epithelium and is normally about 1 mm thick. Normal sinus mucosa is not visualized on radiographs; however, when the mucosa becomes inflamed from either an infectious or allergic process, it may increase in thickness 10 to 15 times, which may be seen radiographically. This inflammatory change is referred to as mucositis. **(Dolan et al., 1983)**

C. Clinical Features

The thickness of sinus mucosa in an asymptomatic individual may vary considerably over a relatively short period of time. Consequently, the discovery of thickened mucosa in an individual who is otherwise asymptomatic does not necessarily imply that further investigations are warranted or that treatment is required. Most of the inflammatory episodes that result in thickening of the mucosal lining of the sinuses are unrecognized by the patient and are discovered only incidentally on a radiograph.

D. Radiographic Features

The image of thickened mucosa is readily detectable in the radiograph as a non corticated band noticeably more radiopaque than the air- filled sinus, paralleling the bony wall of the sinus as shown in (as shown in Fig. 1-27). **(White & Pharoah, 2014)**

FIGURE 1-27. Thickened sinus mucosa (arrows) is portrayed as a radiopaque band paralleling the contour of the maxillary antral floor. **(White & Pharoah, 2014)**

1.6.1.2 Sinusitis

A. Disease Mechanism

Sinusitis is a generalized inflammatory condition of the sinus mucosa caused by an allergen, bacteria, or a virus. Inflammatory changes may lead to ciliary dysfunction and retention of sinus secretions and sometimes blockage of the ostiomeatal complex.

The term pansinusitis describes sinusitis affecting all the paranasal sinuses. In children with pansinusitis, the possibility of cystic fibrosis should be considered. Sinusitis is often categorized as acute or chronic based on the length of time that the disease is present. If the disease is present for 4 weeks or less, it is termed acute sinusitis; If it is present for more than 12 consecutive weeks, it is considered chronic. For sinusitis lasting from more than 4 weeks up to 12 weeks, the term subacute may be used. **(Druce, 1996)**

B. Clinical Features

Acute sinusitis signs and symptoms often include:

- Thick, yellow or greenish mucus from the nose (runny nose) or down the back of the throat (postnasal drainage).

- Blocked or stuffy nose (congestion) causing difficulty breathing through your nose.

- Pain, tenderness, swelling and pressure around your eyes, cheeks, nose or forehead that worsens when bending over.

The pain may also be referred to the premolar and molar teeth on the affected side and these teeth may develop sensitivity to percussion. Chronic maxillary sinusitis is a sequela of an acute infection that fails to resolve by 3 months. Generally, no external signs occur except during periods of acute exacerbations when increased pain and discomfort are apparent. Chronic sinusitis may develop with anatomic derangements, including deviation of the nasal septum and the presence of concha bullosa (pneumatization of the middle concha) that inhibit the outflow of mucus, or with allergic rhinitis, asthma, cystic fibrosis, and dental infections. **(Wyler et al., 2019)**

C. Imaging Features

Thickening of sinus mucosa and the accumulation of secretions that accompany sinusitis reduce the air space of the sinus and cause it to become increasingly radiopaque. The most common radiopaque patterns that occur in the Waters view are localized mucosal thickening along the sinus floor, generalized thickening of the mucosal lining around the entire wall of the sinus, and near-complete or complete radiopacification of the sinus as shown in (as shown in Fig1-28 and 1-29). **(White & Pharoah, 2014)**

FIGURE 1-28. Water's view demonstrating complete radiopacification of the left maxillary and frontal sinuses and ethmoid air cells. An air-fluid level is visible in the right maxillary sinus (arrows). **(White & Pharoah, 2014)**

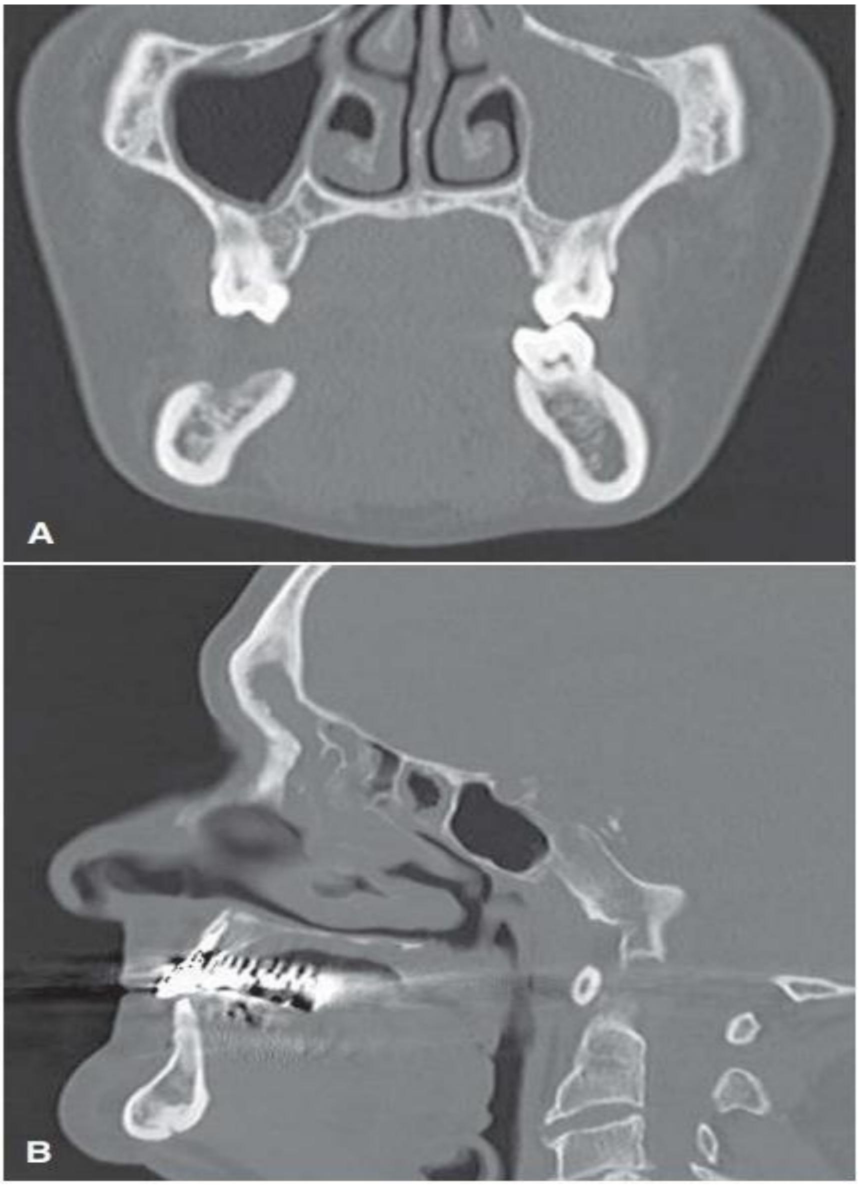

FIGURE 1-29. A, Coronal view of the maxillary sinuses showing complete radiopacification of the left sinus and circumferential mucosal thickening of the right sinus. B,Sagittal MDCT image of mucositis of the ethmoid air cells. **(White & Pharoah, 2014)**

Such changes are best seen in the maxillary sinuses, but the frontal and sphenoid sinuses may be similarly affected. Scrutinizing the area around the maxillary ostium on plain images or CT images may reveal the presence of thickened mucosal tissue, which may cause blockage of the ostium. Mucosal thickening in just the base of the sinus may not represent sinusitis. Rather, it may represent the more localized thickening or mucositis that can occur in association with rarefying osteitis from a tooth with a non vital pulp. However, this condition may progress to involve the entire sinus.

The image of thickened sinus mucosa may be uniform or polypoid. In the case of an allergic reaction, the mucosa tends to be more lobulated. In contrast, in cases of infection, the thickened mucosal outline tends to be smoother, with its contour following that of the sinus wall. The inability to perceive the delicate walls of the ethmoid air cells is a particularly sensitive sign of ethmoid sinusitis **(Druce, 1996)**. An air-fluid level resulting from the accumulation of secretions also may be present. Because the radiopacities of transudates, exudates, blood, and pathologically altered mucosa are similar, the differentiation among them relies on their shape and distribution. When present, fluid appears radiopaque and occupies the inferior or so-called dependent aspect of the sinus. The border between the radiopaque fluid and the relatively radiolucent air in the antrum is horizontal and straight, and a meniscus may be seen at the periphery where the fluid meets a sinus wall. Chronic sinusitis may result in persistent radiopacification of the sinus with sclerosis and thickening of the bony walls as the sinus periosteum is stimulated as shown in (as shown in Fig. 1-30). **(White & Pharoah, 2014)**

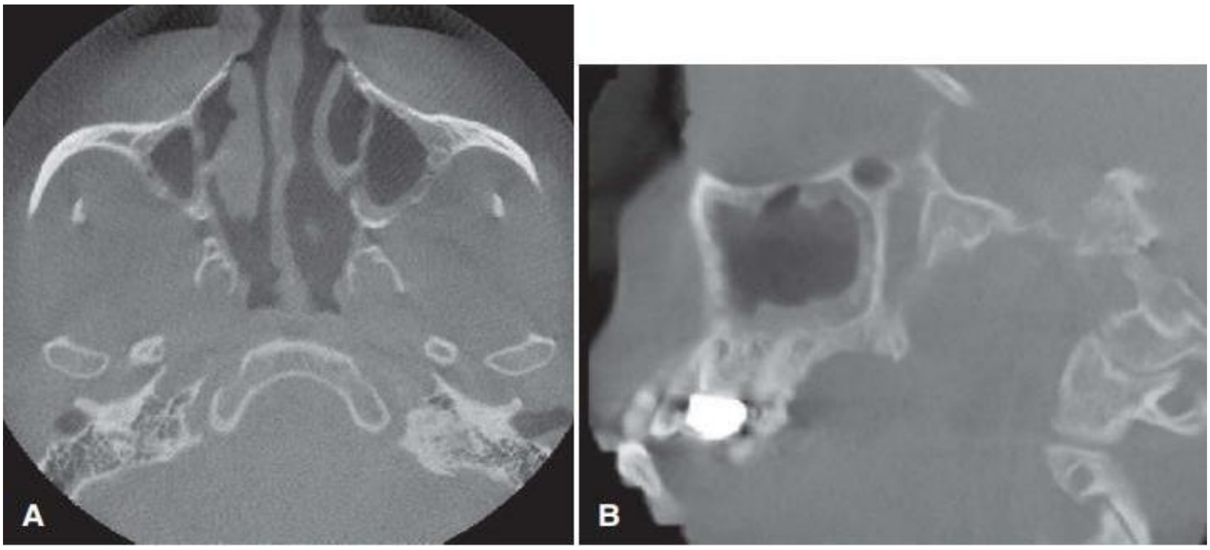

FIGURE 1-30. Axial (A) and sagittal (B) CBCT images show peripheral bony thickening of the left maxillary sinus from chronic sinusitis. **(White & Pharoah, 2014)**

The resolution of acute sinusitis becomes apparent on the image as a gradual increase in the radiolucency of the sinus. This can first be recognized when a small clear area appears in the interior of the sinus; the thickened mucous membrane gradually shrinks so that it begins to follow the outline of the bony wall. In time, the image of the mucous membrane is not visible, and the sinus appears normal. In chronic sinusitis, the changes to the sinus wall may persist. **(Fireman, 1998)**

1.6.1.3 Retention pseudocyst

Synonyms for retention pseudocyst include antral pseudocyst, benign mucous cyst, mucus retention cyst, mucus retention pseudocyst, mesothelial cyst, pseudocyst, interstitial cyst, lymphangiectatic cyst, false cyst, retention cyst of the maxillary sinus, benign cyst of the antrum, benign mucosal cyst of the sinus, serous nonsecretory retention pseudocyst, and mucosal antral cyst. **(Dolan & Smoker, 1983)**

A. Disease Mechanism

The term retention pseudocyst is used to describe several related conditions that result in the development of cyst like lesions that are not lined by epithelium. The pathogenesis of these lesions is controversial, but because their clinical and imaging features are similar, no attempt is made to distinguish between them. **(White & Pharoah, 2014)**

B. Location

Partial images of retention pseudocysts of the maxillary antrum may appear on maxillary posterior periapical images (as show in Fig. 1-30,A), but they are best demonstrated on extraoral images (as show in fig 1-30,B). One or more pseudocysts may occur within the same or different sinus cavities. These pseudocysts usually form on the floor of the sinus (as shown in Fig.1-30, D), although they may form on any wall or the roof (as shown in Fig.1-30,C). **(White & Pharoah, 2014)**

Retention pseudocysts may vary in size from that of a fingertip to completely filling the sinus and making it radiopaque. **(White & Pharoah, 2014)**

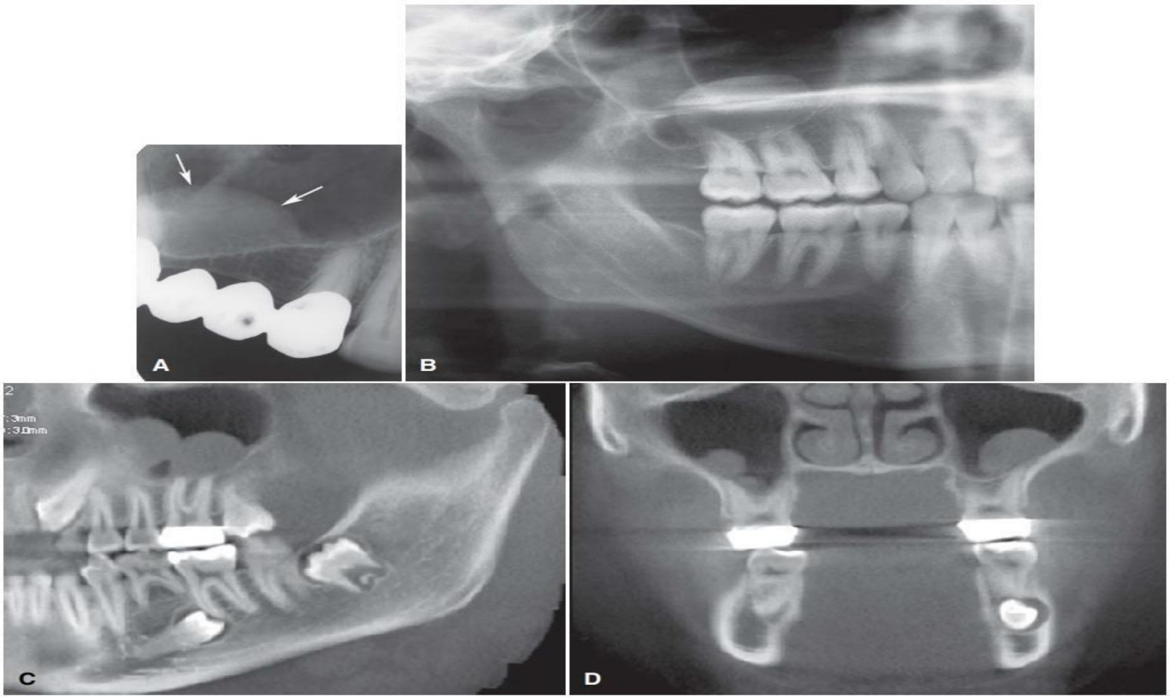

FIGURE 1-31. Noncorticated, dome-shaped retention pseudocyst (arrows) imaged on periapical (A), panoramic (B), reconstructed panoramic (C), and coronal (D) CBCT images. Retention pseudocysts have noncorticated borders, indicating that they arise from within the sinus.

C. Periphery and Shape

Retention pseudocysts usually appear as well-defined, noncorticated, smooth, dome-shaped, mostly sessile radiopaque masses. Because the lesion originates from within the sinus, it does not have a radiopaque, corticated border. **(White & Pharoah, 2014)**

D. Internal Structure

The internal aspect is homogeneous and more radiopaque than the surrounding air of the sinus cavity ,The radiopacity of the lesion is caused by the accumulation of fluid in the soft tissue lining of the sinus, which is relatively more radiopaque than air. Effects on Surrounding Structures: There are no effects on the surrounding structures The adjacent sinus floor is always intact. When a retention pseudocyst occurs adjacent to the root of a tooth, the lamina dura surrounding the root is intact, and the width of the periodontal ligament space is unaffected. **(Kaffe et al., 1988)**

1.6.1.4 Polyps

A. Disease Mechanism

The thickened mucous membrane of a chronically inflamed sinus frequently forms into irregular folds called polyps. Polyposis of the sinus mucosa may develop in an isolated area or in many areas throughout the sinus.

B. Clinical Features

Polyps may cause displacement or destruction of bone. In the ethmoid air cells, polyps may cause destruction of the medial wall of the orbit (lamina papyracea of the ethmoid bone) and an ipsilateral proptosis.

C. Imaging Features

1-extensive mucosal polyps occupying and obliterating the nasal cavity and the paranasal sinuses.
2- usually, they are hypodense, but may be hyperdense due increased protein content or fungal infection.
3- enlargement of infundibula.
4- attenuation of the ethmoid sinus walls and nasal septum.
5- occasionally sparing of the inferior nasal meatus.
6-truncation of middle turbinate 4**. (Drutman et al., 1992)**

1.6.1.5 Antrolith

A. Disease Mechanism

Antroliths occur within the maxillary sinuses and are the result of deposition of mineral salts, such as calcium phosphate, calcium carbonate, and intrinsic such as masses of stagnant or in spissated mucus or cellular debris in sites of previous inflammation.

B. Clinical Features

Smaller antroliths are usually asymptomatic and discovered as incidental findings on imaging examination. If they continue to grow, the patient may have associated sinusitis, blood stained nasal discharge, nasal obstruction, or facial pain. **(White & Pharoah, 2014)**

C. Imaging Features:

1. Location: Antroliths occur within the maxillary sinus and are positioned above the floor of the maxillary antrum in either periapical or panoramic images (as shown in Fig.1-31). **(White & Pharoah, 2014)**

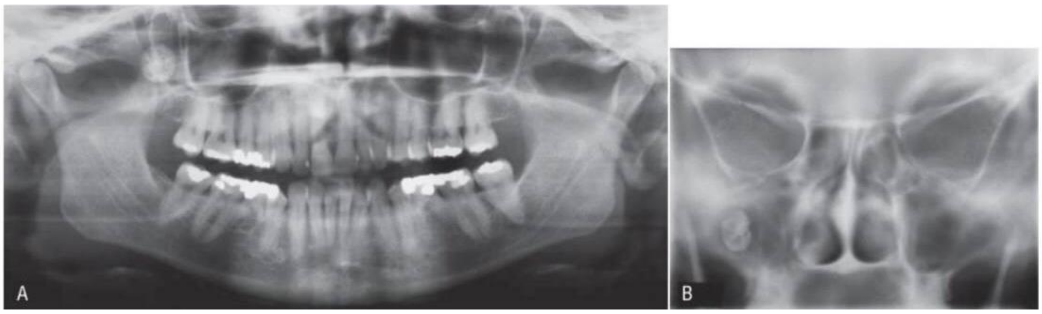

FIGURE 1-32. the alternating circular radiopaque and radiolucent pattern of an antrolith is seen on a panoramic image (A)superimposed over the posterior wall of the right maxillary sinus (B) confirm the location of the antrolith within the sinus and further more show the antrolith attached to the adjacent sinus wall. **(White & Pharoah, 2014)**

2. Periphery and Shape: Antroliths have a well-defined periphery and may have a smooth or irregular shape.

3. Internal Structure: The internal aspect may vary from a barely perceptible radiopacity to an extremely radiopaque structure. The internal radiopacity may be homogeneous or heterogeneous. In some instances, alternating layers of radiolucency and radiopacity in the form of laminations may be seen. **(Dolan & Smoker, 1983)**

D. Differential Diagnosis

Antroliths may be distinguished from root fragments in the sinus by inspection of the mass for the usual root anatomy such as the presence of a root canal. A displaced root fragment in the sinus may move when imaging is performed with the head in different positions, unless it is lodged between the bone and the sinus lining. Rhinoliths are similar calcifications but are found within the nasal fossae. Posteroanterior and lateral skull views or advanced imaging can help identify the location of a rhinolith**. (White & Pharoah, 2014)**

E. Management:

An otolaryngologist may need to remove symptomatic antroliths. **(Dolan & Smoker, 1983)**

1.6.1.6 Mucocele

A. Synonyms

Empyema, pyocele, and mucopyocele are synonyms for mucocele.

B. Disease Mechanism

A mucocele is an expanding, destructive lesion that results from a blocked sinus ostium. The blockage may result from intra antral or intranasal inflammation, polyp, or neoplasm. The entire sinus becomes the pathologic cavity. As mucus secretions accumulate and the sinus cavity fills, the increase in pressure within the cavity results in thinning, displacement, and destruction of the sinus walls in some cases. When the cavity is filled with pus, it is termed an empyema, pyocele, or mucopyocele. **(Atherino, 1984)**

C. Clinical Features

A mucocele in the maxillary sinus may exert pressure on the superior alveolar nerves and cause radiating pain. The patient may first complain of a sensation of fullness in the cheek, and the area may swell. This swelling may first become apparent over the anteroinferior aspect of the antrum , the area where the wall is thin or destroyed. If the lesion expands inferiorly, it may cause loosening of the posterior teeth in the area. If the medial wall of the sinus is expanded, the lateral wall of the nasal cavity deforms, and the nasal airway may become obstructed. If the lesion expands into the orbit, it may cause diplopia (double vision) or proptosis (protrusion of the globe of the eye). **(White & Pharoah, 2014)**

D. Imaging Features

1. Location: About 90% of mucoceles occur in the ethmoid air cells and frontal sinuses and rarely in the maxillary and sphenoid sinuse

2. Periphery and Shape: The normal shape of the sinus is changed into a more circular, “hydraulic” shape as the mucocele enlarges.

3. Internal Structure: The internal aspect of the sinus cavity is uniformly radiopaque (as shown in Fig.1-32, A).

4. Effects on Surrounding Structures: The shape of the sinus changes as its margins are displaced outward and the bone expands. Septa and the bony walls may be severely thinned. When the mucocele is associated with the maxillary antrum, teeth may be displaced or roots resorbed. In the frontal sinus, the usually scalloped border is smoothed by expansion, and any septum may be displaced (as shown in Fig. 1-32, B). **(Atherino, 1984)**

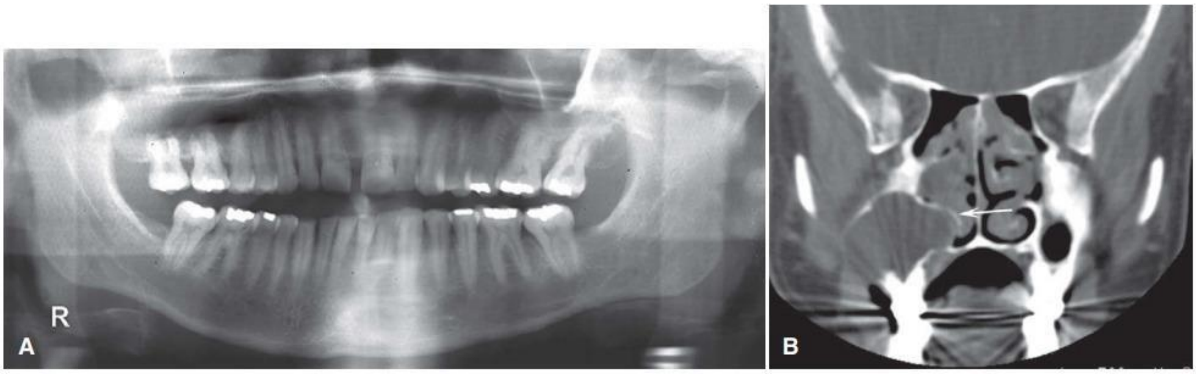

FIGURE 1-33. A mucocele has caused the radiopacification of the right maxillary sinus. A, Note the lack of a distinct border to the sinus on the panoramic image. B, Coronal MDCT image through the mucocele shows expansion into the nasal fossa (arrow) and the infratemporal fossa. **(Atherino, 1984)**

E. Differential Diagnosis

Although it may be impossible to distinguish between a mucocele in the maxillary antrum and a cyst or neoplasm, any suggestion that the lesion is associated with an occluded ostium should strengthen the likelihood of a mucocele. Blockage of the ostium is usually the result of a previous surgical procedure, although a deviated nasal septum or polyps may be a factor. A large odontogenic cyst displacing the maxillary antral floor may mimic a mucocele. One should look for any remnants of the internal aspect of the antrum between the wall of the cyst the wall of the antrum. MDCT or CBCT imaging is the imaging method of choice for making these distinctions. **(Baurmash, 2003)**

1.6.2 Extrinsic Diseases Involving The Paranasal Sinuses (Periostitis and Periosteal New Bone Formation)

A. Disease Mechanism

It is caused by inflammation of the periosteum, a layer of connective tissue that surrounds bone. The condition is generally chronic and needs to be differentiated from stress fracture or shin splints. It is marked by tenderness and swelling of the bone and an aching pain. **(Laskaris, 2000)**

FIGURE 1-34. halo-like appearance of bone surrounding the roots of a maxillary second molar is the result of periosteal new bone formation and displacement of the adjacent maxillary sinus floor (arrows). **(Laskaris, 2000)**

B. Imaging Features

Although the periosteal tissue is not visible on the image per se, this process is referred to as periosteal new bone formation. This new bone may take the form of one or more thin radiopaque lines, or the line may be thick. This new bone should be centered directly above the inflammatory lesion**. (White & Pharoah, 2014)**

1.6.3 NEOPLASMS

Benign neoplasms of the paranasal sinuses other than inflammatory polyps are rare. The imaging features of such benign neoplasms are nonspecific. Usually the involved portion of the sinus cavity appears radiopaque because of the presence of a mass, and there may be displacement of adjacent sinus borders. The most common malignant neoplasms of the paranasal sinuses are squamous cell carcinomas and, to a lesser extent, malignant salivary gland neoplasms. Of carcinomas of the paranasal sinuses, 74% originate in the maxillary sinus. Although radiopacification is a feature of both inflammatory conditions and neoplasms, bone destruction is more common with malignant neoplasms. **(Goepfert et al., 1983)**

1.6.3.1 Benign Neoplasms Of The Paranasal Sinuses

Benign sinonasal tumors are relatively uncommon, the most common being inverted papilloma, hemangioma and osteoma. The treatment for most patients with benign tumors of the nose and sinus is complete excision. **(Drutman et al., 1992)**

1.6.3.1.1 Papilloma

Inverted papilloma (Schneiderian papilloma) is a primarily benign lesion that occurs in the nasal cavity and paranasal sinuses. Clinical problems include a tendency towards local destruction, recurrence and malignant transformation into squamous cell carcinoma**. (Goepfert et al., 1983)**

A. Disease Mechanism:

Epithelial papilloma is a rare neoplasm of respiratory epithelium that occurs in the nasal cavity and paranasal sinuses. It occurs predominantly in men.

B. Clinical Features

Unilateral nasal obstruction, nasal discharge, pain, and epistaxis may occur. The patient may have complained of recurring sinusitis for years and a subsequent nasal obstruction on the same side as the sinusitis. The epithelial papilloma, although benign, has 10% incidence of associated carcinoma. **(Goodnight et al., 1993)**

C. Imaging Features

Imaging features are nonspecific, and the diagnosis can be made only by histopathologic examination of the tissue.

1. Location: The epithelial papilloma is usually in the ethmoidal or maxillary sinus. It may also appear as an isolated polyp in the nose or sinus.
2. Internal Structure: This neoplasm appears as a homogeneous radiopaque mass of soft tissue density.
3. Effects on Surrounding Structures: If bone destruction is apparent, it is the result of pressure erosion**. (Dolan & Smoker, 1983)**

1.6.3.1.2.Osteoma

The osteoma is the most common mesenchymal neoplasm in the paranasal sinuses. **(Goodnight et al., 1993)**

A. Clinical Features

Osteomas are almost twice as common in males compared with females and are most common in the second, third, and fourth decades. Most are usually slow growing and asymptomatic and are usually detected as an incidental finding in an examination performed for another purpose. When symptoms do occur, they are the result of obstruction of the sinus ostium or infundibulum or are the result of erosion or deformity, orbital involvement, or intracranial extension. Osteomas growing in the maxillary sinus may extend into the nose and cause nasal obstruction or a swelling of the side of the nose. They may expand the sinus and produce swelling of the cheek or hard palate. In cases extending to the orbit, the patient may have proptosis. In some cases, external fistulas have developed. Osteomas of the maxillary sinus have been described after Caldwell-Luc operations. **(Dolan & Smoker, 1983)**

B. Imaging Features:

1. Location: Although osteomas occasionally develop in the maxillary sinus, they more often occur in the frontal and ethmoidal sinuses. The incidence in the maxillary antrum ranges from 3.9% to 28.5% of the incidence in all paranasal sinuses. **(Goodnight et al., 1993)**

2. Periphery and Shape: An osteoma is usually lobulated or rounded and has a sharply defined margin (as shown in Fig. 1-34). **(White & Pharoah, 2014)**

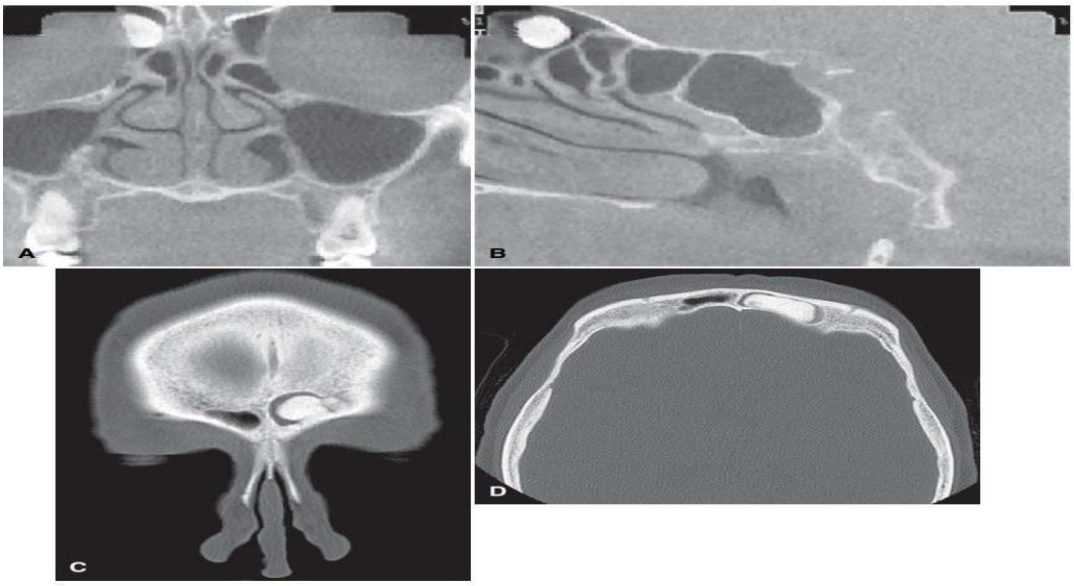

FIGURE 1-35. Coronal (A) and sagittal (B) CBCT images show an osteoma attached to the lateral wall of an anterior ethmoid air cell. Coronal (C) and axial (D) CT images of an osteoma in the frontal sinus**. (White & Pharoah, 2014)**

3. Internal Structure: The internal aspect is homogeneous and extremely radiopaque. **(White & Pharoah, 2014)**

1.6.3.2 Malignant Neoplasms Of The Paranasal Sinuses

Malignant neoplasms of the paranasal sinuses are exceptionally rare, accounting for less than 1% of all malignancies in the body. Squamous cell carcinoma accounts for 80% to 90% of the cancers in this site and is the most common primary malignant neoplasm of the paranasal sinuses. Other primary neoplasms include adenocarcinoma, carcinomas of salivary gland origin, soft and hard tissue sarcomas, melanoma, and malignant lymphoma. Factors that contribute to a poor prognosis for cancer of the paranasal sinuses include the advanced stage of the disease when it is finally diagnosed and the close proximity of vital anatomic structures. The clinical signs and symptoms may masquerade as an inflammatory sinusitis. The early primary lesions may appear only as a soft tissue mass in the sinus before they cause bone destruction. The lesion may become extensive, involving the entire sinus, with evidence of bone destruction before symptoms become apparent. Therefore, any unexplained radiopacity in the maxillary sinus of an individual older than 40 years should be investigated thoroughly. **(Pierre & Baker, 1983)**

1.6.3.2.1 Squamous Cell Carcinoma

Squamous cell carcinoma likely originates from metaplastic epithelium of the sinus mucosal lining. **(Hasso, 1984)**

A. Clinical feature

The most common symptoms of cancer in the maxillary sinus are facial swelling, epistaxis, dysesthesia, paresthesia, nasal obstruction, and the presence of a lesion in the oral cavity. The mean patient age is 60 years (range, 25 to 89 years).Twice as many men as women are affected. Lymph nodes are involved in about 10% of cases, and symptoms are present for about 5 months before diagnosis. **(Larheim et al., 1984)**

B. imaging Features

Sometimes the imaging findings, especially in early malignant disease of the paranasal sinuses, are nonspecific. It may be impossible to differentiate the early manifestations in images of the maxillary sinus from the radiopacity of the sinus that develops in sinusitis and polyp formation. Evidence relies on changes seen in the surrounding bone, the sinus walls, and the maxillary alveolar process. **(Hasso, 1984)**

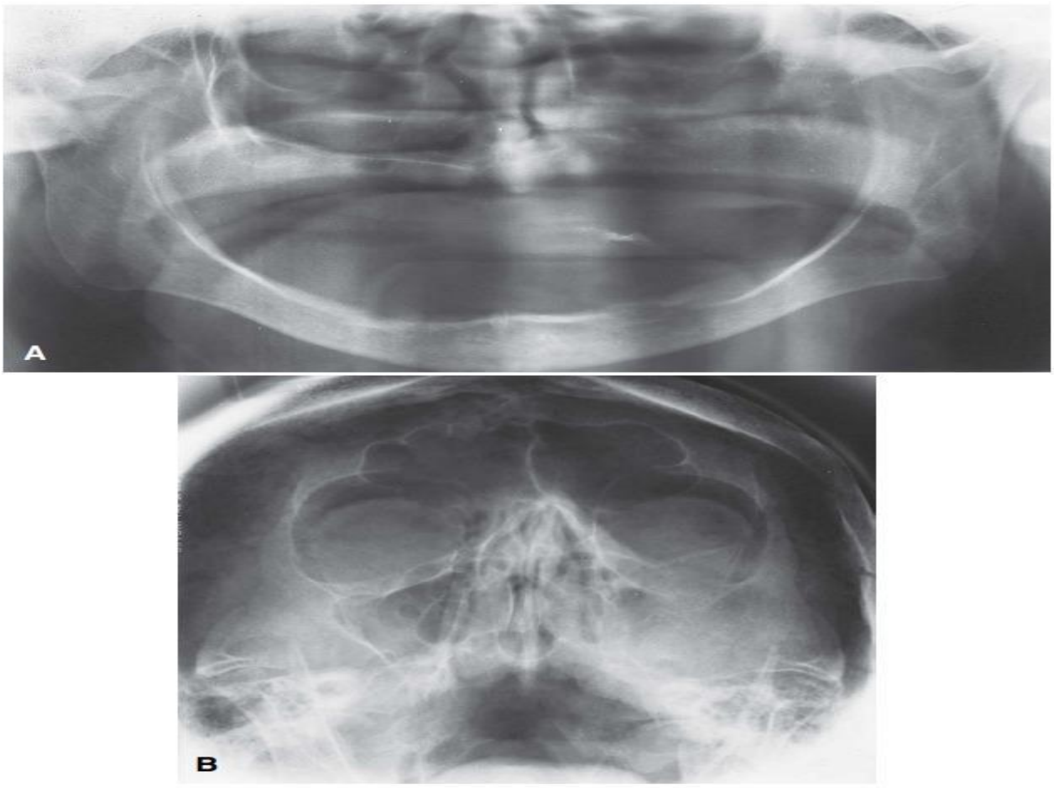

FIGURE 1-36. A, Panoramic image of a squamous cell carcinoma shows loss of definition of the cortex of the left maxillary sinus, nasal floor, and alveolar crest. B, Waters view of the same patient shows a similar loss of cortical integrity to the lateral wall of the left maxilla and radiopacification of the left maxillary sinus. **(White & Pharoah, 2014)**

1. Location; Most carcinomas occur in the maxillary sinuses, but involvement of the frontal and sphenoid sinuses is also comparatively common.
2. Internal Structure; The internal aspect of the maxillary sinus has a soft tissue radiopaque appearance. **(Larheim et al., 1984)**
3. Effects on Surrounding Structures; As the lesion enlarges, it may destroy sinus walls and in general cause irregular radiolucent areas in the surrounding bone. A detailed examination of the adjacent alveolar process may reveal bone destruction around the teeth or irregular widening of the periodontal ligament space. Frequently, the medial wall of the maxillary sinus is thinned or destroyed, although there may also be destruction of the floor and anterior or posterior walls that may be detected in the panoramic film. The medial wall of the maxillary sinus is best seen on the Caldwell and Waters projections. In addition to loss of the medial wall, it may extend into the nasal cavity. **(Hasso, 1984)**

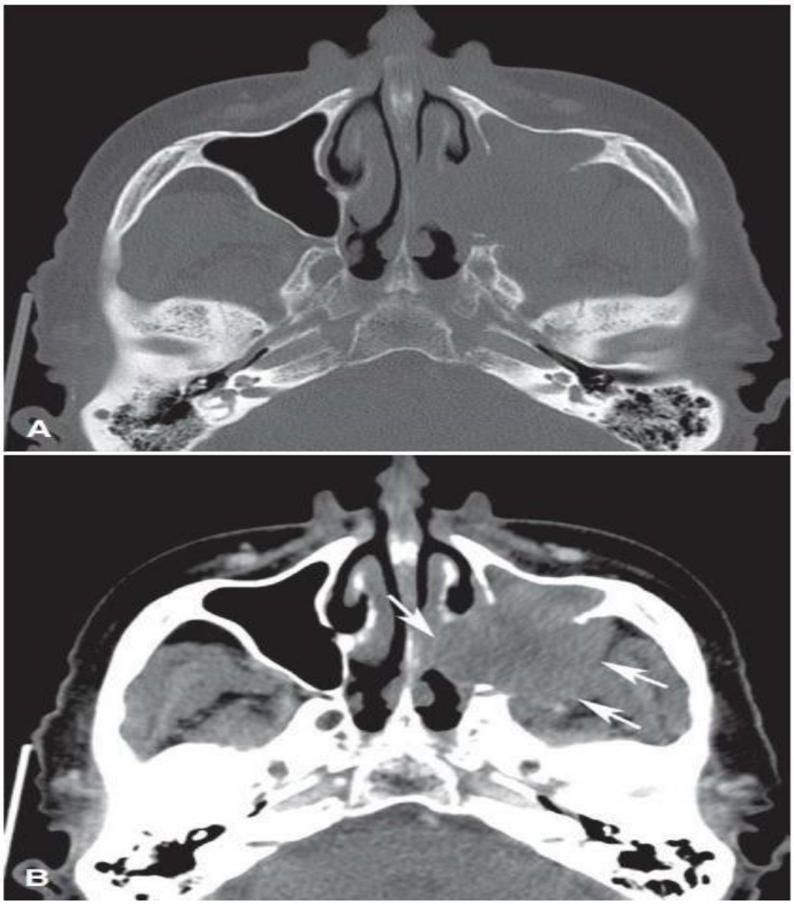

FIGURE 1-37. A, Axial bone algorithm CT image of a squamous cell carcinoma of the left maxillary sinus shows destruction of the postero-lateral wall and the medial wall of the sinus. B, Same axial image slice with soft tissue algorithm demonstrates extension of the malignant neoplasm into the surrounding soft tissues (arrows). **(White & Pharoah, 2014)**

1.6.3.2.2 Pseudotumor

A. Synonyms

Synonyms for pseudotumor include invasive fungal sinusitis, inflammatory pseudotumor, fibroinflammatory pseudotumor, plasma cell granuloma, sinonasal fungal disease, mucormycosis, aspergillosis, zygomycosis of the paranasal sinuses, and Rhizopus sinusitis**. (Butugan et al., 1996)**

B. Disease Mechanism:

Pseudotumor is a descriptive name for a group of apparently related diseases of fungal origin that occur in the paranasal sinuses and in other parts of the head and neck**. (Zapico et al., 1996)**

C. Clinical Features

Pseudotumor often occurs after a series of recurrent infections. The symptoms may not be very specific. There may be recurring pain and a mass simulating a neoplasm. The latter may cause erosion of the walls of the involved sinus and proptosis if the orbit is involved. Altered nerve function Resulting from involvement of the nerve or occlusion of blood vessels by the mass has also been reported. Although cases have been reported in otherwise healthy individuals, many cases appear in patients who are immunocompromised or who have systemic diseases, such as diabetes mellitus, von Willebrand's disease, or myelodysplasia. **(Zapico et al., 1996)**

D. Imaging Features

The imaging findings in pseudotumor include masses simulating malignant neoplasms that cause erosion of bony walls of the involved sinuses. **(Butugan et al., 1996)**

E. Differential Diagnosis

The differential diagnosis includes benign and malignant neoplasms. **(Zapico et al., 1996)**

1.6.4 Benign Odontogenic Cysts and Tumors

Cysts of the paranasal sinuses may be categorized as intrinsic, which originate in the mucosa of the paranasal sinuses, or extrinsic, which originate in the adjacent structures, such as the dental tissues.

1.6.4.1 Odontogenic cyst

The appearances and effects of benign odontogenic cysts and neoplasms on the maxillary sinuses may be similar. Odontogenic cysts are the most common group of extrinsic lesions that encroach on the maxillary sinuses. The most common are radicular cysts, followed by dentigerous cysts and odontogenic keratocysts ،As the odontogenic cyst grows, its border becomes indistinguishable from the sinus border. With continued growth, the cyst encroaches on the space of the sinus, displaces its borders, and the air-filled space decreases in volume (as shown in Fig. 1-36,A). **(Tkatch et al., 1993)**

A thin radiopaque line divides the contents of the cyst from the sinus cavity. This appearance is in contrast to a retention pseudocyst, which, being inside the sinus, does not have a cortex around its periphery**. (White & Pharoah, 2014)**

A. Radiographic features

1. Periphery and shape: The invaginating cyst has a curved or oval shape defined by a corticated border .

2. Internal Structure: The internal structure of the cyst is homogeneous and radiopaque relative to the air-filled sinus cavity. The degree of radiopacity may appear to be that of bone resulting from the extreme contrast to the radiolucent air within the sinus. **(Lee et al., 1996)**

3. Effects on Surrounding Structures: The cyst may displace the floor of the maxillary antrum. Large dentigerous or odontogenic keratocysts can displace third molars as far as the floor of the orbit. in some cases the cyst may enlarge to the point that it has encroached on almost the entire sinus, and the residual sinus space may appear as a thin crescent of air adjacent to the cyst (as shown in Fig.1-36, B). **(White & Pharoah, 2014)**

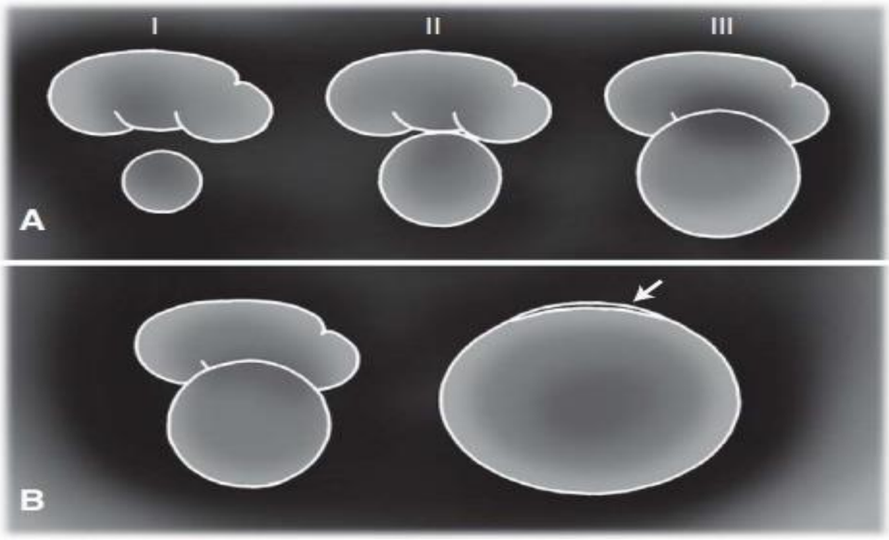

FIGURE 1-38. A, An odontogenic cyst or neoplasm develops adjacent to the floor of a sinus (I). As the lesion enlarges, it abuts the maxillary sinus floor (II) and ultimately displaces the floor superiorly as it enlarges (III). The border of the cyst and the border of the sinus are now the same line of bone. B, As it continues to enlarge, the lesion may encroach on almost all the space of the sinus, leaving a small saddle-like sinus over it (arrow). The appearance may mimic sinusitis. **(Tkatch et al., 1993)**

B. Differential Diagnosis

Odontogenic cysts must be differentiated from the relatively common retention pseudocyst. Although both lesions may have similar shapes, only odontogenic cysts have a cortex at the periphery (as shown in Fig. 1-37).

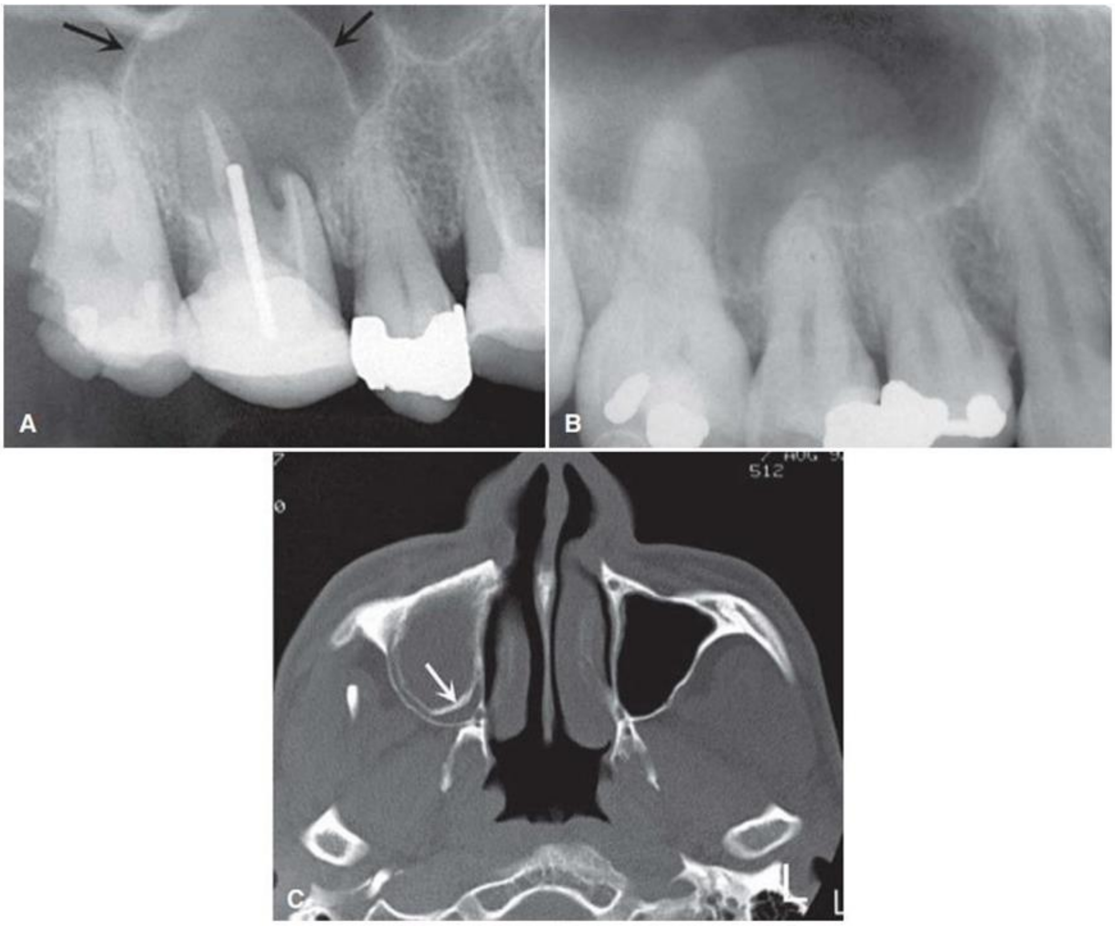

FIGURE 1-39. A, Periapical image of a small radicular cyst, note the peripheral cortex (arrows) compared with B, a periapical image of a pseudocyst, note the lack of a peripheral cortex. **(White & Pharoah, 2014)**

It is not usually possible to differentiate a dentigerous cyst from an odontogenic keratocyst that has a pericoronal relationship to the third molar. Very large cysts may completely efface the sinus cavity. When this occurs, no radiographic evidence may exist of the air space left, and it may appear as if the cyst is within the sinus. In this case, because of the radiopacity Of the cyst, the appearance may resemble sinusitis with radiopacification of the sinus. Evaluation of such conditions is aided by noting that the wall of the cyst is often thicker and more regular than that of a sinus. In addition, the normal vascular markings on the wall of the maxillary sinus are not present on the walls of a cyst. A cyst that occupies the entire sinus usually causes expansion of the medial wall (middle meatus) of the sinus and will alter the sigmoid contour of the posterolateral wall of the sinus as viewed in axial CT images. After the successful treatment of an odontogenic lesion in the maxilla, healing will ensue in the affected area. This may include “collapse” of the bony cavity and remodeling of the sinus floor. The end result is the appearance of an irregularly shaped bone formation along the floor of the sinus**. (Utaş et al., 1995)**

FIGURE 1-40. peripheral cortex (arrow) inside the outer cortex of the sinus **(White & Pharoah, 2014)**

1.6.4.2 Odontogenic Tumors

Generally, benign odontogenic tumors can cause facial deformity, nasal obstruction, and displacement or loosening of teeth. The nature of bony barriers in this region of the face, and the relatively good blood supply, are probably also responsible for efficient local spread. Some odontogenic tumors, particularly the ameloblastoma and the myxoma, show a more aggressive pattern of growth in the maxilla and have a close proximity to vital structures in the skull base. Therefore management of such tumors in the maxillae is often more aggressive than in cases involving the mandible. **(Tkatch et al., 1993)**

1. Features Periphery and Shape: The enlarging tumor may have a curved, oval, or multilocular shape that may be defined by a thin cortical border as it encroaches on the sinus. More aggressively growing tumors may even lack a portion of the border.

2. Internal Structure: The internal structure of the tumor may have coarse or fine septae or regions of dystrophic calcification, depending on the histopathologic nature of the tumor. **(Utaş et al., 1995)**

3. Effects on Surrounding Structures: The tumor may displace the floor of the maxillary antrum and cause thinning of the peripheral cortex. As with odontogenic cysts, in some cases the tumor may enlarge to the point where it has almost completely encroached on the sinus air space, and this residual space may appear as a thin saddle over the tumor. The bony walls of the sinus may be thinned or eroded, and adjacent structures may be displaced. A tooth or part of a tooth may be embedded in the neoplasm**. (Tkatch et al., 1993)**

FIGURE 1-41. Odontogenic tumor developing occlusal to the left second mandibular molar causing expansion of the mandibular body and ramus to the sigmoid notch and condylar neck and inferior displacement of the mandibular second molar and root resorption of the alveolar left first molar. **(White & Pharoah, 2014)**

Chapter Two: Conclusion

1. A great knowledge about the paranasal sinuses and their diseases for the dentist is of a prominent importance because of their great proximity between the paranasal sinuses (especially the maxillary sinus) with the teeth and oral cavity. so imaging of the paranasal sinuses and knowledge of their features is of a great importance to the dentist to facilitate diagnosis and management of the diseases using CT scan, MRI, CBCT depending on each case.

2. Evaluation of the paranasal sinuses requires detailed knowledge of the anatomy and common anatomic variants.

3. Imaging is also important in delineating complications of sinusitis, such as orbital or intracranial involvement. Finally, benign and aggressive sinonasal masses, distinction between inflammatory and malignant disease, postsurgical changes, and post-traumatic injuries can be readily recognized based on their characteristic patterns.

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