# PREVALENCE OF DEVIATED SEPTUM IN AN ORTHODONTIC POPULATION

by

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## DEDICATION

This thesis is dedicated to my parents, to whom I owe everything. Your faith and your commitment to each other and to our family is truly inspiring. Congratulations on 50 years of marriage this year. To my dad, who taught me early on that perseverance beats any circumstance. To my mom, whose tenacity, toughness and selflessness are second to none. To my brother and sister-in-law for their support and encouragement. And to my niece and nephew for always keeping me on my toes, yet making me feel like a superhero aunt.

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**PREVALENCE OF DEVIATED SEPTUM IN AN ORTHODONTIC POPULATION**

Abstract

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ANDREA KATELIN JENNINGS

**Introduction**: Our objective was to determine the prevalence of deviated septum in the population seeking orthodontic treatment. A second objective was to determine if there is a correlation between septum deviation and NOSE score.

**Methods**: The study was approved by the Institutional Review Board of Case Western Reserve University. The sample consisted of 146 patients seeking orthodontic care who completed the health history and the NOSE survey and had a CBCT taken between February 2020 and April 2023 at Case Western Reserve University School of Dental Medicine in the Orthodontic Department (CWRU). Septum deviation (in degrees) was measured on a coronal CBCT view using Crista Galli and Crista Nasalis as the vertical midline creating an angle with the point of greatest septum deviation. Deviation angle was categorized into mild (<9°), moderate (9-15°) and severe (>15° ). NOSE scores were based on a 5-point Likert scale with 5 questions regarding patient experience with nasal obstruction symptoms within the past month. NOSE scores were placed into mild (5-25), moderate (30-5-), severe (55-75) and extreme (80-100) categories.

**Results**: In this sample, mean septum deviation angle was 9.53 ± 3.7 (95% CI: 8.9-10.1). The prevalence of septum deviation was 44.6%, 49.3% and 6.2% for mild, moderate and severe nasal septum deviation angles respectively. The prevalence of moderate or greater septum deviation was 55.5%. Mean NOSE score was 8.01 ± 11.9 (95% CI: 6.1-

10.0). 50% of the population scored mild or above on the NOSE questionnaire. No significant correlation was found between septum deviation angle (SDA) and NOSE score (p = .321), SDA and age (p =.532) or NOSE score and age (p= .893).

**Conclusions**: The results indicate a 55% prevalence of moderate or greater septum deviation in our orthodontic population. There was no correlation between NOSE score and septum deviation angle, NOSE score and age or septum deviation angle and age.

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## INTRODUCTION

The importance of nasal breathing has been well documented, and its benefits are numerous, yet the nose if often an underrated organ. Per otolaryngologist Dr. Pat Barelli: “The role of the nose in health and in respiration has historically been greatly neglected by physicians.” (Timmons and Ley 1994). It could be argued that the dental profession also could improve its focus on the benefits of nasal breathing as well as signs and symptoms of mouth breathing since dental professionals often are the first providers to notice these signs.

The advantages of nasal breathing far outweigh oral breathing. While both provide the necessary oxygen we need to survive, breathing through the nose is far superior to breathing through the mouth. In addition to filtering, warming, and humidifying inhaled air, nasal breathing contributes to proper craniofacial development and mental health (Speth 2019). Additionally, nasal breathing has another advantage that mouth breathing does not; nitric oxide is an endogenous signaling molecule formed in the nasal passages. It promotes vasodilation, and it also plays a role in increasing our immune defense to pathogens, thereby giving nasal breathing an anti-microbial advantage to oral breathing (Lundburg 2008).

It is presumed that the nose is for breathing and the mouth is for eating, but when nasal obstruction is present, oral breathing becomes the default. There are many causes of nasal obstruction resulting in oral breathing. The sensation of congestion results from narrowing of the nasal cavity, which can be due to an anatomical blockage or swollen tissue in the nose. Anatomical causes of blockage could include a deviated nasal septum, turbinate hypertrophy, nasal polyps, enlarged

adenoids, tumors or nasal valve collapse due to lateral wall insufficiency. Deviated septum is considered the most common structural abnormality that causes nasal obstruction (Lajadim et al. 2022). It's prevalence in the literature has been found to be as high as 75% or greater (Clark et al. 2018, Mladina et al. 2008). Septoplasty to correct deviated nasal septum is the most common ear, nose and throat operation in adults (van Egmond 2015).

Many consequences have been documented as a result of mouth breathing due to nasal airway obstruction. The classic example of the relationship between airway obstruction and abnormal craniofacial growth is the patient described as having "adenoid facies," which includes increased anterior facial height, a high narrow palate, anterior open bite, dental crowding and increased overjet due to downward/backward rotation of the mandible (Tomes 1872). It has also been shown that mouth breathers are at increased risk for dental caries (Nascimento 2014). Mouth breathing has also been found to negatively affect cervical spine posture (Vig 1980). Young (1997) found that men and women with nasal obstruction were more likely to be habitual snorers, and had frequent episodes of apnea and hypopnea, indicative of sleep-disordered breathing. Finally, anxiety and depression has been linked with nasal obstruction in patients with nasal septal deviation (Ma et al. 2020).

Due to the noted benefits of nasal breathing, this literature review was completed to gain a comprehensive understanding of the causes and consequences of nasal airway obstruction in an effort to create more awareness of nasal obstruction in our patient population. The hope is that more awareness will bring more resolution to this common health concern.

## REVIEW OF THE LITERATURE

### Importance of Nasal Breathing

Despite the fact that the nose is designed for smelling and breathing and the mouth is designed for speech and consumption of food, up to 30-50% of adults breathe through their mouth. Breathing through the nose has many health benefits. Cottle (1958) notes that the nose has at many roles and protective functions, including warming, humidifying, and filtering air to prepare it to be delivered to the lungs. The stream of air is regulated in the nose in regards to velocity and direction by various structures in the nose. These structures maximize air exposure to networks of nerves, lymphatic tissue, vasculature and mucous membranes. Nose breathing can impose as much as 50 percent increased resistance to the air stream than mouth breathing, which can result in uptake of 20 percent more oxygen. Bony shelves called turbinates (or concha) help to slow passage of air during nasal breathing and they create mixing of air with nitric oxide, a gas that is produced in the nasal sinuses. Breathing through the nose increases blood levels of oxygen and carbon dioxide, decreases the breathing rate and overall creates an improvement in lung function. Nasal breathing also helps promote the parasympathetic nervous system. This important “rest and digest” system helps relax the body, decreases heart rate and breathing rate and promotes proper digestion (Brown, 2012).

Carbon dioxide is essential for proper performance of the human body, and has multiple essential functions. Oxygen content in our blood is determined by the arterial oxygen saturation of hemoglobin as well as the concentration of hemoglobin, as 95% of oxygen in our blood is attached to hemoglobin. When capillary carbon dioxide ($CO_2$)

levels increase, oxygen is unloaded in the tissues. And when there is a reduction in carbon dioxide levels, the bond between oxygen and hemoglobin becomes stronger, which causes release of less oxygen to organs and tissues of the body. This is called the Bohr Effect.

The Bohr effect was first described in 1904 by a Danish physiologist named Christian Bohr. He described how red blood cells are able to adapt to biochemical changes in the environment to maximize binding capability of oxygen and hemoglobin in the lungs while also optimizing delivery of oxygen to tissues that need it the most. There is a shift in the oxygen dissociation curve based on the pH or carbon dioxide concentration in the environment, because carbon dioxide reacts with water to form carbonic acid. Therefore, an increase in $CO_2$ creates in a decrease in the pH of the blood (acidic environment), causing hemoglobin proteins to release their load of oxygen. Conversely, pH will increase (creating alkaline environment) when the levels of carbon dioxide decrease, thus resulting in more binding of oxygen to hemoglobin (Bohr, 1904).

In 1995 the production of nitrous oxide (NO) gas was discovered in the paranasal sinuses. It was found that healthy sinus epithelium produces large amounts of NO, a bioactive signaling molecule, which can be measured in breath exhaled by the nose. NO exhibits potent vasodilatory and antimicrobial effects, and likely enhances local host defense mechanisms via stimulation of mucociliary activity which helps inhibit growth of pathogens. Patients with certain diseases such as cystic fibrosis and primary ciliary dyskinesia present with very low levels of NO in the nose, which likely contributes to the frequent chronic sinusitis found in these patients. In 2005 Lundberg found that inhibition of NO in the sinuses can have negative impacts on host defense. He found evidence

that NO aids in sinus host defense, and its lack of presence may make one more susceptible to sinus infections. In earlier studies, he also showed that nasal breathing reduces pulmonary vascular resistance and enhances pulmonary oxygen uptake in subjects without lung disease when compared to oral breathing (Lundberg et al., 1995). More recently, Weitzberg and Lundberg (2002) found that NO measurements increased significantly during humming. They found that the oscillating sound waves produced during humming significantly sped up the exchange of gas over the sinus ostium, creating high levels of detectable nitrous oxide. This may help to evaluate how well sinuses are ventilated. Obstruction of the sinuses creates drops in oxygen levels, depriving many of the oxygen-dependent mechanisms of mucosal defense, thereby creating favorable conditions for growth and invasion of bacteria (Drettner and Aust, 1977).

Research has shown that nasal breathing also plays a significant role in the regulation of respiration during sleep. The negative effects of mouth breathing during sleep were documented as early as the sixteenth century (Levinus, 1581), yet the recognition of the importance of nasal breathing has been slower. About two hundred years later, George Catlin explored the notion that North American Indians were much healthier than those living in city dwellings. He made extensive observations of the lives of North and Central American Indians and their habits, and he found that from infancy the Indians were trained to sleep with their mouths closed. He noted that those who slept with shut mouths woke up with less oral dryness and general fatigue, and they snored less as well. His findings led him to name his publication “Shut Your Mouth and Save Your Life” (1861). Later Guye found a connection between obstructive nasal breathing and poor concentration and memory, which inspired his title, “Shut Your Mouth

and Save Your Brain" (1889). In 1892 Cline documented a link between daytime sleepiness and obstructed nasal breathing. In the 1960s Cottle further delineated the intimate relationship of the quality of sleep and nasal breathing by evaluating sleep patterns of those with nasal obstructions (Cottle 1972). In 1982 Lavie found that deviated nasal septum caused multiple disordered breathing events in sleep, which were associated with chronic fatigue and excessive daytime sleepiness. One year later he found that mechanical obstruction caused a significant increase in the number of midsleep awakenings (Lavie et al., 1983). Correction of the deviation with surgery improved the quality of breathing in sleep as well as diurnal vigilance. In one of Lavie's later reviews entitled "Shut Your Mouth and Save Your Sleep," he concludes "to ensure a good night's sleep, it is as essential to shut the mouth, as it is to turn off the lights" (Lavie, 1987).

**Causes of Nasal Obstruction**

Nasal airway obstruction is a common symptom of patients in primary care and otolaryngology offices. Nasal obstruction constitutes anything which hinders the flow of air into and out of the nose, affecting either only one or both nasal passages. This can be due to an anatomical blockage or some form of tissue swelling creating the feeling of nasal congestion. Anatomical causes of blockage could include a deviated nasal septum, turbinate hypertrophy, nasal polyps, enlarged adenoids, tumors or nasal valve disfunction. Nasal valve dysfunction often pertains to nasal valve collapse due to lateral wall insufficiency. Swelling of the nasal tissue can occur from inflammatory causes such as allergic rhinitis or non-allergic rhinitis. Temporary causes of nasal congestion can include chronic sinusitis, allergic rhinitis, environmental irritants (i.e., smoke or dust),

sinus infection, cold/flu or certain medications. Obstruction of the nose can lead to snoring, sleep-disordered breathing and obstructive sleep apnea (OSA). Many patients have multiple reasons/causes for their nasal obstruction (Clark, 2018 and Jessen 1987).

Up to 30% of the general population seeks treatment for complaints of nasal obstruction. The nose is designed to filter, humidify and warm the air on its way to the lungs. The nose maximizes air's contact with mucosal surfaces inside the nasal cavities. Optimal nasal airflow is dependent on many factors including the following: nasal passages that are patent, sufficient mucociliary function, lack of mucosal inflammation and normal airflow receptors. Air flows through the nasal value, past the septum and turbinates, and eventually through the nasopharynx. The turbinates create changes in flow and air temperature sensed by thermoreceptors that regulate the nasal patency sensation. Any dysfunction in any of these steps of the process can create adverse nasal flow and the sensation of less air passing through.

Hsu and Shu (2018) focus on the anatomic causes of nasal obstruction including nasal valve collapse, septal deviation, enlarged septal swell body, inferior turbinate hypertrophy, nasopharyngeal obstruction, choanal stenosis, and scarring from previous nasal surgery. The most external portion of the nasal framework is the skin-soft tissue envelop (SSTE). Skin is thickest at nasion, the bony junction of the two nasal bones with the frontal bone. The SSTE is thinnest at rhinion and does thicken as it descends to the nasal tip. The subcutaneous layer of the nose has a superficial fatty later, a fibromuscular layer, a deep fatty layer, and periosteum/perichondrium. The investing nasal musculature is deep to the SSTE, consisting of elevator and depressor muscles,

as well as compressor muscles. The internal nasal lining consists of keratinized squamous epithelium at the vestibule. Pseudostratified ciliated columnar respiratory cells sit inside the nasal cavity with seromucous glands.

The nose framework is divided into thirds: the upper third consists of the osseous nasal vault compromised of the nasal bones, the middle third consists of the upper lateral cartilages (ULCs), and the lower third is defined by the lower lateral cartilages (LLCs). The osseous vault is comprised of the paired nasal bones that attach superiorly to the frontal bone and laterally to the frontal process of the maxilla. The keystone area of the nose is the fibrous connection between the upper lateral cartilage and the nasal bones. The principal support of the nose is provided by the septum and the bony framework (Hsu, 2018).

The middle and lower thirds of the nose are made up by the nasal cartilages. The middle third is composed of paired upper lateral cartilage which are fused midline to the septum. The interval nasal valve is formed by the edge of the ULC as well as the septum, the floor of the nose and the inferior turbinate. The lower third of the nose is composed of the lower lateral cartilage (LLCs) which are divided into three sections: the medial, intermediate and lateral crus. The LLCs and the septum provide support for the nasal tip (Hsu, 2018).

Figure 1: Nasal Thirds (Hsu 2018)

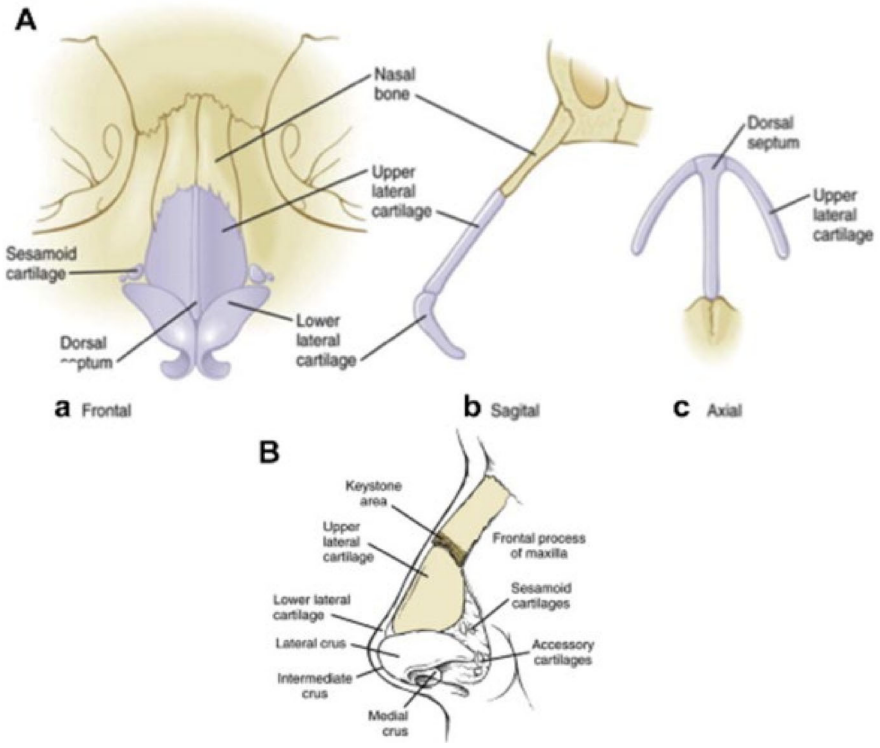



**Fig. 1.** (*A*) Nasal thirds: nasal bones represent upper nasal third, upper lateral cartilages represent the middle third, and lower lateral cartilages represent the lower third. (a – frontal view, b – sagittal view, c – axial view). (*B*) Keystone area: the strong fibrous connection between the nasal bones and the upper lateral cartilages provides stability to the nose. (*From* [*A*] McCarn KE, Downs BW, Cook TA, et al. The middle vault: upper lateral cartilage modifications. In: Azizzadeh B, Murphy MR, Johnson CM, et al, editors. Master techniques in rhinoplasty. Philadelphia: Saunders; 2011. p. 159–67, with permission; and [*B*] Chegar BE, Tatum, SA. Nasal fractures. In: Flint PW, Haughey BH, Lund V, et al, editors. Cummings otolaryngology. Philadelphia: Saunders; 2015. p. 494, with permission.)

The nasal septum acts as a support for the structure of the nose. A deformed nasal septum can create disruption of nasal airflow. Nasal septum deviation is considered to be the most common cause of nasal obstruction, but often may not produce symptoms. Deviation of the septum can be the result of trauma later in life or can even result from birth trauma or microfractures early in life that cause abnormal growth of the septum. From anterior to posterior the septum is composed of a membranous, a cartilaginous and an osseous/bony component. The membranous layer is made of fibrofatty tissue while the cartilage layer is made of quadrangular cartilage.

The posterior portion of the septum is composed of the perpendicular plate of the ethmoid, the nasal crest of the palatine and maxillary bones, and the vomer (Hsu, 2018).

Figure 2: Nasal Septum Anatomy (Hsu, 2018)

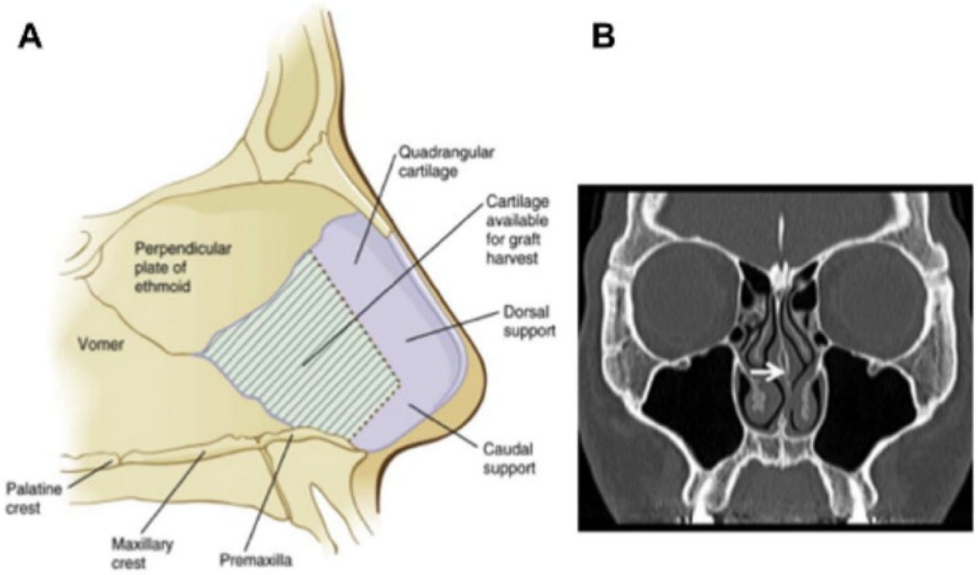



**Fig. 2.** (*A*) Nasal septum anatomy. (*B*) Nasal swell body: coronal computed tomographic image showing the nasal swell body (*arrow*). (*From* [*A*] Sarkissian RD. Cartilage grafting in rhinoplasty and nasal reconstruction. In: Azizzadeh B, Murphy MR, Johnson CM, et al, editors. Master techniques in rhinoplasty. Philadelphia: Saunders; 2011. p. 143–57, with permission; and [*B*] Koo SK, Kim JD, Moon JS, et al. The incidence of concha bullosa, unusual anatomic variation and its relationship to nasal septal deviation: a retrospective radiologic study. Auris Nasus Larynx 2017;44(5):561–70, with permission.)

The nasal swell body is a wide portion of the anterior nasal septum that is anterior to the middle turbinate and is called the septal turbinate.

The three pairs of turbinates and their corresponding meati are critical structures of the lateral nasal wall. The middle and superior turbinates arise from the ethmoid bone. Turbinates are comprised of thin bone covered with mucoperiosteum. The submucosal portion of the inferior and middle turbinates can become hypertrophied in response to allergens or irritants. The inferior turbinate regulates nasal airflow and maximizes the intranasal surface area and facilitates warming and humidification of inspired air. Minor

increases in congestion of the inferior turbinate can cause significant increases in airflow resistance. Chronic congestion of the inferior turbinate is often seen in chronic rhinitis due to hypertrophy of bone and soft tissue in this area (Hsu, 2018).

Figure 3: Nasal Concha (Anatomy, Head and Neck 2023)

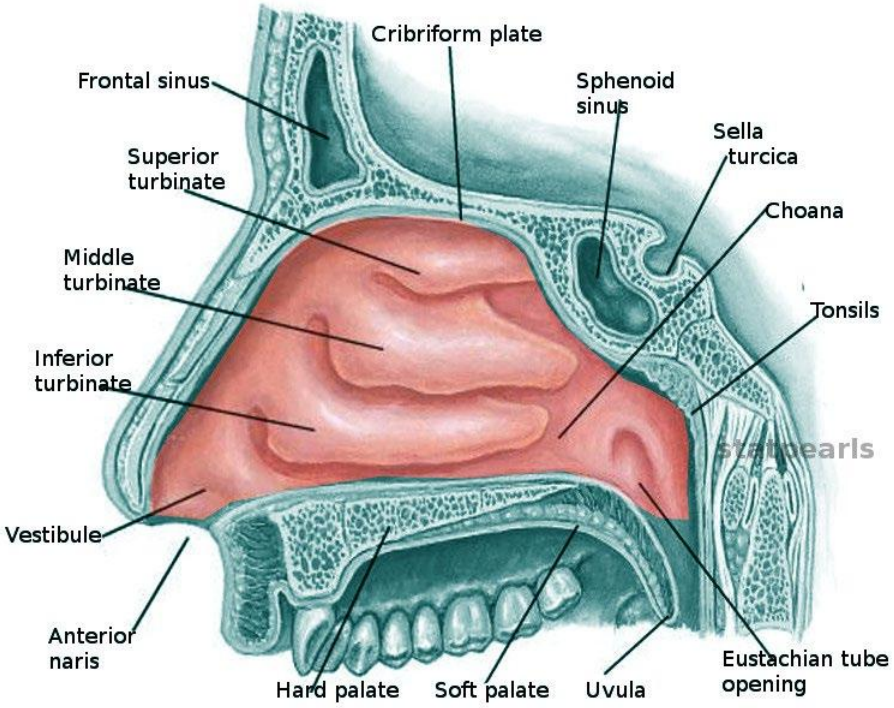
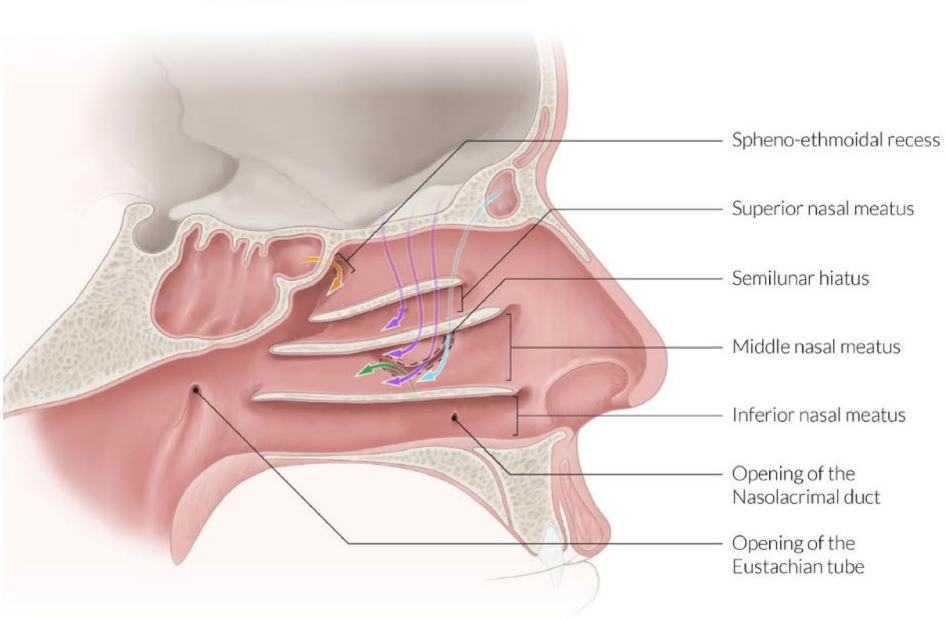



Figure 4: Nasal Meati (Anatomy, Head and Neck 2023)




The nasal value is divided into the external and internal nasal valves. The narrowest portion of the nasal airway is at the internal valve; this creates the greatest resistance to overall airflow, which accounts for approximately two-thirds of overall nasal airway resistance. Increased narrowing of this area can be associated with nasal obstruction. Airflow resistance first occurs at the external nasal valve area. Obstruction here is often due to alar cartilage weakness, ptosis or deformation of the nasal tip, other anatomic anomalies (Hsu, 2018).

The nasopharynx is where the nasal cavity and the superior part of the pharynx meet. Hypertrophic adenoids, tumors or scarring from previous surgery are possible obstructive causes in this area.

Pseudostratified ciliated columnar respiratory cells and submucosal glands make up nasal mucosa. The mucosa creates a moist, mucus blanket that traps harmful

particles and mobilizes them back toward the nasopharynx to prevent upper respiratory infections. The nasal mucosa provides mucociliary transport (MCT) and ensures healthy airway surfaces by clearing out allergens and microbes.

The structures within the nasal cavity create nonlaminar flow which decelerates inspired air to allow conditioning of the air. A decrease in pressure creates a vacuum effect, favoring nasal valve collapse (Bernoulli principle). Hence why it is critical that the cartilage is resilient to prevent collapse in this area. Poiseuille law explains how a decrease in nasal diameter can dramatically decrease airflow.

Rhinitis refers to a group of nasal disorders characterized by nasal itching, sneezing, congestion and runny nose. There are two form of rhinitis, non-allergic and allergic rhinitis. Allergic rhinitis is a very common condition estimated to affect approximately 20% of American adults. Nonallergic rhinitis has many forms and can be linked to vasomotor issues, hormonal changes, medications or systemic disease. Autonomic dysfunction, vascular dilation and/or general inflammation in these conditions can create hypertrophy of the inferior turbinate. Sinusitis often results in nasal obstruction from presence of nasal polyposis, edema of mucosa or purulence. Nasal airflow can be affected by anatomic blockage, MCT disruption and airflow receptor anomalies. Nasal congestion perception is worsened by inflammation of mucosal tissues and blockage of pathways for sinus drainage. Causes of nasal obstruction are most likely multifactorial but can be isolated as well (Hsu, 2018).

**The Effects of Nasal Obstruction**

When upper airway obstruction is present and nasal breathing is not feasible, mouth breathing becomes the compensatory response. The literature has heavily explored the deleterious effects of mouth breathing. The most notable effects of mouth breathing in the literature pertain to dental occlusion, craniofacial growth, dentofacial health, cervical posture, sleep disordered breathing and mental health. Nasal obstruction and pathological tonsil and/or adenoid hypertrophy are frequent primary etiologic factors of mouth breathing in children (Lin, 2022). Mouth breathers may have various types of malocclusion and growth patterns, and they can also be more susceptible to dental caries and periodontal disease. Vig (1991) and Wu (2019) define mouth breathing as 25-30% of the air passing through the mouth rather than the nose, often due to upper airway obstruction which reduces nasal airflow. According to the functional matrix theory created by Moss and Salentijn in 1969, normal respiratory function of the nose is essential for balanced growth of the craniofacial structures.

Obstruction in any of the four areas of the upper airway (nasal cavity, nasopharynx, oropharynx, laryngopharynx) can result in mouth breathing. The upper airway is affected by the position and shape of the surrounding nasal mucosa, tonsils and adenoids. Airflow passage can be affected by changes in these tissues (Zhao, 2019). Lin (2022) explains that in addition to the previously discussed potential causes of mouth breathing such as nasal inflammation and anatomic obstruction, hypertrophied adenoids and tonsils are also common causes of oral breathing. In the majority of people, these tissues atrophy and eventually disappear by the age of 15, yet pathological presentation of tonsils and adenoids is due to their inability to properly atrophy. In this instance they can block nasal breathing by reducing the pharyngeal area.

Effects of Nasal Obstruction: Malocclusion

The impact mouth breathing can impart on malocclusion has been heavily researched. Dental development is affected by the position of muscles within the mouth as well as outside of the mouth. (Proffit, 1978). Children with normal breathing patterns tend to have closed lips with the tongue superiorly positioned against the palate and lingual surface of maxillary anterior teeth. Muscle imbalance from mouth-breathing can lead to craniofacial growth abnormalities. Galeotti (2019) found that mouth breathing children had malocclusion more frequently than nasal breathing children. Mouth breathing children also have a lower tongue posture which creates a decrease in tongue pressure, thus contributing to a constricted maxillary dental arch (Pereira, 2019 and Azevedo, 2018). With mouth-breathing the mandible rotates posteriorly which leads to super-eruption of posterior teeth, increasing the risk of an open bite occlusion (Poddebniak, 2019). A cross-sectional study of children aged 3-6 years old found a correlation between mouth breathing and posterior crossbite, increased overjet, and anterior open bite (Paolantonio, 2019). In 2021, Festo et al. evaluated 356 mouth-breathing children to assess presence of deviated nasal septum and presence of tonsil/adenoid hypertrophy. They also had orthodontists examine occlusion. They found that 81.4% of children presented with malocclusion, including Cl II relation and increased overjet. They concluded that mouth-breathing children have a higher occurrence of orthodontic problems.

Effects of Nasal Obstruction: Craniofacial Growth

Mouth breathing also has an impact on craniofacial growth and skeletal development. The classic example of the relationship between airway obstruction and

abnormal craniofacial growth is the patient described as having “adenoid facies,” as a result of mouth breathing. CV Tomes was the first to coin this term in 1872, and described the characteristics as such: a high narrow palate, an increased anterior facial height, dental crowding, anterior open bite and increased overjet due to downward/backward rotation of the mandible. In 1907 Angle noted asymmetrical development of the facial muscles in mouth breathers, as well as asymmetry of the bones of the nose and the jaws, which caused derangement of the tongue, lips and cheeks. He also noted a narrow and lengthened upper arch due to unequal pressure form muscles, and an underdeveloped mandible. Angle also astutely made a connection to systemic effects of mouth breathing by noting that the lungs receive insufficient quality and quantity of air to fully oxygenate the blood when one breathes through the mouth.

Figure 5: Proffit (2019)



McNamara in 1981 presented four clinical cases to explore a potential relationship between craniofacial growth and obstruction of the upper airway by examining the significant changes in patterns of facial growth after removal of the obstruction. He concluded that the cases illustrated the relationship between form and function (i.e. obstruction and abnormal growth), but reiterated the need for more documentation from randomized controlled clinical trials. Also in 1981, Harvold et al. carried out an experiment by using plugs to obstruct nasal passages of rhesus monkeys. They found an increase in face height and steeper plane angle of the mandible in nasally obstructed monkeys due to a lower position of the mandible. The traditional view of mouth breathing children is a skeletal Cl II profile with maxillary protrusion and mandibular retrustion (Rossi 2015), an increase in lower facial height (Chambi-Rocha, 2018), incompetent lip

seal (Nogami, 2021), tongue position on the floor of the mouth (Milanesi, 2017) and high palatal vault (Petraccone, 2014). Many cephalometric studies have been performed to assess skeletal characteristics of mouth breathers. Ascanio (2010) compared cephalometric features of mouth breathers versus nasal breathers to evaluate a potential influence of septum deviation on craniofacial growth. He found that mouth breathers had a statistically significant increase in anterior facial height, increased palatal height, increased overjet, and significantly retrognathic position of the maxilla and mandible. He also found that mouth breathing children showed Cl II malocclusion and high prevalence of crossbite compared to nasal breathers. In 2016 El Aouame et al. examined cephalograms of mouth breathers compared with nasal breathing controls and found an increase of anterior face height and a decrease of posterior face height in a disproportionate manner, otherwise known as hyperdivergence. In 2020 Zheng found evidence of retrognathic mandible in mouth breathers, as well as increased mandibular plane angle and downward/backward rotation of the mandible.

Effects of Nasal Obstruction: Dentofacial Health

Correlations have also been found between mouth breathing and negative effects on dentofacial health. Saliva can be negatively altered by mouth-breathing, which causes a decrease in the cleaning effect of saliva, thereby inhibiting saliva's self-mediated defense. Saliva evaporates with oral breathing, which then causes a decreased oral cavity humidity. As we know, saliva has many beneficial properties to help maintain the pH balance in the oral cavity, and it also has anti-bacterial functions to help with prevention of dental caries. Studies have indicated that chronic mouth breathing children are at a higher risk of caries (Nascimento, 2014). Research as shown

higher levels of plaque and streptococcus mutans in adolescent mouth-breathers (Mumolo, 2018).

Effects of Nasal Obstruction: Craniocervical Posture

Mouth breathing has also been found to negatively affect cervical spine posture. In 1980 Vig et al. found an immediate change in head posture with the head tipping back approximately 5 degrees upon total nasal blockage. They then noticed a return to original head posture position once the nasal obstruction was relieved. In 2015, Sabatucci et al. investigated the influence of oral breathing on head posture by measuring craniocervical angles of oral and nasal breathers. Their results showed greater craniocervical angles in the mouth breathing group, meaning that patients who tend to breathe orally rather than nasally showed a proinclination of the head and a reduction of cervical lordosis. This suggests greater extension and abnormal elevation of the head when compared to the cervical spine. A recent study analyzed CBCTs of patients with/without nasal septum deviation. They found that the group with nasal septum deviation had a statistically significantly shorter nasopharyngeal length, a longer vertical airway length and a larger cervical column curvature angle than those without septum deviation. They concluded that children with a 4mm or greater septum deviation on CBCT are more susceptible to unfavorable craniocervical and pharyngeal postural changes (Sadry et al., 2021).

Effects of Nasal Obstruction: Sleep Disordered Breathing

Nasal obstruction has frequently been considered a possible causative factor of sleep-disordered breathing. Changes in airflow resistance and velocity due to nasal

obstruction potentially lead to sleep-disordered breathing events including snoring, hypopnea and apnea. Young and colleagues explored if nasal obstruction (in the form of nasal congestion due to rhinitis) was a risk factor for sleep disordered breathing. Young (1997) found that men and women with nasal obstruction were more likely to be habitual snorers, with a proportion also experiencing frequent episodes of hypopnea and apnea, indicating severe sleep-disordered breathing. Kara and colleagues investigated the effect of nasal septum deviation in the absence of obstructive sleep apnea on quality of sleep by using the Pittsburgh Sleep Quality Index. Compared with controls, patients with deviated nasal septums displayed significantly higher scores in all parameters of the Index, indicating worse sleep quality (Kara et al., 2015).

Cai and colleagues reiterate the important role of the nose in the physiology of sleep by stimulating ventilation. They note that nasal obstruction is common in sleep apnea and can contribute to OSA; they also mention that nasal obstruction can interfere with tolerance of OSA treatments and appliances such as the CPAP device. They comment that tolerance of CPAP and OSA-related quality of life were improved with surgical correction of nasal obstruction via sinus surgery, rhinoplasty, septoplasty or turbinate reduction (Cai et al., 2020). Shuab and colleagues considered whether functional rhinoplasty (septorhinoplasty) alone would result in a significant improvement in obstructive sleep apnea for patients with nasal obstruction. Patients underwent surgery to repair the nasal inlet, with review of pre and post-operative polysomnography. Their results showed for that mean apnea-hypopnea scorew dropped from 24.7 to 16, a reduction of 35 percent. For patients with body mass index greater than 30, the mean apnea-hypopnea scores improved by 57 percent. They concluded that severity of

obstructive sleep apnea for select patients with nasal obstruction may be greatly improved with functional rhinoplasty via modification of pharyngeal aerodynamics with improvement in nasal airflow (Shuaib, 2015).

### Effects of Nasal Obstruction: Quality of Life, Depression and Anxiety

Nasal airway obstruction is a diagnosis that can affect a person's quality of life in a considerable way. Mohan and colleagues reviewed advances in diagnostic and therapeutic management of nasal airway obstruction. They found that of the subjective measures of quality of life available for nasal airway obstruction, the NOSE (Nasal Obstruction Symptom Evaluation) scale was "outstanding" regarding disease-specific validation and correlation with related symptoms. They note that an adequate diagnosis includes a thorough history and physical exam and requires a patient quality of life measure such as the NOSE scale (Mohan et al., 2018).

Ma and colleagues investigated anxiety and depression in patients with nasal septal deviation. Symptoms of depression and anxiety were assessed between patients with nasal obstruction and controls using a self-report questionnaire. Results showed more severe levels of anxiety and depression in the group with septum deviations (Ma et al., 2020). Muthubabu and colleagues researched quality of life in patients with nasal septal deviation after surgical septal correction using the NOSE scale. They found that NOSE scores were better post-surgery and concluded that surgical septal correction is relevant for symptomatic improvement for a healthier lifestyle (Muthubabu et al., 2019).

## Prevalence of Nasal Obstruction

Nasal obstruction is thought to affect up to one-third of the population (Hsu, 2018). There are various possible etiologic factors, including anatomic, physiologic and pathophysiologic explanations for nasal obstruction. The physiological and anatomic components of nasal obstruction are complicated. Patency of nasal passages, mucociliary transport capabilities, autonomic function and inflammation of the mucosa can have an effect on these components. Frequent anatomic causes of obstruction include septal deviation, turbinate hypertrophy or collapse of the nasal valve. Physiologic causes can be iatrogenic or due to inflammation of sinonasal structures.

Nasal obstruction can be difficult to define and measure. As Jessen notes, what one patient considers to be nasal obstruction may bother another patient minimally. Thus, it is challenging to obtain a realistic estimate of how common nasal obstruction is (Jessen, 1997). A questionnaire was sent to about 1,500 randomly selected people aged 16-82 and based on responses, Jessen and Janzon found 2-3% of the respondents reported that septum deviation was causing their nasal obstruction. The same study also showed 4.5% reported suffering from allergic rhinitis. 20.7% of respondents fulfilled criteria for non-allergic (non-infectious rhinitis) nasal complaints. Jessen mentions that drug induced rhinitis can also be common and was likely very prevalent in the mid-1900s due to nasal congestion side effects of anti-hypertensive drugs at that time. Most modern antihypertensives now do not cause congestion. Jessen concludes that simple prevalence figures as he provided in his study do not provide a fair and valid estimate of how common nasal obstruction is. He notes that many factors need to be considered, including duration of the nasal obstruction. He recommends that questionnaires also directly ask about when obstruction occurs (i.e., continuous, only at night, after exercise,

etc.) as well as degree of obstruction and whether it is unilateral or bilateral (Jessen, 1997).

Clark and colleagues explored the prevalence of anatomic contributors to nasal airway obstruction. Their study was performed to determine that prevalence of septal deviation, nasal valve collapse and turbinate hypertrophy in 1,906 patients with sinonasal complaints who were examined by otolaryngologists in varying regions of the United States. Patients first filled out the NOSE survey and they also had a physical exam to determine presence of the three anatomic contributors. They found that 67% of patients had nasal valve collapse, 76% had septal deviation and 72% showed inferior turbinate hypertrophy. They also found that 64% of patients had severe/extreme NOSE scores. In the patients with extreme NOSE scores they found the prevalence of nasal valve collapse to be 73%, septal deviation was 80% and inferior turbinate hypertrophy accounted for 77%. 82% of the 236 patients with severe/extreme NOSE scores who had septoplasty and/or inferior turbinate reduction surgery prior had collapse of the nasal valve, which highlighted the importance of evaluating the lateral nasal wall when planning surgical intervention for nasal airway obstruction (Clark et al., 2018).

## Nasal Septum Deviation: Anatomy and Prevalence

The nasal septum provides critical underlying support structure for the nose. The septum is a mixed cartilaginous and osseous structure composed of five parts: the perpendicular plate of the ethmoid bone, the vomer, the septal cartilage, the nasal crest of maxillary bones and the nasal crest of palatine bones. The osseous/bony portion of the septum consists of the ethmoid bone and the vomer. The anterior portion of the septum contains the septal cartilage that articulates with the nasal crest (von Arx, 2019).

In 2016 Hur et al. noted that 43% of the nasal septum surface area was comprised of the perpendicular plate of the ethmoid bone, while the vomer and the septal cartilage were responsible for 25.8% and 25.6% respectively. The nasal crest only made up 5.6% of the total nasal septum surface area.

In 2017 Koo et al. Found prevalence of septum deviation to range from 14-80 percent. Deviation is defined as any bend of the septal contour in the axial or coronal plane (Shpilberg et al., 2015). Typically, deviation occurs at the junction of the vomer with the setpal cartilage or with the perpendicular plate of the ethmoid bone (Hur et al., 2016). Nasal septal deviation often occurs in concert with unilateral or bilateral conchae bullosa (Stallman et al., 2004). This results in convexity of the nasal septum toward the side opposite of the enlarged middle concha, yet includes preservation of the air channel between the deviated septum and the widened concha (von Arx, 2019).

Septal cartilage often takes a triangular or quadrangular shape and is connected anteriorly to the anterior nasal spine via loose connective tissue fibers which allow mobility (Hafkamp et al. 1999). Sometimes the septal cartilage has a posterior process between the vomer and perpendicular plate of the ethmoid bone (Hur et al. 2016). This sphenoidal process is a remnant of the septal cartilage due to delayed ossification of the nasal septum. Kim et al. (2010) found the mean length of the posterior process in patients with septum deviation to be 26.1 versus controls with 12.0. They concluded that a long posterior/sphenoidal process contributes to worsening of septal deviation severity (Kim et al. 2012).

Figure 6: Nasal Septum (von Arx, 2019)

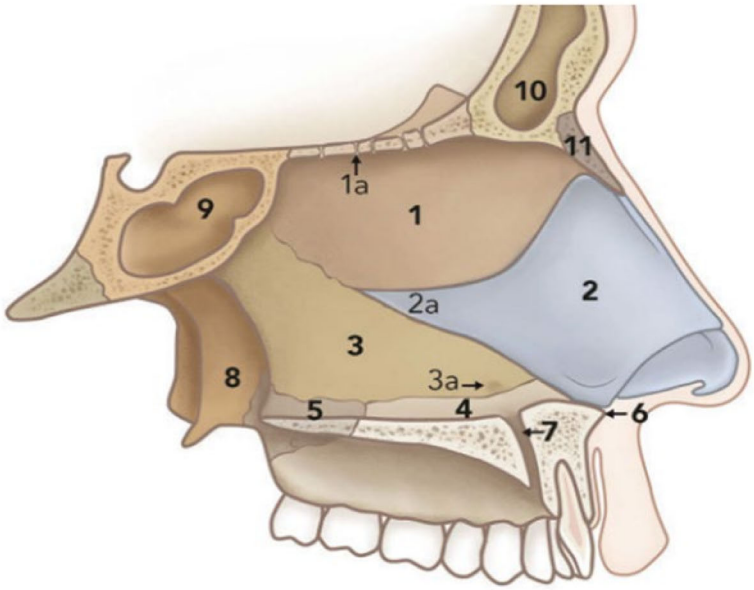



**Fig. 13** Graphic illustration of the nasal septum (right side) and adjacent structures
1 = perpendicular plate of ethmoid bone; 1a = cribriform plate of ethmoid bone; 2 = septal cartilage; 2a = posterior (sphenoidal) process of septal cartilage; 3 = vomer; 3a = vomeronasal cavity; 4 = nasal crest of maxillary bone; 5 = nasal crest of palatine bone; 6 = anterior nasal spine; 7 = nasopalatine (incisive) canal; 8 = medial plate of pterygoid process of sphenoid bone; 9 = sphenoid sinus; 10 = frontal sinus; 11 = nasal bone

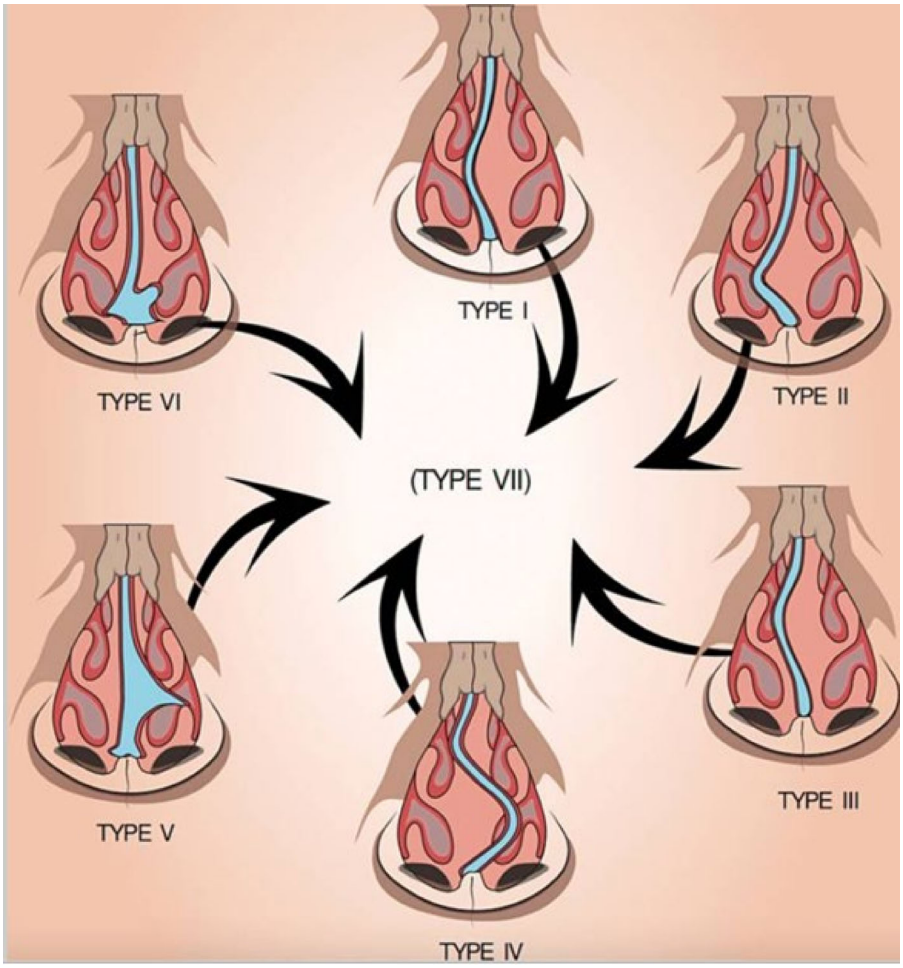
Nasal septal deviation has revealed a wide range of prevalence. A 2008 study found the prevalence of nasal septum deviation to be approximately 90% in adults (Mladina et al. 2008). As previously mentioned, Clark and colleagues found a septum deviation prevalence of 76% of 1,906 patients with sinonasal complaints. In patients with the highest NOSE scores (severe/extreme classification), septum deviation was found to have an 80% prevalence (Clark et al. 2018). A 2019 study showed the septal deviation rate among patients complaining of nasal obstruction was 85%. Nearly 90% of patients had two or more types of anatomic pathology in CT analysis (Ustun et al. 2019). Most

recently, Moshfeghi and colleagues investigated the prevalence of nasal septum deviation and its relation to gender, age and history of trauma using cone-beam computed tomography (CBCT). They classified the level of deviation according to Mladina's system. They found that 86.6% of the 386 patients had nasal septum deviation, 30% of which had the most severe form of deviation. They also found that with every 10-year increase in age, the odds of septal deviation increased. Gender and history of trauma had no effects on the chance of deviation (Moshfeghi et al. 2020).

**Quantification and Classification of Nasal Septum Deviation**

As previously mentioned, the nasal septum is complex; due to the nature of its complexity, there is often some asymmetry of the nasal cavity and with it, some degree of septum deviation that is considered to be a normal variation. Classification systems for septum deviation have evolved to help describe the variation of nasal septum deviation in an organized fashion. Mladina was the first to create a user-friendly classification system for NSD according to the characteristics of the nasal septum horizontal and vertical views on CBCT. His method classifies deviation into seven categories based on type of deformity (vertical or horizontal) with Type I being the most simplified deviation to a more complex type 7 which is a combination of two or more classification types (Mladina 1987, 2008). NSD can also have a classification system based on deviation extent at the inferior turbinate. This classification has three-degree variations; degree I describes a deviation without reaching the inferior turbinate, degree II shows a deviation that reaches the inferior turbinate and degree III represents a deviation that not only reaches the inferior turbinate, but also compresses it (Vidigal,

2013). A different classification system describes deviation patterns such as S-shaped and C-shaped deviations (Lawson, 1978).




More accurate diagnostic techniques to quantify nasal septum deviation using measurements and reliable landmarks on CBCT have revealed higher prevalence rates of NSD reaching 86.6%. More recently the literature has shown a simple and repeatable means of calculating the amount of deviation via measuring the angle of deviation. In this method, two lines are drawn on a coronal CBCT image to create the angle between the most deviated point of the septum and the midline. The first line is drawn from the crista galli to the premaxilla (to denote the midline), and the second line is drawn from

the most deviated point of the septum to the crista galli. Lee et al. used this measurement method to measure the septal deviation angle (SDA) and to see if this angle correlated with subjective nasal obstruction symptoms (via the NOSE survey). They found that there was a correlation between SDA and anatomical factors (Lee et al. 2013). In 2017 this same method of measurement was used on coronal CT images to find the relationship between degree and direction of nasal septum deviation and nasal bone morphology. Patients were then divided into classification groups of severity based on SDA measurement. The mild deviation group had an SDA of 9 degrees or less, the moderate group had a SDA angle from 10-15 degrees and the severe group was greater than 15 degrees (Serifoglu et al. 2017).

In 2020 Janovic and colleagues examined the relationship between nasal septum morphology and nasal obstruction. They made various measurements, one of which was the SDA in the same fashion as described above. They found that deviated nasal septum prevalence was 92.7%. They also found no correlation between NOSE score and deviated nasal septum angles. In 2022 Shames et al. investigated a possible association between severity of nasal septal deviation and nasopharynx volume using CBCT. They calculated the SDA in the same fashion, and they also classified the severity of the angle based on the mild/moderate/severe scale that was previously mentioned. They found that the more deviated the nasal septum, the smaller the nasopharynx volume (Shams et al., 2022). Two additional recent studies also used the three classification groups (mild 0-9 degrees, moderate 10-15 degrees, severe >15 degrees) according to the severity of septal deviation angle. Sahin et al. examined the relationship between nasal septal deviation and paranasal pneumatization (2020) and

Atsal et al. investigated the relationship between degree of nasal septum deviation with sinonasal structures and variations (2021).

Figure ? Measurement of SDA on coronal CT image (Janovic 2020)

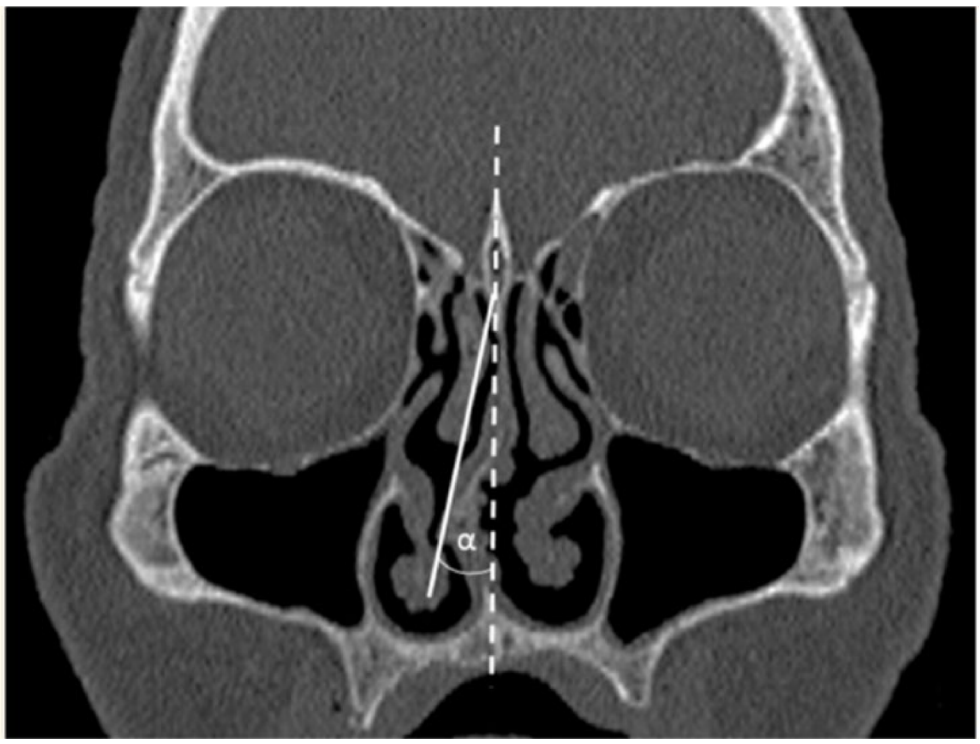
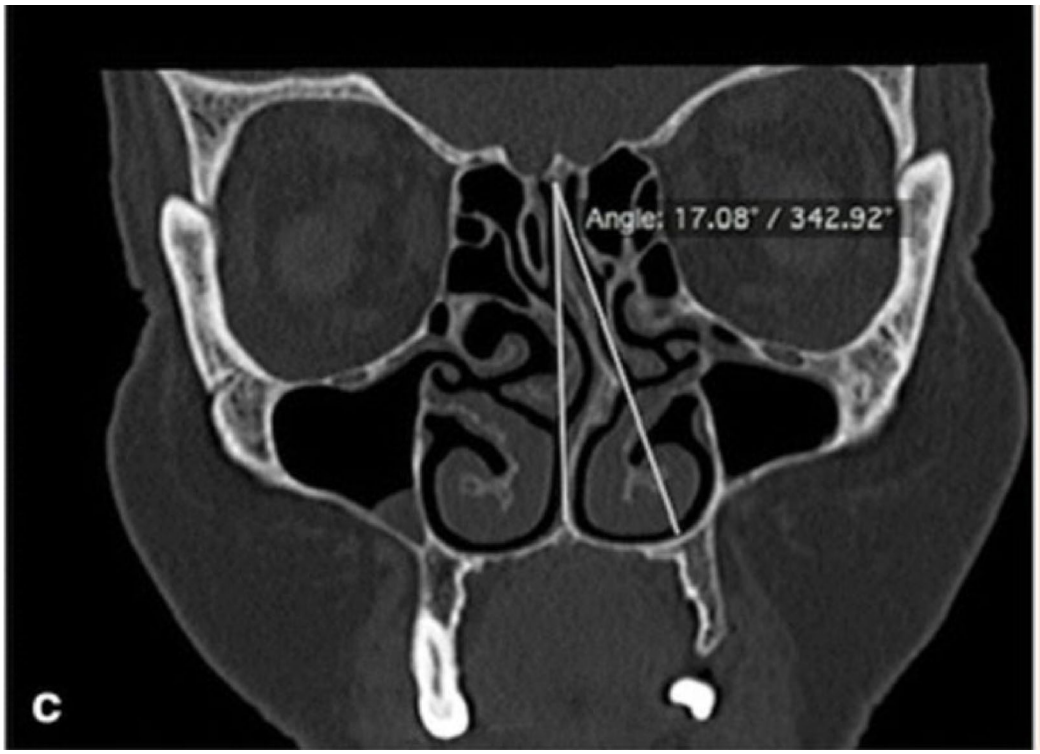



Figure ? Measurement of SDA in coronal plane (Shams et al. 2022)




**The NOSE (Nasal Obstruction Symptom Evaluation) Scale**

The NOSE survey is a validated measure of patient-reported symptoms of nasal obstruction. In their 2018 systematic review, Mohan and colleagues found that the NOSE scale provided significant validation and correlation with disease-specific symptoms. They concluded that the NOSE survey is a key adjunctive role in a complete patient history and physical examination, as it provided a measure of a patient's quality of life. The NOSE scale has been widely used for many years in evidence-based research. In 2004 Stewart and colleagues created the initial form of this survey with 11 items to identify nasal obstruction. The final version included 5 items on a 5-point Likert scale. It was found to have adequate test-retest and internal consistency reliability, and response sensitivity was very high when compared to physical anatomy. They concluded that the NOSE scale was a reliable and valid

instrument to be used for outcome studies in adults with nasal obstruction. They added that it was also a quick and easy survey for patients to complete.

In 2013 Lipan et al. Published a classification system for the severity of the NOSE scale to aid in interpretation of results. Four classes of severity of nasal obstruction were created: mild (5-25), moderate (30-50), severe (55-75) and extreme (80-100).

Figure ? NOSE Survey Instrument (Stewart 2004, Lipan 2013)

Over the past one month, how much of a problem were the following conditions for you?

| | Not a problem | Very mild problem | Moderate problem | Fairly bad problem | Severe problem |
|---|---|---|---|---|---|
| Nasal congestion or stuffiness | 0 | 1 | 2 | 3 | 4 |
| Nasal blockage or obstruction | 0 | 1 | 2 | 3 | 4 |
| Trouble breathing through my nose | 0 | 1 | 2 | 3 | 4 |
| Trouble sleeping | 0 | 1 | 2 | 3 | 4 |
| Unable to get enough air through my nose during exercise or exertion | 0 | 1 | 2 | 3 | 4 |

NOSE score (multiply your total score x5) ____

Nasal obstruction severity classification: mild (5-25) | moderate (30-50) | severe (55-75) | extreme (80-100)

## Research that Finds No Correlation of Septum Deviation with NOSE Score

Some research has found little to no correlation between NOSE score and septum deviation. Ardeshirpour and colleagues (2015) examined whether septal deviation findings on computed tomography (CT) correlated with symptoms of nasal obstruction

as determined by the NOSE scale, as third-party payers were beginning to demand imaging studies to document septal deviation prior to authorizing septoplasties. The had two otolaryngologists and two neurologists evaluate coronal CTs of adult patients, and they also had the patients complete the NOSE survey. They found poor correlation between NOSE scores and degree of deviation on CT scans, and they also found poor concordance between the side of the nose in which symptoms were reported and the side that observers thought was most deviated on CT. Per their results they concluded that CT scans should not be considered clinically necessary tests to evaluate uncomplicated nasal obstruction.

Janovic and colleagues (2020) investigated the impact of nasal septum morphology on the severity of obstruction symptoms via assessment of computed tomography (CT). The study included 386 patients who were referred for CT of paranasal sinuses. CT images were used to estimate prevalence of general deviated nasal septum, as well as the prevalence of Mladina's seven septum deviation types, and deviated nasal septum angle measured on CBCT. The NOSE questionnaire was used to assess severity of nasal obstruction. The relationship between NOSE score and deviated nasal septum angle was examined. They found no significant association between deviated septum angles or types with NOSE scores.

**Evidence that Supports Correlation of Septum Deviation with NOSE Score**

Many studies have found a positive correlation between NOSE score and septum deviation. In 2012 Lee and colleagues evaluated the relationship between subjective symptoms of nasal obstruction and the corresponding nasal anatomical parameters using paranasal CT. They studied 277 patients who completed the NOSE survey and

had CT images. They measured the septum deviation angle at three levels of the nose. They found that subjective nasal obstruction symptoms were correlated with the septal deviation angle at certain levels of the nose. They concluded that coronal paranasal sinus CT revealed a relationship between subjective nasal obstructive symptoms and anatomical factors at the middle and posterior nasal levels, especially in patients complaining of a stuffy nose.

In the same year, Kahveci and colleagues (2012) evaluated the efficacy of the NOSE scale for septoplasty outcomes as compared to other methods of examination. They found a correlation between NOSE score and physical examination as well as computed tomography findings. They concluded that patient-reported symptoms from the NOSE scale related well to physical obstruction caused by deviation of the nasal septum and anatomical correction of this defect.

In 2016 Lindsey and colleagues examined the relationship between the NOSE score and clinical examination. They constructed a nasal anatomy worksheet that was used to assess anatomical features such as the septum, turbinates and the nasal valve. They also found that NOSE scores correlated with the mean total anatomical worksheet scores, which led them to conclude that patient-reported nasal symptoms (via the NOSE scale) correlated to the total nasal anatomic score.

Sahin and colleagues (2020) investigated the possible relationship between severity of nasal septum deviation and related complaints. They enrolled 75 patients with nasal obstruction complaints. The affected nasal cavity was divided into 4 separate sections (antero-superior, antero-inferior, postero-superior, postero-inferior). The nasal septum deviation score was calculated separately for each section. Nasal obstruction

complaints were assessed via the NOSE scale. Patients were male and female between the ages of 18 and 44 years. They calculated the mean total nasal septum deviation score and the mean total NOSE score. They found a strong positive correlation between total septum deviation and NOSE scores when the septum deviation was a certain degree of severity. The correlation was also present when each section of the nose was evaluated separately.

## Treatment of Septum Deviation

Septum deviation can be treated surgically. The most common otolaryngological surgical method used to treat nasal septum deviation is septoplasty (van Egmond 2018). This procedure involves expansion of the nasal passage, thus allowing adequate airflow. Septoplasty is typically an open procedure when correcting a caudal septal deviation, but endoscopic methods are used to correct a posterior septal deviation due to its advantage of providing better visualization during the procedure compared with an open procedure. In severe cases of nasal septum deviation, extracorporeal septoplasty is recommended. It can be an open or closed procedure in which the entire septum (cartilaginous and bony) is extracted and reconstructed (Tasca 2018).

Rhinoplasty surgery combined with septoplasty is called Rhinoseptoplasty (or Functional Rhinoplasty). It is used to treat and relieve symptoms of obstruction and improve breathing. In this instance rhinoplasty aids in the repair of the nasal valves while septoplasty aids in the repair of deformed nasal cartilage and bone.

Rhinoplasty may be considered as a secondary option for treating nasal cartilage deviation along with a cosmetic or aesthetic purpose (Bogovic 2019). Septal deviation

can also be accompanied by turbinate hypertrophy. When the nasal septum deviates to one side, the inferior turbinate on the opposite side may hypertrophy as a compensatory mechanism to balance aerodynamic flow between the two sides of the nasal cavity (Lajdam et al 2022). Thus, septoplasty is often performed in conjunction with surgical reduction of hypertrophied inferior turbinates to achieve improved subjective relief of nasal obstruction (van Egmond 2018).

The NOSE scale is often used as an outcome assessment for anatomical correction via septoplasty. Per Ziai and Bonaparte (2017), a 40% improvement in NOSE scores postoperatively is often required to define a nasal airway surgery as successful. Clark et al. (2018) found that of patients that received surgical intervention, 63% had severe or extreme nasal obstruction based on the NOSE scale. 24% of the patients reported moderate nasal obstruction while 11% had mild nasal obstruction. Muthubabu (2019) examined which specific questions on the NOSE survey were most commonly reported. He found that “nasal blockage” was most prevalent, followed by “trouble breathing through the nose” and “nasal congestion.” He surmised that nasal blockage is most commonly reported in patients seeking septoplasty, indicating that the blockage was more anatomical in nature.

The normal anatomical variation in the nasal septum may be asymptomatic. In the presence of obstruction or symptoms related to septal deviation, septoplasty can be indicated, and is considered the most suitable option to correct nasal septum deviation. While the surgery is considered convenient and beneficial, negative side effects may occur, though they are rare. Surgical interventions have shown a great improvement in quality of life of patients (Alghamdi 2022).

## The Role of the Orthodontist with Reported Nasal Obstruction

While studies have been performed to assess prevalence of deviated septum in various populations, and other studies have even assessed a potential correlation between degree of septum deviation and NOSE score, the aim of this study is to examine the prevalence of deviated septum and a potential correlation with NOSE score in an orthodontic population specifically. Orthodontists can play an important role in general assessment of patients for nasal obstruction in terms of knowing when it is appropriate to refer to medical specialists, whether that be otolaryngologists or even sleep medicine physicians.

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## STATEMENT OF THESIS

Our objective was to determine the prevalence of nasal septum deviation in the population seeking orthodontic treatment. A second objective was to examine a possible correlation between nasal septum deviation and NOSE score.

Hypotheses:

1. At least 50% of orthodontic patients will have moderate or greater septum deviation on CBCT measurements.
2. There is a positive correlation between nasal septum deviation and NOSE score.

**PREVALENCE OF DEVIATED SEPTUM IN AN ORTHODONTIC POPULATION**

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## Introduction

Difficulty breathing through the nose due to nasal airway obstruction is a common presenting symptom in primary care and otolaryngology offices [1]. Obstruction is due to inflammation of tissue or a structural blockage resulting in narrowing of the nasal cavity. Anatomical structural blockages can be a result of nasal septum deviation, turbinate hypertrophy, adenoid hypertrophy, nasal value collapse, nasal polyps, allergic rhinitis (nasal allergies) or rhinosinusitis (sinus infection) [2,3]. This obstruction results in mouth breathing, which has been linked with dental and craniofacial growth patterns such as an Angle Cl II dental malocclusion, increased vertical facial height, narrow palate, increased overjet and maxillary and mandibular retrognathia [4,5] (Tomes 1872, D'Ascanio 2010). Mouth breathing has been connected with increased risk of dental caries and halitosis resulting from dry mouth [6] (Nascimento 2014), as well as poor cervical spine posture [7,8] (Vig et al. 1980, Sadry et al. 2021). Chronic nasal obstruction is associated with snoring, daytime sleepiness and obstructive sleep apnea [9,10] (Young 1997, Ishi 2011). Finally, nasal septum deviation specifically was found to cause more depression and anxiety in patients [11] (Ma 2020). Deviated septum is considered the most common structural abnormality that causes nasal obstruction [12] (Lajadim et al. 2022). It's prevalence in the literature has been found to be on average 60% or greater [13-15] (Clark et al. 2018, Mladina et al. 2008, Papadopoulou et al. 2021). Septoplasty to correct deviated nasal septum is the

most common ear, nose and throat operation in adults [16] (van Egmond 2015). Recent literature has shown a simple and repeatable means of calculating the amount of deviation via measuring the angle of deviation. In this method, two lines are drawn on a coronal CBCT image to create the angle between the most deviated point of the septum and the midline. The first line is drawn from the crista galli to the premaxilla (to denote the midline), and the second line is drawn from the most deviated point of the septum to the crista galli [17-19] (Serifoglu et al. 2017, Janovic et al. 2020, Sham et al. 2022). Some studies have found a positive correlation between total nasal septum deviation and NOSE scores [20,21] (Lee 2013, Sahin 2020). Classification groups have also been formed based on septum deviation measurement (in degrees) with mild (9 degrees or less), moderate (10-15 degrees) and severe (greater than 15 degrees) categories [17,19,21] (Serifoglu, Shams, Sahin 2020, Atsal 2022).

There is no gold standard in orthodontics for identification and referral due to nasal airway obstruction, however, the Nasal Obstruction Symptom Evaluation (NOSE) scale is one validated instrument used to identify patient-reported nasal airway obstruction, and can be used as a screening instrument [22,10] (Stewart 2004 and Ishi 2011). This evaluation tool has 5 items on a 5-point (0-4) Likert scale. Patients add their scores and multiply by 5, and the resulting score is 0-100. Scores are then classified into mild (5-25), moderate (30-50), severe (55-75) and extreme (80-100) categories.

Since deviated septum is the most common form of structural nasal obstruction resulting in mouth breathing, and mouth breathing can result in malocclusion, it is

possible that patients seeking orthodontic treatment may have a higher incidence of septum deviation. Therefore, the objective of this study is to determine the prevalence of deviated septum in an orthodontic population. A secondary objective is to evaluate a possible correlation between septum deviation and NOSE score.

## Materials and Methods

This study was approved by the Institutional Review Board of Case Western Reserve University. The sample consisted of 146 patients seeking orthodontic care who completed the medical history and NOSE survey and had an initial Cone-Beam Computed Tomography scan taken between February 2020 and April 2023 at the Case Western Reserve University School of Dental Medicine Orthodontic Department.

Patient birthdate, gender, adenoid or tonsil conditions and history of trauma were collected on the NOSE survey. Inclusion criteria consisted of patients who completed the NOSE survey and health history forms within the age range of 18-40. Patients with craniofacial anomalies, such as cleft lip and palate and syndromes, and those reporting current adenoid or tonsil condition were excluded from this sample. Each patient signed a consent form allowing the use of orthodontic records for research purposes. Patients' responses were reviewed. The prevalence of nasal septum deviation was determined by measuring the septum deviation angle on a coronal slice of the CBCT at the point of most deviation of the septum. After skull orientation was completed using the frontozygomatic suture, slices of the scan were set at 0.5mm. The CBCT was opened in 4-volume layout initially and the scan was manipulated in the sagittal view in the area of the crista galli (in the A-P direction) while looking at the point of most deviation of the

nasal septum in the coronal view (Figure 1). Once the point of most deviation was noted in the coronal view, the coronal layout was then brought up on the screen and the septum deviation was measured (in degrees). Two lines were drawn on a coronal CBCT image to create the angle between the most deviated point of the septum and the midline. The first line was drawn from the crista galli to the premaxilla (to denote the midline), and the second line was drawn from the most deviated point of the septum to the crista galli (Figure 2). Classification group was then determined based on septum deviation measurement (in degrees) with mild (9 degrees or less), moderate (10-15 degrees) and severe (greater than 15 degrees) categories. Scores on the 5-point Likert scale for the NOSE survey were multiplied by 5, and were categorized as zero, mild (5-25), moderate (30-50), severe (55-75) or extreme (80-100) (Figure 3).

SPSS software (version 26.0; SPSS, Chicago, Ill) was used for all statistical analyses, and significance levels for all tests were set at $p \leq 0.05$. The Shapiro-Wilk test was used to determine distribution normality of data. Intra-operator as well as inter-operator reliability was tested using the Intraclass Correlation Coefficient. The Chi Square test was used to determine if there was a significant difference between males and females in our sample. The overall prevalence of septum deviation and nasal airway obstruction was calculated, using descriptive statistics, as was prevalence of each in their categories (mild/moderate/severe). The Mann-Whitney U test was used to determine the relationship between genders in regards to septum deviation and NOSE scores. Correlations of NOSE score and septum deviation, NOSE score and age, and septum deviation and age were evaluated using the Spearman's rank correlation coefficient (rho).

## Results

The sample consisted of 146 patients aged 18-40 (99 females and 47 males). Intra-Operator and Inter-Operator reliability were excellent (Table 1, 2). The Shapiro-Wilk test showed that the data was not normally distributed for total NOSE score (sig = 0.00) or for Septum Deviation Angle (sig = 0.017) (Table 3, 4). The Chi-Square test showed no significant difference between males and females in our sample ($p > 0.05$). The mean of septum deviation measurements was 9.53 ± 3.7 (95% confidence interval: 8.9-10.1). The mean of all NOSE scores was 8.01 ± 12.0 (95% confidence interval: 6.1-10.0), ranging from 0-60 on a scale of 100. 55% of patients had moderate or greater nasal septum deviation. 6.2 % of patients had a severe septum deviation. 49.3% of patients reported at least “mild” nasal airway obstruction. 7.5% of patients reported at least “moderate” nasal airway obstruction. Less than 1% of patients reported “severe” nasal airway obstruction. No patients in our sample reported “extreme” nasal airway obstruction. In this sample, patient-reported nasal airway obstruction as indicated by the NOSE scale was not correlated with septum deviation ($p = 0.321$) or age ($p = 0.893$), nor was septum deviation correlated with age ($p = 0.532$).

Table 1. Intra-Operator Reliability

**Intraclass Correlation Coefficient**

| | Intraclass Correlation[b] | 95% Confidence Interval | | F Test with True Value 0 | | | |
|---|---|---|---|---|---|---|---|
| | | Lower Bound | Upper Bound | Value | df1 | df2 | Sig |
| Single Measures | .979[a] | .909 | .995 | 93.213 | 8 | 8 | .000 |
| Average Measures | .989[c] | .952 | .998 | 93.213 | 8 | 8 | .000 |

Table 2. Inter-Operator Reliability

**Intraclass Correlation Coefficient**

| | Intraclass Correlation[b] | 95% Confidence Interval | | F Test with True Value 0 | | | |
|---|---|---|---|---|---|---|---|
| | | Lower Bound | Upper Bound | Value | df1 | df2 | Sig |
| Single Measures | .875[a] | .577 | .967 | 15.015 | 9 | 9 | .000 |
| Average Measures | .933[c] | .732 | .983 | 15.015 | 9 | 9 | .000 |

Table 3. Shapiro-Wilk Test

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Nose_Total | .255 | 146 | .000 | .715 | 146 | .000 |

Table 4. Shapiro-Wilk Test

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SDA_Degree | .063 | 145 | .200* | .978 | 145 | .017 |

Table 5.

**SDA_Cat**

| | | Frequency | Percent | Valid Percent |
|---|---|---|---|---|
| Valid | 0 | 3 | 2.1 | 2.1 |
| | mild | 62 | 42.5 | 42.5 |
| | moderate | 72 | 49.3 | 49.3 |
| | severe | 9 | 6.2 | 6.2 |
| | Total | 146 | 100.0 | 100.0 |

Table 6.

**Nose_Cat**

| | | Frequency | Percent | Valid Percent |
|---|---|---|---|---|
| Valid | 0 | 74 | 50.7 | 50.7 |
| | mild | 61 | 41.8 | 41.8 |
| | moderate | 10 | 6.8 | 6.8 |
| | severe | 1 | .7 | .7 |
| | Total | 146 | 100.0 | 100.0 |

**Nonparametric Correlations**

**Correlations**

| | | | Nose_Total | SDA_Degree | AGE | GENDER |
|---|---|---|---|---|---|---|
| Spearman's rho | Nose_Total | Correlation Coefficient | 1.000 | .083 | .011 | . |
| | | Sig. (2-tailed) | . | .321 | .893 | . |
| | | N | 146 | 145 | 146 | 0 |
| | SDA_Degree | Correlation Coefficient | .083 | 1.000 | .052 | . |
| | | Sig. (2-tailed) | .321 | . | .532 | . |
| | | N | 145 | 145 | 145 | 0 |
| | AGE | Correlation Coefficient | .011 | .052 | 1.000 | . |
| | | Sig. (2-tailed) | .893 | .532 | . | . |
| | | N | 146 | 145 | 146 | 0 |

## Figures

Figure 1. NOSE Scale, obtained from https://ent.stryker.com/conditions/nasal-airway-obstruction

## Over the past one month, how much of a problem were the following conditions for you?

| | Not a problem | Very mild problem | Moderate problem | Fairly bad problem | Severe problem |
|---|---|---|---|---|---|
| Nasal congestion or stuffiness | 0 | 1 | 2 | 3 | 4 |
| Nasal blockage or obstruction | 0 | 1 | 2 | 3 | 4 |
| Trouble breathing through my nose | 0 | 1 | 2 | 3 | 4 |
| Trouble sleeping | 0 | 1 | 2 | 3 | 4 |
| Unable to get enough air through my nose during exercise or exertion | 0 | 1 | 2 | 3 | 4 |

NOSE score (multiply your total score x5) ☐

Nasal obstruction severity classification: mild (5-25) | moderate (30-50) | severe (55-75) | extreme (80-100)

Figure 2.

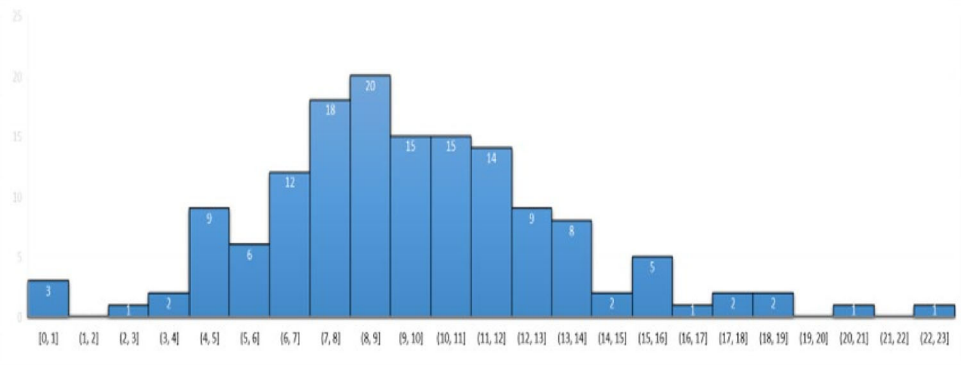



Figure 3.

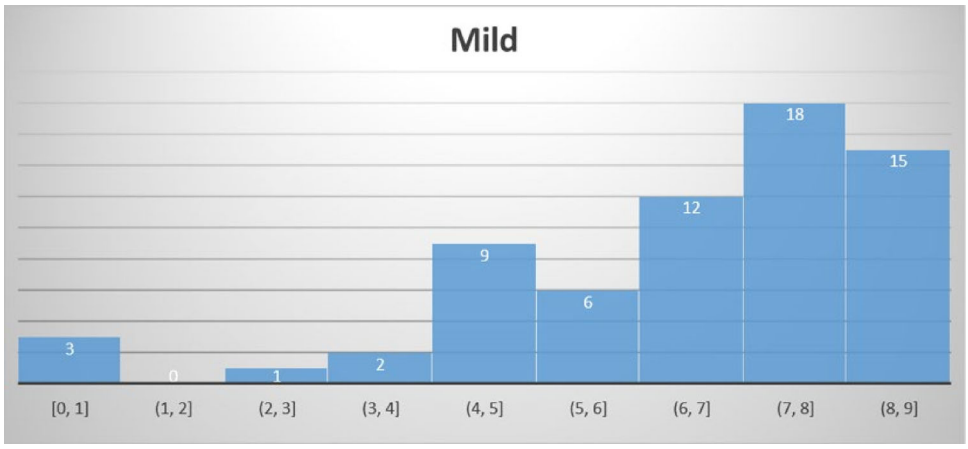



Figure 4.

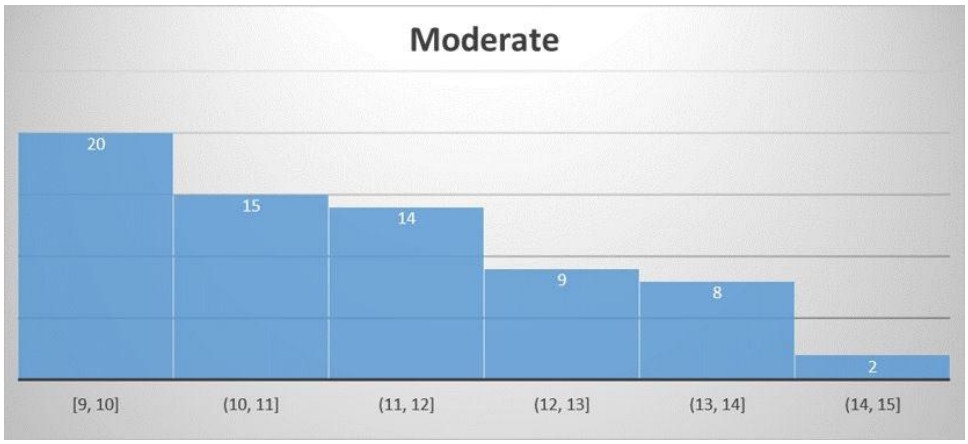
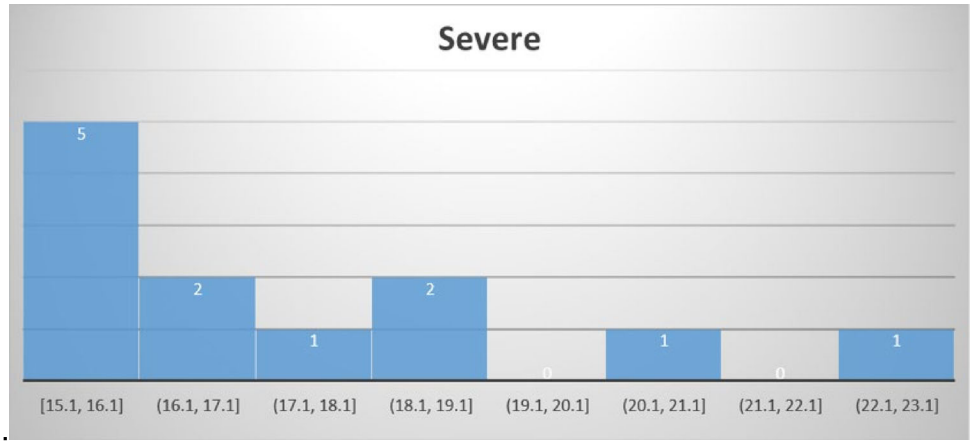



Figure 5.




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## Discussion

Per the Shapiro-Wilk test of normality, our data was not normally distributed for the total NOSE score (sig = .000) or for the septum deviation angle (sig = .017), so we used non-parametric tests for our data analysis and typical descriptive tests to determine prevalence.

In this sample, 98% of patients had some level of septum deviation. This coincides with much of the literature. The mean septum deviation angle of our sample is 9.53 ± 3.7 (95% CI: 8.9-10.1). This is within range of recent literature[17,19].

Our study showed that 55% of the 146 subjects had moderate or greater nasal septum deviation. This result confirms our hypothesis, but it is lower than that reported from other recent studies [17,19]. This could be due to the fact that our study sample size was smaller than the sample size of many septum deviation prevalence studies. Another possible explanation is the age range of current studies compared to ours. Many studies that explore septum deviation in adults have greater age ranges from age 18 (including patients that are middle and elderly ages) [17,19]. Research indicates that greater deviations are found with age; one study found that with every 10-year increase in age, the odds of septal deviation increased [19,23 (Moshfeghi 2020)]. Another potential reason for the fact that our study had smaller prevalence compared to other studies is that some of the more recent literature used ENT patients as their sample population, which means

these patients already had some form of nasal obstruction or issue that brought them in to see an ENT physician.

The mean NOSE score in our study of 8.0 ± 12.0 (95% CI: 6.1-10.0) is lower than that reported from most other populations [7,24,25 (Gerecci 2019, Ghorab 2020)]. This could be due to the dissimilar nature of our sample populations. NOSE scores have traditionally used samples of people who are patients of ENT physician offices. It would make sense that the prevalence of patient-reported nasal obstruction in patients seeking care from specialists may be higher than the general population. Our mean NOSE score does however fall within the standard deviation of multiple studies [26(Stefani 2020),27(Lipan 2013),28(van Zijl 2020)]. In addition, we found a similar mean total NOSE score compared with Dr. Rebecca Petts' project in 2021 on prevalence of patient-reported nasal obstruction in an orthodontic population.

Upon evaluation of nasal obstruction severity based on the categories of mild-extreme, almost half of our population (49.3%) reported at least mild nasal obstruction. This is higher than that reported in a large Swedish study where 26.7% had a nasal complaint [? (Jessen)]. Dr. Pett's project out of Case Western University in 2021 found a similar result (43.9% scored mild or above, 11.4% scored moderate or above).

Due to the fact that our data was not normally distributed, we used Spearman's correlation coefficient to determine any correlations. Not surprisingly, similar to other recent studies [(Weitzman 2020, (Serifoglu 2017)], we did not find a significant

correlation between total NOSE score and age (Spearman's rho p = .893 ) [(Weitzman 2020)], nor did we find a significant correlation between septum deviation and age (Spearman's rho p = .532 ) [(Serifoglu 2017)]. However, surprisingly, we did not find a significant correlation between NOSE scores and septum deviation (Spearman's rho p = .321). It is possible that the lack of correlation found is due to the limited age range in our study since it has been found in the literature that deviation tends to worsen in severity over time [(Moshfeghi)]. Another possible explanation is that many of the NOSE score studies include patients that are already complaining of nasal obstruction and are being treated by otolaryngologists. Other explanations include the possibility that the NOSE scale could be more correlated with other causes of nasal obstruction (i.e. allergic rhinitis) or possibly septum deviation in conjunction with presence of other anatomic contributors to nasal obstruction would correlate more with NOSE score.

## Conclusions

- Prevalence of moderate or greater septum deviation in our orthodontic population was found to be 55.5%.
- No correlation was found between NOSE score and septum deviation.

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