ORIGINAL ARTICLE
RHINOLOGY
DOI: 10.5152/B-ENT.2020.19013

Is an increase in the depth of the olfactory fossa caused by excessive vertical facial growth? A radiological study

Christian Calvo-Henríquez[1], Alberto Ruano-Ravina[2,3], Gabriel Martinez-Capoccioni[1], Silvia Martins-Neves[4], Miguel Mayo-Yáñez[5], Sergio Alosilla-Sandoval[6], Sonsoles Junquera-Olay[6], Ernesto Varela[1]

[1]Clinic of Otolaryngology, Hospital Complex of Santiago de Compostela, A Coruña, Spain
[2]Department of Preventive Medicine and Public Health, University of Santiago de Compostela, A Coruña, Spain
[3]CIBER de Epidemiología y Salud Pública, CIBERESP, Madrid, Spain
[4]Dentofacial Orthopedics, Hospital of Lusiadas, Lisbon, Portugal
[5]Clinic of Otolaryngology, Hospital Complex of La Coruña, A Coruña, Spain
[6]Clinic of Radiology, Hospital Complex of Santiago de Compostela, A Coruña, Spain

Cite this article as: Calvo-Henriquez C, Ruano-Ravina A, Martinez-Capoccioni G, et al. Is an increase in the depth of the olfactory fossa caused by excessive vertical facial growth? A radiological study. B-ENT 2020; 16(1): 25-30.

ABSTRACT

Objective: Maxillary growth is highly influenced by environmental factors. In some cases, facial growth in the horizontal plane is compromised in favor of vertical growth. When a patient experiences excessive vertical facial growth, the frontal bone remains stable, whereas the maxilla and ethmoid gradually drop. We hypothesized that the lowering of the ethmoid could explain the gap between the ethmoidal notch and lamina cribosa and therefore be a cause of the differences in olfactory fossa depth.

Methods: We selected 201 consecutive CT sinonasal scans and analyzed 3D-reconstruction planes. Four indicators of excessive vertical facial growth were measured (saddle angle, sella-nasion-anterior maxilla [SNA] angle, indicator line, and facial index).

Results: The mean olfactory fossa depth was 5.63 mm. There was a statistically significant association ($p<0.001$) between olfactory fossa depth and the four indicators of excessive vertical facial growth combined. There was also an association between olfactory fossa depth and each indicator: facial index ($p<0.001$), saddle angle ($p<0.001$), SNA angle ($p<0.001$), and indicator line ($p=0.001$).

Conclusion: We found a statistically significant relationship between the four indicators of excessive vertical facial growth and the depth of the olfactory fossa. These results support our hypothesis, which states that the middle face drops in vertical facial growth, creating a gap in the olfactory fossa. Our results compel otolaryngologists to thoroughly check the depth of the olfactory fossa when treating patients with excess vertical facial growth scheduled for endoscopic sinus surgery.

Keywords: Ethmoid sinus, Keros, long face syndrome, olfactory fossa, vertical facial growth

Introduction

"Long face syndrome" is well known in Otolaryngology. In facial growth, the complex formed by the pterigoids, sphenoid, and frontal bones remain stable despite excessive vertical facial growth (1). In contrast, maxillary growth is highly influenced by environmental factors. The maxilla grows in the horizontal plane because of the pressure of the tongue, both during swallowing and when it rests against the palate (2). However, in some cases, when the tongue does not stimulate the maxilla, growth in the horizontal plane is compromised in favor of vertical growth of the face.

There is a high prevalence of individuals with excessive vertical facial growth in the developed world (3) because of multiple factors such as rhinitis (4), adenoid hypertrophy (4), soft diet (5), septal deviation (6), overuse of pacifiers (7), and parafunctional phonation and swallowing (8) among others.

There are several different cephalometric measurements that can be used to assess excess vertical facial growth, but there are discrepancies regarding which measurement describes it better. Some of the most used measurements are the angles formed by the cranial base, such as the saddle angle and sella-nasion-anterior maxilla (SNA) angle (9); the distance between the incisors and the tip of the nose, measured using the

Corresponding Author: Christian Calvo-Henriquez; christian.calvo.henriquez@gmail.com
Received: May 1, 2019 **Accepted:** August 20, 2019
Available online at www.b-ent.be

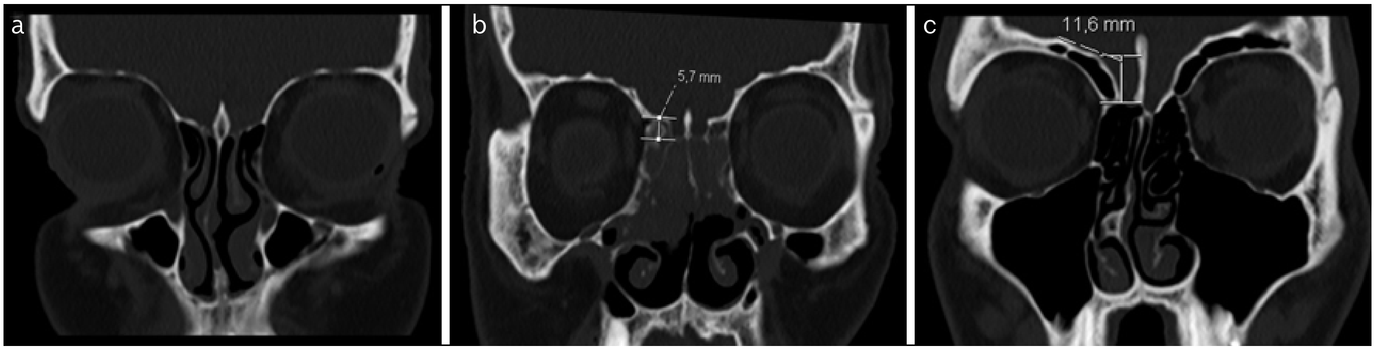

Figure 1. a-c. Keros classification: (a) Keros I (1 mm), (b) Keros II (5.7 mm), (c) Keros III (11.6 mm)

indicator line (10); and the relationship between the face width and height, measured using the facial index (11).

Currently, endoscopic sinus surgery is one of the most common surgeries in otolaryngology; however, it is not exempt from risk. To minimize the possibility of complications, it is of paramount importance to carry out a thorough preoperative study of anatomical variations in the CT scan, including the depth of the olfactory fossa (OF) (12).

The OF is located in the center of the horizontal portion of the frontal bone, in the ethmoidal notch. It is limited inferiorly by the lamina cribosa of the ethmoid and laterally by the lateral lamella. The ethmoid roof is not usually aligned with the frontal bone as it lies inferior to it. This gap between the frontal bone and the ethmoid roof is the depth of the OF, which was classified by Keros in 1962 into three categories, as follows (12): Keros I, 1-3 mm; Keros II, 4-7 mm; and Keros III: 8-16 mm (Figure 1). The most common variation is type II, followed by type III and, finally, type I. The lateral lamella of the OF is the thinnest region of the cranial base and therefore the point of maximum risk for iatrogeneous lesion at the cranial base. Approximately 0.5%-1% of patients who undergo endoscopic sinus surgery develop major complications, including cerebrospinal fluid leak (13). Communication between the nasal cavity and intracranial space increases the risk of meningitis and pneumocephalus, which often requires surgical repair.

When a patient suffers excessive vertical facial growth, the frontal bone remains stable while the maxilla and ethmoid gradually drop. We hypothesize that the drop of the ethmoid could explain the gap between the ethmoidal notch and the lamina cribosa and therefore be a cause for the differences in the depth of the OF. This study aimed to analyze the association between excessive vertical facial growth and the depth of the OF.

Main Points:

- Excessive vertical facial growth is statistically related to an increase in the depth of the olfactory fossa. These results support our hypothesis, which states that the middle face drops in vertical facial growth, creating a gap in the olfactory fossa.
- We found Keros II (76.29%) to be the most prevalent. Less frequently, we observed Keros III (13.92%), followed by Keros I (9.79%).
- Otolaryngologists should pay attention to facial growth, which is related to our field in several areas.
- Our results will compel otolaryngologists to thoroughly check the depth of the OF when examining a patient with excess vertical facial growth who is undergoing endoscopic sinus surgery.

Methods

Design and sample size

We conducted a descriptive study including 201 consecutive CT sinonasal scans performed at a tertiary hospital and obtained independently of the diagnosis. The study period was from December 2016 to May 2017.

The inclusion criterion was having undergone a sinonasal CT scan. There was no restriction by age or illness. We reviewed the medical records of all patients to obtain data on their diagnosis and history of previous sinonasal surgery. For patients scheduled for sinonasal surgery, a pre-surgery CT scan was obtained, and patients without a pre-surgery CT scan were excluded. A further exclusion criterion was the CT scan not including the insertion of the incisors.

Image study

CT scans were analyzed by an otolaryngologist (CC) and two radiologists (SA, SJ) using the Sectra DICOM viewer. The 3D-reconstruction planes were obtained from axial images.

Prior to the analysis, we aligned the views in the three planes of study (coronal, axial, and sagittal).

Assessment of the depth of the olfactory fossa

We examined the coronal views to find the point of maximum depth of the OF. At that point we measured, in a perpendicular plane, the distance from the lamina cribosa inferiorly to the point of maximum height of the lateral lamella superiorly. Data from both sides were recorded.

Saddle angle assessment

The saddle angle is defined by points N (nasion), S (sella), and Ar (the intersection between the posterior margin of the ascending ramus and outer margin of the cranial base) (9).

We carried out saddle angle assessment using a CT scan instead of teleradiography. The sagittal plane through the septum was selected. Two planes were defined, one adjacent to the posterior face of the clivus and the second adjacent to the cranial base. The angle at the intersection of the two planes was measured (Figure 2).

SNA angle
The SNA angle is defined by points S (sella), N (nasion), and A (the most concave point of the anterior maxilla) (14).

We measured the SNA angle in a CT scan using the sagittal plane through the septum (Figure 2).

Indicator line
The indicator line was defined by Mew (10). We used an adaptation of the indicator line as most sinonasal CT scans do not include teeth. We defined a plane parallel to the Frankfort plane in the point of maximum projection of the nose. The indicator line was measured from the eruption of the crown of the incisors in the maxilla, tangent to the columella, to the intersection with the aforementioned horizontal plane (Figure 2).

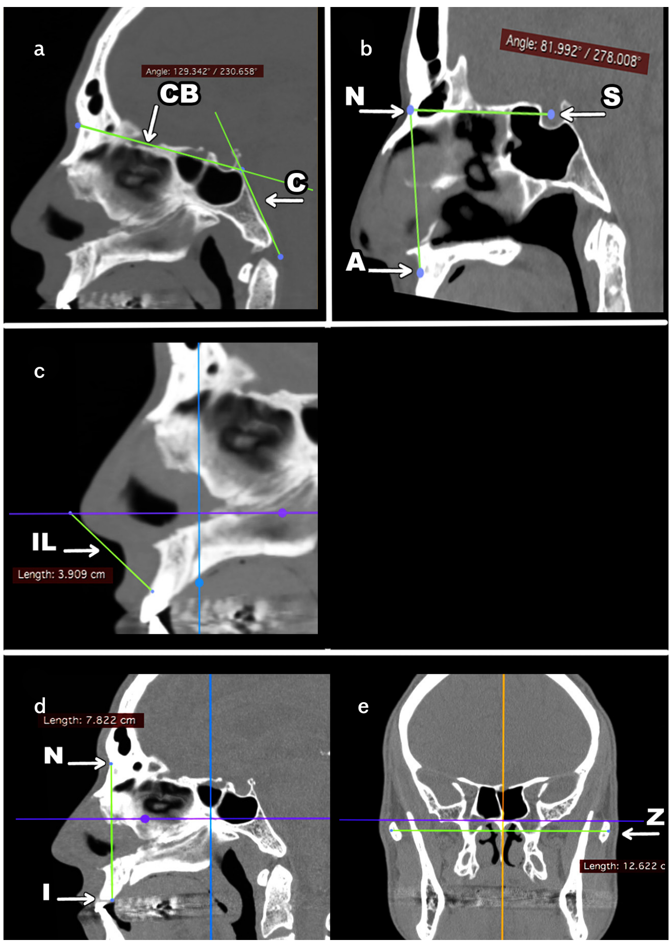

Figure 2. a-d. Measurements: (a) saddle angle: (CB) cranial base plane, (C) clivus plane. (b) SNA angle: sella (S), nasion (N), point a (A). (c) Indicator line: (IL) indicator line, (black arrow) horizontal plane. (d,e) Facial index: (N) nasion, (Z) zygoma, (I) incisors' crown eruption

Table 1. Depth of the olfactory fossa

Depth of the olfactory fossa	Right (mm) (n=194)	Left (mm) (n=194)	Total (mm)
Mean	5.68 (CI 95% 5.35-6.01)	5.57 (CI 95% 5.25-5.90)	5.63
Keros type I	20 (10.31%)	18 (9.23%)	38 (9.79%)
Keros type II	143 (73.71%)	153 (78.87%)	296 (76.29%)
Keros type III	31 (15.98%)	23 (11.86%)	54 (13.92%)

Facial index
Facial index is defined as the ratio between the length and width of the face (11). We used an adaptation of it as sinonasal CT scans do not include the jaw. The maximum width between both zygomata was measured in a coronal plane. The length of the face was measured in a sagittal plane through the septum as the distance between the radix and the eruption of the crown of the incisors, parallel to the vertical plane (Figure 2).

Ethic committee approval
The study was performed in accordance with the ethical standards outlined in the Declaration of Helsinki. The study protocol was approved by the Research and Ethics Committee of the Hospital of Santiago de Compostela, register code 2017/038.

Statistical analysis
To analyze the associations between indicators of excessive vertical facial growth and the depth of OF, we used linear regression where the independent variable was each indicator of facial growth and the dependent variable was the depth of the OF. We used the ANOVA test and Kruskal-Wallis test when the variables did not follow a normal distribution. We had previously checked the normality of the variables using the Kolmogorov-Smirnov test.

Furthermore, we studied the difference between the depths of the OF on the right and left sides, applying the independent samples T-test.

Statistical significance was determined at $p<0.05$; statistical analysis was carried out using the IBM Statistical Package for Social Sciences version 23.0 (IBM Corp.; Armonk, NY, USA).

Results

Participants
Of the 201 CT sinonasal scans initially selected, 7 were excluded because both the olfactory fossa and the radix were not included in the CT scan.

One CT scan was excluded because the zygomatic arches were not shown and 38 more were excluded because the insertions of the incisors were not included. Although these last 38 scans were excluded from the study, they were considered when analyzing the depth of the OF.

Four scans did not include the tip of the nose and were, consequently, not suited to study the indicator line. However, they were used to analyze the facial index and the depth of the OF.

One participant had a firearm-related injury of the clivus; therefore, the scan was excluded from the assessment of the saddle angle.

The final sample consisted of 194 CT sinonasal scans. There were 102 women (52.58%) and 92 men (47.42%). The median age was 53.66 years, and the interquartile range (25%-75% percentile range) was 38.87-67.52.

Depth of the olfactory fossa - Keros
A description of the depth of the OF is shown in Table 1.

The mean depth on the right side was 5.68 mm (95% CI 5.35-6.01), and on the left it was 5.57 (95% CI 5.25-5.90). There were no statistically significant differences between the two sides (p=0.694).

The mean asymmetry between sides was 1.22 mm (95% CI 1.08-1.36). In 44.33% of participants, there was asymmetry greater than 1 mm, and in 5.67%, it was greater than 3 mm.

Excessive vertical facial growth

Facial index

In total, 153 participants were assessed. The mean facial index was 0.54 (95% CI 0.53-0.55, standard deviation 0.04, range 0.45-0.64, interquartile range 0.51-0.57).

The facial index had a normal distribution (p=0.09).

Saddle angle

A total of 157 participants were assessed. The mean was 123.95° (95% CI 123.01-124.89, SD 6.64, range 71.3-140, interquartile range 120.45-128).

The saddle angle did not have a normal distribution (p = 0.02).

SNA angle

In this instance, 157 participants were assessed. The mean was 87.02° (95% CI 86.04-88, standard deviation 6.2, range 71.1-102.4).

The SNA angle had a normal distribution (p=0.2).

Indicator line

In total, 149 participants were assessed. The mean was 40.64 (95% CI 39.81-41.48, standard deviation 5.15, range 19-56.4, interquartile range 37.55- 43.90).

The indicator line values were not normally distributed (p=0.02).

Relationship between the depth of the OF and excessive vertical facial growth

We analyzed the four indicators of excessive vertical facial growth combined as independent variables, and the total depth of the OF as the dependent variable. There was a statistically significant difference (p<001).

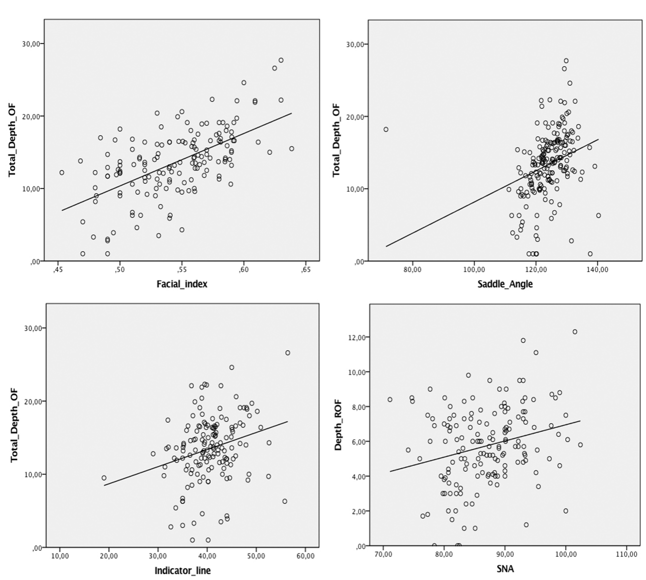

Figure 3. Correlation between the depth of the olfactory fossa and vertical facial growth indicators

We also analyzed each indicator of excessive vertical facial growth independently. There were statistically significant differences for the facial index (p<0.001), saddle angle (p<0.001), SNA angle (p<0.001), and the indicator line (p=0.001).

A graphical representation of the correlations between variables can be seen in Figure 3.

Discussion

Pre-surgery CT-scanning is an important safety-associated factor in endoscopic sinus surgery. It is always critical, particularly for inexperienced surgeons, to check the depth of the OF (12), especially in patients with advanced sinonasal disease and reinterventionS (15). Therefore, knowledge of this anatomical variation and the factors related to it is of paramount importance. This is the first study to observe a potential cause for variation in the depth of the OF, as it was assumed that it was an anatomical variation without a cause until now.

We found a statistically significant relationship between the four indicators of excessive vertical facial growth and the depth of the OF. These results support our hypothesis, which states that the middle face drops when there is excessive vertical facial growth, creating a gap in the OF. Our hypothesis is further supported by the work of Anderhuber, who found that before the age of 2 years, a deep OF is less common (16), as excessive vertical facial growth becomes more evident only from the age 2 years onward (17).

The relationship found is not perfectly linear. We found patients with severe excessive vertical facial growth and a shallow OF and vice versa. It can be concluded that excessive vertical facial growth may be only one of multiple etiologic factors for a deep olfactory fossa.

This association, although significant, was lower for the indicator line. While some authors have highlighted the indicator line as the most reliable method of determining whether the maxilla is in a retruded position (17), we found some difficulties measuring it as several patients had no teeth and their alveolar bone was retruded. Furthermore, some elderly patients had a ptosis of the nasal tip due to the loss of elastin with age, which might have altered this measurement. We believe the indicator line is more suitable for pediatric than for adult patients.

We found a significant correlation between the depth of the OF and the saddle angle. When a patient suffers excess vertical facial growth, the middle face and the clivus become retruded, creating a more obtuse saddle angle. Even though the saddle angle is a highly valuable measurement, Trotman (18) et al. found that excess vertical facial growth is associated with a proportional reduction in the length of the cranial base, thereby modifying the angles related to the cranial base (SNA and SNB), which then do not change as is expected. Consistent with this, we found a narrow range of results, with an interquartile range of only 8 degrees. Our findings support the observation made by Trotman (18) et al. that although the saddle angle is more obtuse when there is an excess of vertical facial growth, the increase in the angle is not as great as one would expect (18).

The depth of the OF is usually asymmetric. In our work, we found asymmetry in 44.33% of participants, although the asymmetry was severe (>3 mm) in only 5.67% of participants. Those cases are important as this asymmetry could mislead the surgeon during surgery. According to our hypothesis, facial growth could also explain the asymmetry as facial growth is also frequently asymmetric, related to asymmetries in masticatory muscle activity during chewing.

With regard to Keros prevalence, we found Keros II (76.29%) to be the most prevalent. This is similar to published data and almost the same prevalence was found by Skorek et al (19), but a higher prevalence than reported by the rest of the studies published to date (20-24). Less frequently, we observed Keros III (13.92%), followed by Keros I (9.79%). All other authors have reported the same result, except V and Santosh (23) and Adeel et al (21). who reported Keros type I as the second most prevalent form.

A strength of our study is the sample size. We included a large sample (n=201) from the same healthcare delivery area. Skorek et al. (19) studied 120 patients; Saglam et al. (20); Erdogan et al. (22); Adeel et al. (21); V and Santosh (23); and Alrumaih et al. (24). A further strength of our work is the use of CT, a precise imaging procedure, as most papers related to cephalometry are based on photography and teleradiography.

A limitation of our work is the high rate of lost participants. Another weakness is that we had to adapt the instruments used to measure facial growth. It prevented us from comparing our results with published data. Finally, with our sample size, we were not able to determine whether these differences vary with age or with a particular disease.

Finally, our study draws two major conclusions. First, it reinforces the fact that otolaryngologists should pay attention to facial growth, which is related to our field in several areas. Second, our results will compel otolaryngologists to thoroughly check the depth of the OF when examining a patient with excess vertical facial growth who is undergoing endoscopic sinus surgery.

Ethics Committee Approval: The study was performed in accordance with the ethical standards outlined in the Declaration of Helsinki. The study protocol was approved by the Research and Ethics Committee of the Hospital of Santiago de Compostela, register code 2017/038.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – C.C.H., G.M.C., S.MN.; Design – C.C.H., S.A.S, S.J.O.; Supervision – A.A.R., G.M.C.; Resources – C.C.H., G.M.C.; Materials – S.A.S., S.J.O.; Data Collection and/or Processing – C.C.H., S.A.S., S.J.O.; Analysis and/or Interpretation – C.C.H., A.R.R., E.V.; Literature Search – C.C.H., E.V.; Writing Manuscript – C.C.H., M.M.Y., S.M.N.; Critical Review – C.C.H., A.R.R., G.M.C., S.M.N., M.M.Y., S.A.S., S.J.O., E.V.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

References

1. Couly G. Bone statics of the face: the frontal-sphenoid-pterygoid bone pillars as biomechanic equivalents of the mandible. Rev Stomatol Chir Maxillofac 1975; 76: 607-19.
2. Hanson ML, Cohen MS. Effects of form and function on swallowing and the developing dentition. Am J Orthod 1973; 64: 63-82. [CrossRef]
3. Cardoso M de A, Castro RCFR de, Li An T, Normando D, Garib DG, Capelozza Filho L. Prevalence of long face pattern in Brazilian individuals of different ethnic backgrounds. J Appl Oral Sci 2013; 21: 150-6. [CrossRef]
4. Linder-Aronson S. Adenoids. Their effect on mode of breathing and nasal airflow and their relationship to characteristics of the facial skeleton and the denition. A biometric, rhino-manometric and cephalometro-radiographic study on children with and without adenoids. Acta Otolaryngol Suppl 1970; 265: 1-132.
5. Alabdullah M, Saltaji H, Abou-Hamed H, Youssef M. Association between facial growth pattern and facial muscle activity: a prospective cross-sectional study. Int Orthod 2015; 13: 181-94. [CrossRef]
6. 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: 1180-3. [CrossRef]
7. Bishara SE, Warren JJ, Broffitt B, Levy SM. Changes in the prevalence of nonnutritive sucking patterns in the first 8 years of life. Am J Orthod Dentofacial Orthop 2006; 130: 31-6. [CrossRef]
8. Woda A, Foster K, Mishellany A, Peyron MA. Adaptation of healthy mastication to factors pertaining to the individual or to the food. Physiol Behav 2006; 89: 28-35. [CrossRef]
9. Lewis AB, Roche AF. The saddle angle: constancy or change? Angle Orthod 1977; 47: 46-54.
10. Mew J. Use of the 'indicator line' to assess maxillary position. Funct Orthod 1991; 8: 29-32.
11. Torres-Restrepo AM, Quintero-Monsalve AM, Giraldo-Mira JF, Rueda ZV, Vélez-Trujillo N, Botero-Mariaca P. Agreement between cranial and facial classification through clinical observation and anthropometric measurement among Envigado school children. BMC Oral Health 2014; 14: 14-50. [CrossRef]
12. Keros P. On the practical value of differences in the level of the lamina cribrosa of the ethmoid. Z Laryngol Rhinol Otol 1962; 41: 9-13.
13. Borsetto D, Ciorba A, Cazzador D, Volo T, Denaro L, D'Avellal ED, et al. Transnasal endoscopic management of anterior cerebrospinal fluid (CSF) leak: experience from a large case series. B-ENT. 2017; 13: 15-21.
14. Ronchi P, Novelli G, Colombo L, Valsecchi S, Oldani A, Zucconi M,et al. Effectiveness of maxillo-mandibular advancement in obstructive sleep apnea patients with and without skeletal anomalies. Int J Oral Maxillofac Surg 2010; 39: 541-7. [CrossRef]
15. Chou TW, Chen PS, Lin HC, et al. Multiple analyses of factors related to complications in endoscopic sinus surgery. J Chin Med Assoc 2016; 79 :88-92. [CrossRef]
16. Anderhuber W, Walch C, Fock C. Configuration of ethmoid roof in children 0-14 years of age. Laryngorhinootologie. 2001; 80: 509-11. [CrossRef]
17. Galella SA, Jones EB, Chow DW, Jones E, Masters A. Guiding atypical facial growth back to normal. Part 2: Causative factors, patient assessment, and treatment planning. Int J Orthod Milwaukee 2012; 23: 21-30.
18. Trotman CA, McNamara JA, Dibbets JM, van der Weele LT. Association of lip posture and the dimensions of the tonsils and sagittal airway with facial morphology. Angle Orthod 1997; 67: 425-32.
19. Skorek A, Tretiakow D, Szmuda T, Przewozny T. Is the Keros classification alone enough to identify patients with the 'dangerous

ethmoid'? An anatomical study. Acta Otolaryngol 2017; 137: 196-201. [CrossRef]
20. Saglam M, Salihoglu M, Tekeli H, Altundag A, Sivrioglu AK, Cayonu M. Is there an association between olfactory bulb volume and the Keros type of fossa olfactoria? J Craniofac Surg 2014; 25: 1273-6. [CrossRef]
21. Adeel M, Ikram M, Rajput MSA, Arain A, Khattak YJ. Asymmetry of lateral lamella of the cribriform plate: a software-based analysis of coronal computed tomography and its clinical relevance in endoscopic sinus surgery. Surg Radiol Anat 2013; 35: 843-7. [CrossRef]
22. Erdogan S, Keskin IG, Topdag M, Ozturk M, Sari F, Mutlu F. Ethmoid roof radiology; analysis of lateral lamella of cribriform plate. Otolaryngol Pol 2015; 69: 53-7.[CrossRef]
23. V AM, Santosh B. A study of clinical significance of the depth of olfactory fossa in patients undergoing endoscopic sinus surgery. Indian J Otolaryngol Head Neck Surg 2017; 69: 514-22. [CrossRef]
24. Alrumaih RA, Ashoor MM, Obidan AA, Al-Khater KM, Al-Jubran SA. Radiological sinonasal anatomy. Exploring the Saudi population. Saudi Med J 2016; 37: 521-6. [CrossRef]