CASE REPORT

Improvement of nasal septal deviation in response to Orthodontic treatment in an adult patient

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ABSTRACT

Here we present an improvement in nasal septal deviation (NSD) in an adult male patient who received non-surgical treatment for a skeletal Class III malocclusion due to maxillary deficiency, hypo-divergent facial pattern, and significant asymmetry. The patient had already received extractions at another clinic in preparation for orthognathic surgery, and mid-treatment was seeking a non-surgical treatment option. Cone-beam computed tomography (CBCT) analysis showed a nasal septal deviation and an enlarged polyp that was accompanied by a cant in the nasal floor. In addition, the patient presented a significant crossbite, mandibular shift, and occlusal plane cant. Transverse and sagittal correction of the maxilla and condylar remodeling was addressed through orthopedic treatment by Neuro-Immuno-Mechanotherapy (NIM), including sutural stimulation, cortical drift, periosteal stimulation accompanied with micro-osteoperforations (MOPs), and osteogenic stimulation using high-frequency acceleration. At the end of treatment, significant improvement in skeletal and dental relations were observed. In addition, the patient's NSD demonstrated a significant improvement that was accompanied by a decrease in the size of the polyp and improvement of the nasal floor cant.

Background

The adult nasal septum is composed of three parts: the cartilaginous septum, the perpendicular plate, and the vomer. The perpendicular plate of the ethmoid and the vomer bone make up the bony component of the nasal septum.

Nasal septal deviation (NSD) is defined as deviation from the facial midline of either the bony or cartilaginous septum or both. It has been estimated that NSD is a common abnormality that can be observed in 80% of the population [1-3].

Mild NSD might be unproblematic; however, more prominent NSD has been associated with severe nasal obstruction that can increase nasal airway resistance [4, 5]. Resultant impaired nasal breathing can lead to preferential mouth breathing, which if chronic, may cause craniofacial alterations [6]. The nasal airway obstruction resulting from NSD may also contribute to Sleep Disordered Breathing [5, 7]. Additionally, NSD alters the air flow pattern of the nasal cavity, nasal cycle and mucociliary clearance, which is associated with chronic sinusitis [5, 8-10].

The etiology of NSD is unclear. While some deviation has been related to facial trauma, many people believe NSD is genetic or results from maxillary deficiency [11-13].

While surgery has been suggested as an option of choice to correct NSD [14, 15], improvement in NSD has been observed in growing children treated with maxillary expansion [16-18]. However, to the best of our knowledge, no improvement in NSD following orthodontics treatment in adults has been reported in the literature.

Here we present an adult patient with a severe maxillary deficiency who was undergoing orthodontic treatment in preparation for orthognathic surgery. However, the patient changed his mind mid-treatment and refused to proceed with the surgical treatment. The patient was referred to the CTOR clinics for a possible non-surgical treatment option. CBCT examination, in addition to a maxillary deficiency, demonstrated a significant NSD and a large polyp associated with a nasal floor cant. In addition, the patient demonstrated some degree of dental root resorption. The previous Orthodontist had already extracted the maxillary first premolars and mandibular second premolars in preparation for the decompensation stage of orthognathic surgery, which made the non-surgical treatment of this malocclusion more challenging. To address the skeletal problem Neuro-Immuno-Mechanotherapy (NIM) was proposed to stimulate cortical drift, sutural stimulation and asymmetry correction to gradually improve the maxillary-mandibular relation. Personalized mechanotherapy [19], combined with micro-osteoperforations (MOPs) in the mandible, was designed to decrease the possibility of further root resorption [20]. Later in treatment, high-frequency acceleration was applied to facilitate further bone formation and alveolar bone remodeling [21-24]. The final CBCT demonstrated improved skeletal Class III relation, a Class I dental relation and significant improvement in the NSD.

Patient Presentation, Etiology and Diagnosis

A healthy 29.4-year-old male presented to our clinic with a chief concern of unsatisfactory orthodontic treatment and facial esthetics due to a crossbite and a protrusive chin. He had been in treatment with fixed orthodontic appliances for 1 year, and the maxillary first premolars and mandibular second premolars were extracted in preparation for orthognathic surgery. Clinical examination revealed bilateral temporomandibular joint (TMJ) clicking during opening and closing, which the patient reported was non-painful. The patient had no history of trauma.

Extraoral examination and frontal portrait photographs (Figure 1) showed a brachyfacial pattern and a decreased lower facial third. Facial asymmetry was noted and the mandible deviated to the right upon closure. No lip incompetence or mentalis strain at rest were observed.

Portrait photographs (Figure 1) showed a concave profile with a deficient maxillary lip relative to the E-plane and a protrusive mandibular lip relative to the maxillary lip. The labiomental angle was acute and the chin-to-throat angle was obtuse (89° and 132°, respectively) (Table I). Full smile was broad with increased buccal corridor width and asymmetric incisal display (70 to 50%).

Intraoral examination (Figure 1) showed fair oral hygiene and normal frenum attachments. Severe proclination of the maxillary anterior teeth was noted. The maxillary midline was deviated 3 mm toward the right relative to the facial midline, while the mandibular midline was deviated 1.5mm to the left relative to the maxillary midline. Measurements indicated that there was a 6° incisal plane cant that was higher on the right side.

Digital cast analysis showed Class III canine and molar relationships on both sides. The overjet was -2.1 mm and the overbite varied from -1.5 to 1.48 mm. The maxillary dental arch was constricted with an inter-canine and inter-molar width of 52.1 mm and 58.4 mm, respectively, whereas the mandibular dental arch was broad with an inter-canine and inter-molar width of 45.1 mm and 46.2 mm, respectively. Extraction spaces in the maxilla and mandible had not been addressed leaving 8 mm spacing in the maxillary dental arch and 15 mm spacing in the mandibular dental arch. An anterior Bolton discrepancy of 3 mm due to maxillary excess was also measured. A crossbite was observed extending from the maxillary right second premolar to the maxillary left second premolar. The mandibular dental arch showed a severe curve of Wilson.

The panoramic radiograph (Figure 2) revealed a complete dentition except for the maxillary first premolars and mandibular second premolars, which had been previously extracted. All third molars were present. Roots on all teeth were fully developed. Mild to moderate root resorption was seen on maxillary and mandibular anterior teeth and the maxillary second premolars. Asymmetric condyles showed some degree of remodeling. Mandibular morphology showed prominent and asymmetric gonial angles.

Figure 1: Pre-treatment portrait and intra-oral photographs. *Adult male patient who was receiving orthodontic treatment (with fixed appliances shown in photos) in another clinic in preparation for orthognathic surgery. Patient was referred to CTOR clinics for possibility of non-surgical treatment. Lateral profile photograph showed a brachyfacial concave profile, a decrease in the mandibular facial third, a protrusive chin, and deficient maxillary lip and acceptable mandibular lip position. Frontal portrait photographs show dark buccal corridors, asymmetric incisal display upon smiling, maxillary dental midline deviated 3 mm to the right in relation to the facial midline, mandibular midline deviated 1.5 mm to the left with respect the maxillary dental midline. Measurements indicated a cant of the incisal plane elevated on the right side. Facial asymmetry noted as the mandible deviated to the right. Intraoral photographs reveal a constricted maxilla, spacing in area of maxillary first premolars and mandibular second premolars as they were previously extracted. A crossbite observed extending from the maxillary right premolar to left first premolar, and a Class III canine and molar relationship.*

Figure 2: Pre-treatment panoramic radiograph. *Panoramic radiograph shows a complete dentition except for maxillary first premolars and mandibular second premolars. Roots on all teeth were fully developed and showed mild to moderate root resorption on the anterior teeth and the maxillary premolars. Bone loss is clear around the mandibular anterior teeth and the maxillary canines. Asymmetric condyles showed some degree of remodeling and flattening on their anterior surface. Mandibular morphology shows prominent and asymmetric gonial angles with some degree of remodeling on the left side. Nasal polyp is visible along the medial wall of the left nasal cavity*

Lateral cephalometric analysis (Figure 3 and Table I) showed a skeletal Class III relation (ANB = -3.9°) with a hypodivergent (FMA = 14°, SN-MP = 23.3°) and protruded mandible (SNB = 86.1°). Both maxillary and mandibular incisors were proclined (U1°- SN = 112.4°, IMPA = 101.2°).

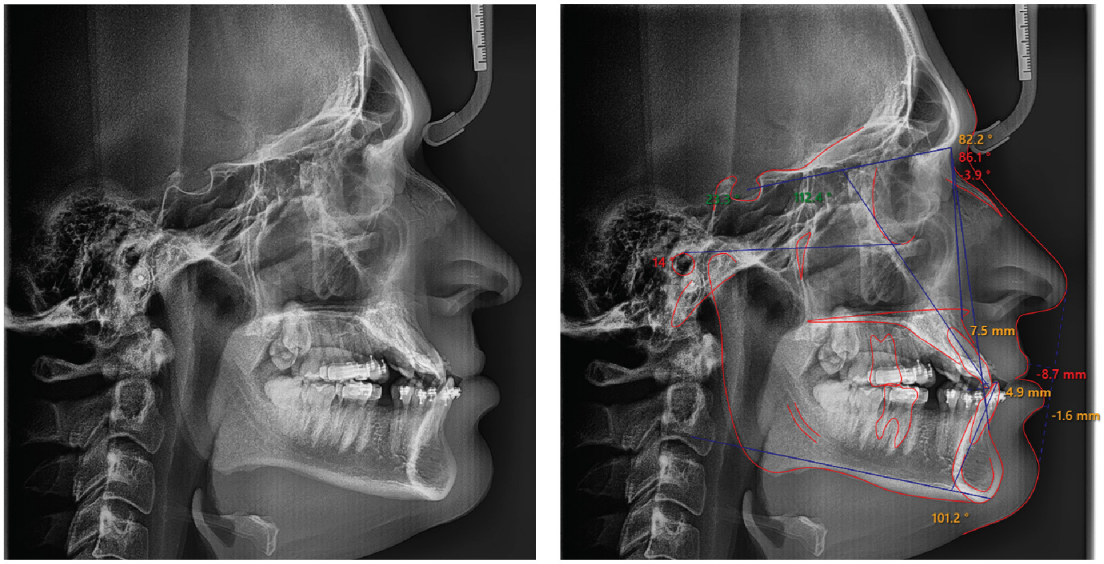

Figure 3: Pre-treatment lateral view of cephalometric radiograph. *Cephalometric analysis showed a Class III tendency (ANB= -3.9°), hypo-divergent profile and protruded mandible (FMA= 14°, SN-MP= 23.3°, SNB= 86.1°), severely proclined maxillary incisors (U1°-SN= 112°), proclined mandibular incisors (IMPA= 101.2°) and an anterior crossbite with -2.1 mm of overjet.*

Measurement	Initial Value	Final Value	Norm
SNA (deg)	82.2°	83°	81.8 ± 3.7°
SNB (deg)	86.1°	84.6°	79.2 ± 2.3°
ANB (deg)	-3.9°	-1.6°	2.6 ± 2.4°
FMA (deg)	14°	17.9°	25.8 ± 3°
SN-MP (deg)	23.3°	27.4°	31.2 ± 3°
Maxillary Incisor to SN (deg)	112.4°	107.8°	102.4 ± 5.5°
IMPA (deg)	101.2°	79.5°	92.1 ± 9°
Maxillary Incisor to NA (mm)	7.5 mm	4.1 mm	3.8 ± 2.7 mm
Mandibular Incisor to NB (mm)	4.9 mm	-1 mm	3.4 ± 3.6 mm
Maxillary Lip to E-Plane (mm)	-8.7 mm	-9 mm	-2 ± 2 mm
Mandibular Lip to E-Plane (mm)	-1.6 mm	-8.3 mm	-2 ± 2 mm
Nasolabial Angle (deg)	99.9°	103.1°	90-95°
Labiomental Angle (deg)	89°	91°	120 ± 10°
Chin-Throat Angle (deg)	132°	124°	120 ± 126°
Chin Throat Length (deg)	53 mm	48.2 mm	42 ± 6 mm

Table I: Cephalometric Analysis Pre- and Post- Treatment. *Angular and linear measurements were measured using craniofacial skeletal, dental and soft tissue landmarks identified on pre- and post-treatment lateral cephalograms (° - degrees, mm - millimeters).*

The CBCT scan (Figure 4) showed a NSD towards the left (Figure 4A), and a large polyp that changed the contour of the nasal floor and contributed to the nasal floor cant (Figure 4B). Soft tissue analysis (Table I) indicated that the upper lip was deficient but the lower lip was protrusive compared with upper lip, but retrusive relative to the E-line (-8.7 and -1.6 respectively).

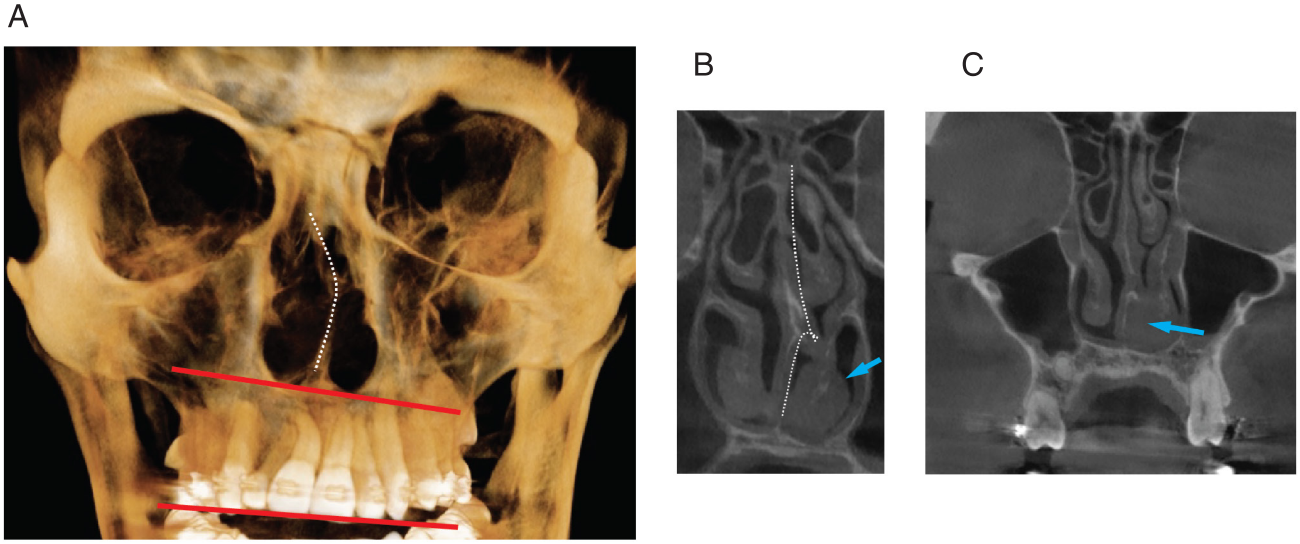

Figure 4: Pre-treatment frontal view of cone-beam computed tomography (CBCT) scan. *A) Pre-treatment frontal view of CBCT scan shows a nasal septal deviation towards the left side (vertical dotted line positioned slightly to the right of the septum to show bone deviation), and an asymmetric mandibular position canted upwards towards the right side (horizontal red lines). B) Coronal section localizing the nasal polyp (arrow in B and C) to the left nasal cavity. Cant of the nasal cavity floor up to the right is clearly visible. C)*

Treatment Objectives

The primary objectives were to establish an optimal functional outcome, harmonic and stable occlusion and improve the facial and dental esthetics, which in more detail included the following:

I. Facial esthetics: improve the facial profile, labiomental and chin-to-throat angles, decrease the buccal corridors, increase lower facial height, correct the occlusal plane cant and improve incisal display.

II. Skeletal objectives: improve the maxillary transverse deficiency, improve sagittal jaw disharmony, decrease the hypo-divergency, and improve the asymmetric mandible.

III. Dental objectives: Correct the crossbite, improve the dental midlines, close the extraction spaces, improve incisal inclination, establish proper overjet and overbite relation, establish a functional and stable Class I canine and molar relationship, correct the incisal/occlusal cant, improve marginal ridge discrepancies, level gingival margins and gingival height of contour around the anterior teeth, prevent or minimize further root resorption.

Treatment Options

The patient expressed opposition to orthognathic surgery; therefore, this option was not discussed. After comprehensive assessment, non-surgical orthopedic and orthodontic treatment was discussed with the understanding of the limitations posed by the severity of the skeletal malocclusion and the patient's age. Consultation with an ENT specialist was recommended.

Mechanotherapy Plan

The maxillary transverse deficiency was addressed by a tooth-anchored Hyrax expander, which was accompanied by periosteal stimulation to maximize cortical drift. Mandibular sectional mechanics with fixed appliances was used for canine and first premolar retraction, followed with full set up and incisor retraction. Retraction of mandibular teeth was done using MOPs to decrease the risk of further root resorption [20]. These steps were followed with full maxillary and mandibular fixed appliances. NIM therapy principles were used to address the mandibular asymmetry and re-establish normal mandibular function. After major skeletal and dental corrections, high-frequency acceleration (VPro5; Propel Inc) was started to stimulate bone formation and condylar remodeling. After treatment, fixed lingual retainers from canine to canine were placed in the maxillary and mandibular arches. A customized removable appliance (MA appliance) was used to maintain the maxillary and mandibular sagittal and transverse corrections. The patient was referred for further myofunctional therapy to change the position of the tongue.

Duration of Treatment

The total treatment duration was 29 months.

Treatment Outcome

I. Facial and Soft Tissue analysis

The overall facial balance was improved and the lower facial height was increased. The labiomental angle improved 2^{o}, while the chin-throat angle and the chin-throat length improved 8^{o} and 4.8 mm, respectively (Figure 5 and Table I).

II. Smile analysis

The patient showed a wider maxilla and a significant decrease in buccal corridor width at full smile. Incisal/occlusal plane cant correction also contributed significantly to the improved smile esthetics. Gingival display evaluation showed leveling of the gingival margins and the height of contour around the anterior teeth without detrimental effects on the patient's periodontal health (Figure 5).

III. Intra-oral and Digital Cast analysis

Intra-oral exam and cast analysis at the end of treatment showed the following outcomes (Figure 5):

A) The maxillary dentition was expanded transversely with an increase in the inter-molar width of 1.2 mm and inter-canine width of 3.2 mm.

B) The spaces in the maxillary and mandibular dental arches were closed.

C) The crossbite was resolved, and proper overjet (1.1 mm) and overbite (2.8 mm) were established.

D) Class I canine and molar occlusion was established.

E) Both the maxillary and mandibular dental midlines were aligned with the facial midline.

Figure 5: Post-treatment portrait and intra-oral photographs. *Post-treatment portrait photographs demonstrate an improvement in the facial profile, with an increase in the lower facial height, and improved smile esthetics. Intra-oral photographs show maxillary arch development, aligned maxillary and mandibular dentition, full correction of the crossbite, an ideal overjet and overbite relation, Class I molar and canine occlusal relationship, correction of the incisal/occlusal plane cant and closure of the extraction spaces. Both maxillary and mandibular dental midlines are aligned with the facial midline. Gingival margins and heights of contour improved around the anterior teeth. Lingual fixed retainers are shown extending from canine to canine in both arches.*

F) The incisal/occlusal plane cant was corrected.

G) The patient demonstrated cuspid-rise and a mutually protected occlusion with no additional bone loss or gingival recession. No pain or clicking was reported or observed in either TMJ.

IV. Panoramic Radiograph Analysis

Post-treatment panoramic radiograph (Figure 6) showed root alignment with no additional loss in vertical height of alveolar bone around any teeth, and improvement in the condylar remodeling around the anterior surface of the condyle.

Figure 6: Post-treatment panoramic radiograph. *Panoramic radiograph at the end of treatment shows good root alignment, no additional bone loss and bone remodeling on the anterior surface of the condyle. Noticeable reduction in the size of the nasal polyp is also noted.*

V. Cephalometric Analysis

A) Pre-treatment and post-treatment comparison of lateral cephalometric analyses (Table I and Figure 7) demonstrate significant improvement in the maxillary and mandibular sagittal skeletal relationship, with the ANB angle increasing from -3.9^{o} to -1.6^{o}.

B) The skeletal vertical dimension improved as shown by a change in FMA from 14^{o} to 17.9^{o} (Table I and Figure 7).

C) Superimposition of pre- and post-treatment radiographs showed a clockwise rotation of the mandible resulting from extrusion and uprighting of the maxillary and mandibular molars (Figure 8).

D) Maxillary superimposition showed the extrusion and uprighting of the molars and extrusion, retrusion and retroclination of the anterior teeth (Figure 8).

E) Mandibular superimposition revealed extrusion and uprighting of the molars, and decreased angulation of the mandibular anterior teeth (Figure 8).

F) The post-treatment mandibular movement path was smooth without deviations, and neither clicking nor pain was present in either TMJ at the end of treatment.

VI. CBCT analysis of Nasal Cavity

CBCT analysis demonstrated, improvement in NSD (Figure 9A), decrease in polyp size and leveling of the nasal floor (Figure 9B). In addition, the nasal cavity demonstrated a modest expansion of 2 mm anteriorly and 1 mm posteriorly, as measured by the height of contour of the nasal walls (Figure 10 and Table II).

Discussion

The nasal cavity has significant effects on oral cavity structure. It has been hypothesized that nasal breathing acts as a capsular matrix for development of the maxilla [25]. Chronic nasal cavity obstruction can be accompanied with maxillary constriction, posterior teeth extrusion, hyper-divergency, and even severe Class II or Class III skeletal pattern [6].

While the effect of the nasal cavity on the oral cavity has received some attention, the role of the oral cavity on the nasal cavity is not clear. Since the roof of the oral cavity is the floor of nasal cavity, and the position of the walls of the nasal cavity are defined by the position of the maxilla, one

Figure 7: Post-treatment lateral cephalometric radiograph and analysis. *Post-treatment cephalometric analysis showed overall improvement in maxillary and mandibular relationship (ANB= -1.6°), improved mandibular plane angle (FMA= 17.9°, SN-MP= 27.4°), correction of anterior crossbite into ideal overjet, ideal overbite, improvement in the maxillary incisor inclination (U1°-SN= 107.8°) and mandibular incisor uprighting (IMPA= 79.5°).*

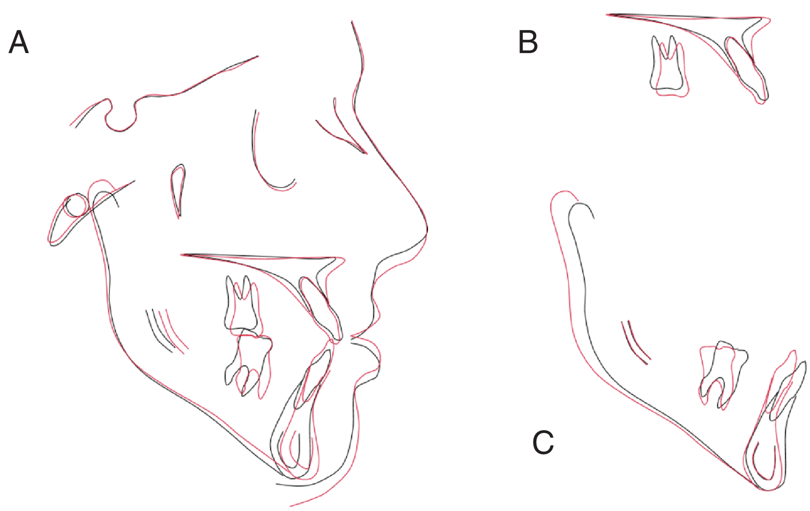

Figure 8: Superimposition of pre- and post-treatment cephalometric tracings. *Cephalometric superimposition of pre-treatment (black tracing) and post-treatment (red tracing) on the anterior cranial base shows clockwise rotation of the mandible, extrusion of the maxillary and mandibular molars, extrusion, retraction and retroclination of the maxillary anterior teeth, and retraction and retroclination of the mandibular anterior teeth (A). Superimposition on the body of the maxilla shows maxillary molar extrusion, uprighting, and mesialization, and incisor retroclination (B). Superimposition based on the inferior-alveolar nerve and inner profile of the mandibular symphysis reveals mandibular molar extrusion and uprighting, and incisor retroclination (C).*

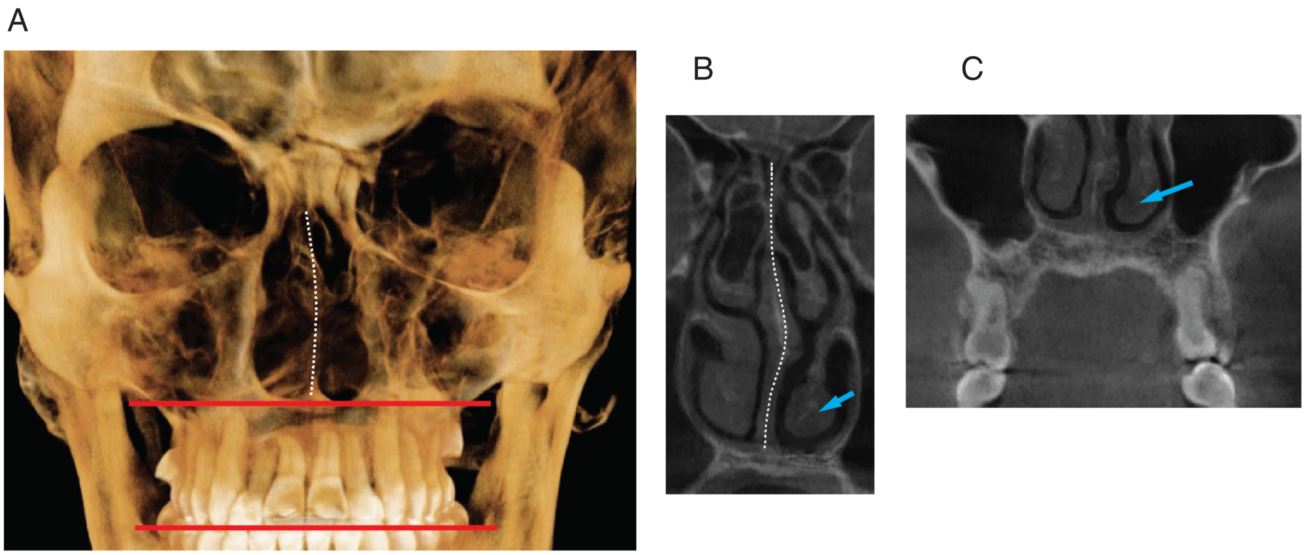

Figure 9: Post-treatment frontal view of cone-beam computed tomography (CBCT) scan. *A) Post-treatment lateral view of CBCT scan showed an overall improvement of the NSD (vertical dotted line) and a correction of mandibular cant (horizontal red lines). Note the leveling of the nasal cavity floor. B) Correction of the NSD and absence of the nasal polyp (white arrows on B and C)*

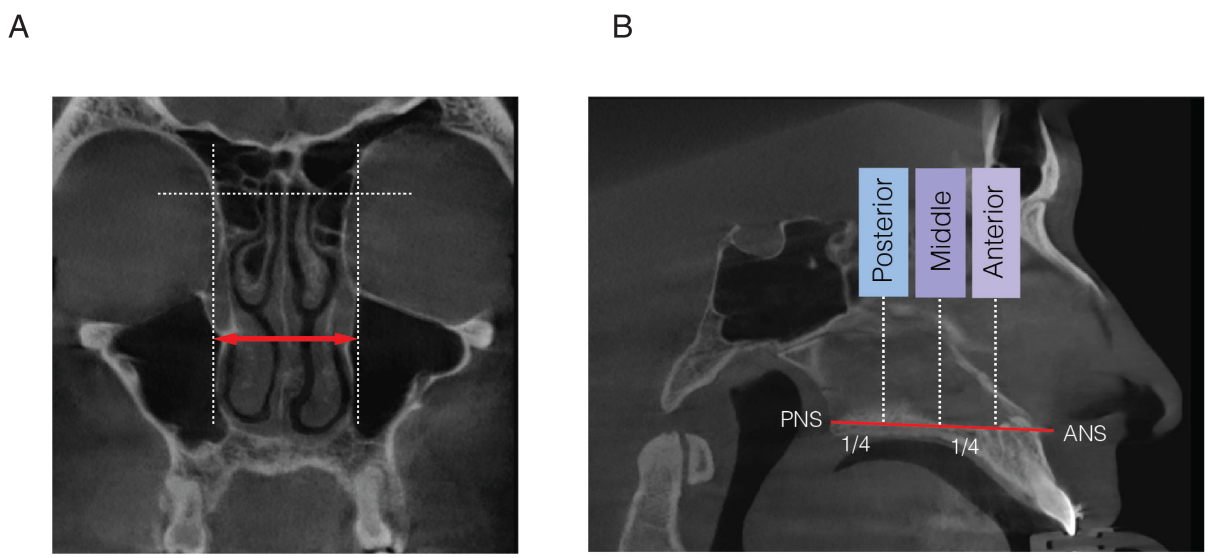

Figure 10: Maximum nasal cavity width in the anterior, middle, and posterior areas. *Linear measurements of the width of the nasal cavity were completed on pre- and post-treatment CBCT images (mm – millimeters). A) Measurements were taken from the widest points of the nasal cavity by drawing vertical lines (vertical dashed lines) perpendicular to the horizontal line joining the center of the right and left orbit (horizontal dashed line). The measurement was taken where the vertical line touched the curvature of the nasal cavity at the anterior, middle and posterior sections of the nasal cavity. B) The regions of the nasal cavity were established by joining ANS to PNS (red horizontal line in B) and dividing the length of that line into 4 equal sections. Vertical lines at the intersection of those 4 segments (vertical lines in B) mark the anterior, middle, and posterior sections where measurement of the with were completed.*

	Pre-treatment	Post-treatment	Difference
Anterior section	23.5 mm	25.6 mm	2.1 mm
Middle section	28.1mm	29.4 mm	1.3 mm
Posterior section	31.6 mm	32.5 mm	0.9 mm

Table II: Maximum width in different sections of the nasal cavity. *Linear measurements of the width of the nasal cavity in the anterior, middle, and posterior sections, were completed on pre- and post-treatment CBCT images (mm – millimeters) as illustrated in figure 10.*

would expect any changes in maxillary transverse, vertical or sagittal dimensions to automatically affect the nasal cavity dimensions. In other words, nasal breathing affects the shape of the oral cavity, which in turn indirectly affects the nasal cavity's shape. Based on this logic, one would expect any deficiency in maxillary growth should manifest itself also as a decrease in the nasal cavity size. On the other hand, any increase in maxillary dimensions should simultaneously be accompanied by increased nasal cavity dimension. For example, it has been shown that maxillary expansion provided during orthodontic treatment has the potential to alter the internal dimensions of the nasal cavity, promote the reduction of nasal resistance, increase in airflow, and even produce a favorable change at the patient's breathing pattern [26-39]. Based on this argument, improvement in nasal breathing in response to orthopedic treatment in children can be related to displacement of hemimaxilla in space and, consequently, circum-maxillary sutural growth. However, these changes in adults are more limited and, by themselves, cannot completely explain the improvement in nasal breathing that is observed after orthodontic treatment. For example, in the patient presented here, orthopedic treatment produced an increase in nasal cavity size both anteriorly and posteriorly, but these increases were modest (1-2 mm). While these changes can partially improve the nasal passage, they cannot be considered as the sole cause of changes that were observed in the nasal cavity by CBCT and improvement of nasal breathing that was reported by the patient after treatment.

One of the main changes that was observed in this patient was the change in the nasal septum's deviation. NSD occurred at both the bony septum and cartilage septum. Improvement of NSD was accompanied by a spontaneous decrease in the polyp size and opening of the nasal passage. These changes could not be simply explained due to application of an expander. While in growing children significant NSD improvement has been observed in response to maxillary expansion [16, 40, 41], expanders alone have not demonstrated any effect on NSD in adults [18, 39].

Could the deviation of the bony nasal septum in this patient before treatment and improvement after treatment be explained by occlusal forces, especially when many studies emphasize the importance of the nasal septum as the middle bar of the naso-maxillary capsule [42]? Based on Wolff's law, any change in the function of bones is followed by changes in their internal and external conformation. Bone architecture changes in ways that keep bone strains significantly below fracture strength of 25000 micro-strain. To achieve this goal, bone realigns itself with the line of action of the applied force to prevent bending. In this patient, his crossbite pushed him to use his right side as the main side for occlusion. This factor, could change the balance of the force on both sides of nasal septum. This change in the balance of the occlusal force could be accompanied by bending moments on the nasal septum. Occlusion correction without a significant increase in the nasal cavity size could balance the forces on both sides of the nasal septum and allow the bony septum to realign itself and decrease its bending. This is similar to the mechanism used to improve the shape of bone after a fracture, if it heals incorrectly [43-45].

In line with the above argument regarding occlusal force impact on NSD, one can consider the biomechanical forces as the contributing factors in the nasal floor cant. This can explain the association that has been reported between NSD and asymmetric facial development [46, 47]. In the case presented here, however, existence of the chronic polyp could also have a local effect in reshaping the nasal floor. Therefore, correcting the nasal floor cant after treatment could be explained by both the improvement in biomechanics and the decrease in the polyp size.

Based on the above discussion, one can conclude that orthodontic treatment can affect different parts of the nasal cavity and can have a significant effect on the overall health of the nasal passage. Perhaps the role of orthopedic treatment to correct the facial structure should be redefined to include the nasal cavity and the medical community could take advantage of the Therapeutic possibilities that this treatment can provide.

Applied Innovation

Nasal septal deviation is a common problem among patients. While the role of occlusion and changes in the balance of forces on NSD have not been reported before, this case report demonstrated significant improvement in NSD following changes in occlusal biomechanics. To the best of our knowledge this is the first time the relation between NSD and occlusion has been reported. Considering that bone shape and curvature are influenced significantly by orthopedic mechanics, the effect of change in force distribution after malocclusion correction (in addition to maxillary displacement) in both children and adults should be further studied.

References

1. Serifoglu I, Oz İ, Damar M, Buyukuysal MC, Tosun A, Tokgöz Ö. Relationship between the degree and direction of nasal septum deviation and nasal bone morphology. Head Face Med. 2017;13(1):3. Epub 20170228. doi: 10.1186/s13005-017-0136-2. PubMed PMID: 28245851; PubMed Central PMCID: PMCPMC5331660.

2. Roblin DG, Eccles R. What, if any, is the value of septal surgery? Clin Otolaryngol Allied Sci. 2002;27(2):77-80. doi: 10.1046/j.1365-2273.2002.00531.x. PubMed PMID: 11994109.

3. van Egmond MM, Rovers MM, Hendriks CT, van Heerbeek N. Effectiveness of septoplasty versus non-surgical management for nasal obstruction due to a deviated nasal septum in adults: study protocol for a randomized controlled trial. Trials. 2015;16:500. Epub 20151104. doi: 10.1186/s13063-015-1031-4. PubMed PMID: 26537948; PubMed Central PMCID: PMCPMC4634847.

4. Kim SK, Heo GE, Seo A, Na Y, Chung SK. Correlation between nasal airflow characteristics and clinical relevance of nasal septal deviation to nasal airway obstruction. Respir Physiol Neurobiol. 2014;192:95-101. Epub 20131219. doi: 10.1016/j.resp.2013.12.010. PubMed PMID: 24361464.

5. Wang J, Dou X, Liu D, Song P, Qian X, Wang S, et al. Assessment of the effect of deviated nasal septum on the structure of nasal cavity. Eur Arch Otorhinolaryngol. 2016;273(6):1477-80. Epub 20150914. doi: 10.1007/s00405-015-3770-y. PubMed PMID: 26370235.

6. Sangsuwon C AF, Alansari S, Alikhani M, Nervina JM, Teixeira CC, Alikhani M. The One-Couple System as an Innovative Tool for Non-Surgical, Non-Extraction Correction of Skeletal Deformities Caused by Mouth-Breathing. Innovation. May 2022. doi: doi:10.30771/2022.1.

7. Alsufyani N, Isaac A, Witmans M, Major P, El-Hakim H. Predictors of failure of DISE-directed adenotonsillectomy in children with sleep disordered breathing. Journal of Otolaryngology - Head & Neck Surgery. 2017;46(1):37. doi: 10.1186/s40463-017-0213-3.

8. Calhoun KH, Rotzler WH, Stiernberg CM. Surgical Anatomy of the Lateral Nasal Wall. Otolaryngology–Head and Neck Surgery. 1990;102(2):156-60. doi: 10.1177/019459989010200210. PubMed PMID: 2113241.

9. Yousem DM, Kennedy DW, Rosenberg S. Ostiomeatal complex risk factors for sinusitis: CT evaluation. The Journal of otolaryngology. 1991;20 6:419-24.

10. Cho SH, Kim TH, Kim KR, Lee JM, Lee DK, Kim JH, et al. Factors for maxillary sinus volume and craniofacial anatomical features in adults with chronic rhinosinusitis. Arch Otolaryngol Head Neck Surg. 2010;136(6):610-5. doi: 10.1001/archoto.2010.75. PubMed PMID: 20566913.

11. Baddam P, Young D, Dunsmore G, Nie C, Eaton F, Elahi S, et al. Nasal Septum Deviation as the Consequence of BMP-Controlled Changes to Cartilage Properties. Front Cell Dev Biol. 2021;9:696545. Epub 20210624. doi: 10.3389/fcell.2021.696545. PubMed PMID: 34249945; PubMed Central PMCID: PMCPMC8265824.

12. Blaugrund SM. Nasal obstruction. The nasal septum and concha bullosa. Otolaryngol Clin North Am. 1989;22(2):291-306. PubMed PMID: 2664653.

13. D'Ascanio L, Lancione C, Pompa G, Rebuffini E, Mansi N, Manzini M. Craniofacial growth in children with nasal septum deviation: a cephalometric comparative study. Int J Pediatr Otorhinolaryngol. 2010;74(10):1180-3. Epub 20100809. doi: 10.1016/j.ijporl.2010.07.010. PubMed PMID: 20696485.

14. Guyuron B, Uzzo CD, Scull H. A practical classification of septonasal deviation and an effective guide to septal surgery. Plast Reconstr Surg. 1999;104(7):2202-9; discussion 10-2. doi: 10.1097/00006534-199912000-00039. PubMed PMID: 11149789.

15. Fettman N, Sanford T, Sindwani R. Surgical Management of the Deviated Septum: Techniques in Septoplasty. Otolaryngologic Clinics of North America. 2009;42(2):241-52. doi: https://doi.org/10.1016/j.otc.2009.01.005.

16. Gray LP. Results of 310 cases of rapid maxillary expansion selected for medical reasons. J Laryngol Otol. 1975;89(6):601-14. doi: 10.1017/s0022215100080804. PubMed PMID: 1095671.

17. Gray LP. Rapid maxillary expansion and impaired nasal respiration. Ear Nose Throat J. 1987;66(6):248-51. PubMed PMID: 3301309.

18. Aziz T, Wheatley FC, Ansari K, Lagravere M, Major M, Flores-Mir C. Nasal septum changes in adolescent patients treated with rapid maxillary expansion. Dental Press J Orthod. 2016;21(1):47-53. doi: 10.1590/2177-6709.21.1.047-053.oar. PubMed PMID: 27007761; PubMed Central PMCID: PMCPMC4816585.

19. Abdullah F, Sangsuwon C, Alansari S. Personalized mechanotherapy: simultaneous correction of posterior crossbite and anterior open bite in the presence of root shortening. Innovation. 2020. doi: doi:10.30771/2020.1.

20. Teixeira CC, Abdullah F, Billings D, Sangsuwon C, Alansari S, Nervina JM, Alikhani M. Novel Application of Micro-Osteoperforations During Treatment of Severe Malocclusion. Innovation. December 2021. doi: doi:10.30771/2021.4.

21. Alikhani M, Khoo E, Alyami B, Raptis M, Salgueiro JM, Oliveira SM, et al. Osteogenic effect of high-frequency acceleration on alveolar bone. J Dent Res. 2012;91(4):413-9. Epub 20120214. doi: 10.1177/0022034512438590. PubMed PMID: 22337699; PubMed Central PMCID: PMCPMC3310758.

22. Alikhani M, Lopez JA, Alabdullah H, Vongthongleur T, Sangsuwon C, Alikhani M, et al. High-Frequency Acceleration: Therapeutic Tool to Preserve Bone following Tooth Extractions. J Dent Res. 2016;95(3):311-8. Epub 20151215. doi: 10.1177/0022034515621495. PubMed PMID: 26672126; PubMed Central PMCID: PMCPMC6728694.

23. Alikhani M, Sangsuwon C, Alansari S, Nervina JM, Teixeira CC. High Frequency Acceleration: A New Tool for Alveolar Bone Regeneration. JSM Dent Surg. 2017;2(4). Epub 20170825. PubMed PMID: 30215055; PubMed Central PMCID: PMCPMC6133260.

24. Teixeira CC, Abdullah F, Alikhani M, Alansari S, Sangsuwon C, Oliveira SP, Nervina JM, Wang H, Alikhani M Orthopedic Effect of Dynamic Loading on Condylar Cartilage. Innovation. June 2022. doi: doi:10.30771/2022.2.

25. Bromage TG. The Functional Matrix Hypothesis Revisited. 5. Orofacial Capsular Matrices Defined. Innovation. September 2022.

26. Cross DL, McDonald JP. Effect of rapid maxillary expansion on skeletal, dental, and nasal structures: a postero-anterior cephalometric study. Eur J Orthod. 2000;22(5):519-28. doi: 10.1093/ejo/22.5.519. PubMed PMID: 11105408.

27. Muniz R, Cappellette M, Carlini D. Changes in nasal volume of patients undergoing rapid maxillary expansion. Revista Dental Press de Ortodontia e Ortopedia Facial. 2008;13:54-9.

28. Timms DJ. The Effect of Rapid Maxillary Expansion on Nasal Airway Resistance. British Journal of Orthodontics. 1986;13(4):221-8. doi: 10.1179/bjo.13.4.221. PubMed PMID: 3535873.

29. Warren DW, Hershey HG, Turvey TA, Hinton VA, Hairfield WM. The nasal airway following maxillary expansion. Am J Orthod Dentofacial Orthop. 1987;91(2):111-6. doi: 10.1016/0889-5406(87)90467-7. PubMed PMID: 3544807.

30. Oliveira De Felippe NL, Da Silveira AC, Viana G, Kusnoto B, Smith B, Evans CA. Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: short- and long-term effects. Am J Orthod Dentofacial Orthop. 2008;134(3):370-82. doi: 10.1016/j.ajodo.2006.10.034. PubMed PMID: 18774083.

31. Ramires T, Maia RA, Barone JR. Nasal cavity changes and the respiratory standard after maxillary expansion. Braz J Otorhinolaryngol. 2008;74(5):763-9. doi: 10.1016/s1808-8694(15)31388-4. PubMed PMID: 19082360.

32. Cappellette M, Jr., Alves F, Nagai LHY, Fujita RR, Pignatari SSN. Impact of rapid maxillary expansion on nasomaxillary complex volume in mouth-breathers. Dental Press J Orthod. 2017;22(3):79-88. doi: 10.1590/2177-6709.22.3.079-088.oar. PubMed PMID: 28746491; PubMed Central PMCID: PMCPMC5525449.

33. Caldas LD, Takeshita WM, Machado AW, Bittencourt MAV. Effect of rapid maxillary expansion on nasal cavity assessed with cone-beam computed tomography. Dental Press J Orthod. 2020;25(3):39-45. Epub 20200819. doi: 10.1590/2177-6709.25.3.039-045.oar. PubMed PMID: 32844972; PubMed Central PMCID: PMCPMC7437151.

34. Tepedino M, Montaruli G, Scapato F, Laurenziello M, Suriano C, Chimenti C, et al. Long-term effect on adenoid dimensions and craniocervical angulation after maxillary expansion with fixed or functional appliances. J Clin Exp Dent. 2021;13(6):e594-e600. Epub 20210601. doi: 10.4317/jced.58171. PubMed PMID: 34188766; PubMed Central PMCID: PMCPMC8223156.

35. Kiliç N, Oktay H. Effects of rapid maxillary expansion on nasal breathing and some naso-respiratory and breathing problems in growing children: A literature review. International Journal of Pediatric Otorhinolaryngology. 2008;72(11):1595-601. doi: https://doi.org/10.1016/j.ijporl.2008.07.014.

36. Baratieri C, Alves M, Jr., de Souza MM, de Souza Araújo MT, Maia LC. Does rapid maxillary expansion have long-term effects on airway dimensions and breathing? Am J Orthod Dentofacial Orthop. 2011;140(2):146-56. doi: 10.1016/j.ajodo.2011.02.019. PubMed PMID: 21803251.

37. Bicakci AA, Agar U, Sökücü O, Babacan H, Doruk C. Nasal airway changes due to rapid maxillary expansion timing. Angle Orthod. 2005;75(1):1-6. doi: 10.1043/0003-3219(2005)075<0001:Nacdtr>2.0.Co;2. PubMed PMID: 15747808.

38. Baccetti T, Franchi L, Cameron CG, McNamara JA, Jr. Treatment timing for rapid maxillary expansion. Angle Orthod. 2001;71(5):343-50. doi: 10.1043/0003-3219(2001)071<0343:Ttfrme>2.0.Co;2. PubMed PMID: 11605867.

39. Altug-Atac AT, Atac MS, Kurt G, Karasud HA. Changes in nasal structures following orthopaedic and surgically assisted rapid maxillary expansion. Int J Oral Maxillofac Surg. 2010;39(2):129-35. Epub 20091229. doi: 10.1016/j.ijom.2009.11.013. PubMed PMID: 20042317.

40. Lagravere MO, Major PW, Flores-Mir C. Long-term skeletal changes with rapid maxillary expansion: a systematic review. Angle Orthod. 2005;75(6):1046-52. doi: 10.1043/0003-3219(2005)75[1046:Lscwrm]2.0.Co;2. PubMed PMID: 16448254.

41. Farronato G, Giannini L, Galbiati G, Maspero C. RME: influences on the nasal septum. Minerva Stomatol. 2012;61(4):125-34. PubMed PMID: 22441415.

42. Badoux DM. Framed structures in the mammalian skull. Acta Morphol Neerl Scand. 1966;6(3):239-50. PubMed PMID: 6008209.

43. Frost HM, Schönau E. The "muscle-bone unit" in children and adolescents: a 2000 overview. J Pediatr Endocrinol Metab. 2000;13(6):571-90. doi: 10.1515/jpem.2000.13.6.571. PubMed PMID: 10905381.

44. Frost HM. From Wolff's law to the mechanostat: a new "face" of physiology. J Orthop Sci. 1998;3(5):282-6. doi: 10.1007/s007760050054. PubMed PMID: 9732563.

45. Frost HM. A 2003 update of bone physiology and Wolff's Law for clinicians. Angle Orthod. 2004;74(1):3-15. doi: 10.1043/0003-3219(2004)074<0003:Auobpa>2.0.Co;2. PubMed PMID: 15038485.

46. Kim YM, Rha KS, Weissman JD, Hwang PH, Most SP. Correlation of asymmetric facial growth with deviated nasal septum. Laryngoscope. 2011;121(6):1144-8. Epub 20110414. doi: 10.1002/lary.21785. PubMed PMID: 21495046.

47. Hartman C, Holton N, Miller S, Yokley T, Marshall S, Srinivasan S, et al. Nasal Septal Deviation and Facial Skeletal Asymmetries. Anat Rec (Hoboken). 2016;299(3):295-306. Epub 20160122. doi: 10.1002/ar.23303. PubMed PMID: 26677010.