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SCIENTIFIC SECTION

Nasal morphology as an indicator of vertical maxillary skeletal pattern

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Objective: To investigate the relationship between nasal morphology and vertical maxillary skeletal pattern.

Design: A retrospective study.

Setting: Department of Orthodontics and Dentofacial Orthopaedics, Armed Forces Medical College, Pune, India.

Subjects and methods: The sample included the lateral cephalometric radiographs of 190 Indian adults (103 women, 87 men), aged 18 to 27 years with no previous history of trauma, surgical intervention, congenital disease or orthodontic treatment. Seven skeletal parameters of vertical facial growth and six nasal parameters were measured.

Results: There was a significant correlation between vertical maxillary skeletal and soft tissue nasal parameters. Nasal length significantly correlated with upper anterior facial height ($r=0.850$, $P<0.001$) and inclination of palatal plane ($r=0.433$, $P<0.001$). Upward nasal tip inclination showed a significant negative correlation with inclination of the palatal plane ($r=-0.462$, $P<0.001$).

Conclusion: The clinical significance of this study is that the nasolabial angle in itself may not reflect a midface vertical discrepancy, however its upper component, i.e. the degree of upturn of the nose with decreased nasal length in an adult subject may indicate an underlying change in inclination of the palatal plane. This might be of value during orthodontic diagnosis and treatment planning.

Key words: Vertical maxillary skeletal pattern, nasolabial angle, upturned nose, inclination of palatal plane

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Introduction

The nose dominates the middle portion of the face and in close harmony with lips and chin defines the characteristic facial appearance of an individual.[1–4] Thorough knowledge of the relationship between these facial structures, and the changes expected during and after growth, with orthodontic and surgical treatment is essential for an orthodontist to achieve the desired treatment goals.[5–11]

Nasal growth proceeds at a relatively constant rate into adolescence and is almost completed by the age of 16 in girls and 18 in boys;[12–17] however long term studies by Behrents[18] indicate a considerable amount of nasal growth during adulthood. Vertical growth of the facial skeleton, continues well after puberty both in males and females, even after the completion of growth in the sagittal and transverse dimensions.[19,20] Scott[21] suggested that the cartilaginous nasal septum is a primary growth centre that pushes and thrusts the midface downwards and forward. Although this hypothesis is not unanimously accepted, numerous authors [22–25] have shown that prenatal and/or postnatal impaired growth of the nasal septum due to genetic or traumatic aetiology causes maxillary hypoplasia in the sagittal dimension. The relationship between nasal morphology and facial skeletal pattern has received attention in the orthodontic literature;[26–29] however the relationship between nasal morphology and vertical midface growth remains largely unexplored. The primary purpose of this study was therefore, to study the relationship between maxillary vertical skeletal pattern and nasal morphology.

The nasolabial angle depicts a close relationship between the lips and the nose and has been studied with great interest by various authors in the orthodontic literature.[30,31] Acuteness of the nasolabial angle may be due to a proclined maxillary dentition, a short nasal projection and/or a lower nasal tip. An acute nasolabial angle due to a protrusive maxilla or maxillary incisors may be corrected with extraction of premolars and retraction of the maxillary anterior teeth.[32–35] The nasolabial angle has two components: the inclination of the upper lip (lower nasolabial angle – LNLA) and

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the upward nasal tip inclination (upper nasolabial angle – UNLA). While the change in inclination of the upper lip (LNLA) has demonstrated a strong correlation with the amount of retraction of the upper incisors and increase in the lower anterior facial height (LAFH),[35,36] the UNLA has not been found to be correlated either with incisor retraction or sagittal skeletal parameters.[35,36] It is, however a clinical observation of the authors that an upturned nose is frequently associated with change in the inclination of the palatal plane and this aspect of the nasolabial angle has not been studied in the orthodontic literature.

The aim of this study was thus twofold:

1. to investigate the relationship between vertical maxillary skeletal pattern and nasal morphology;
2. to explore the relationship between the degree of upturn of the nose and the inclination of the palatal plane.

The null hypotheses (H_o) for this study stated that:

1. no relationship exists between the vertical maxillary skeletal pattern and nasal morphology;
2. there exists no relationship between the degree of upturned of the nose and the inclination of the palatal plane.

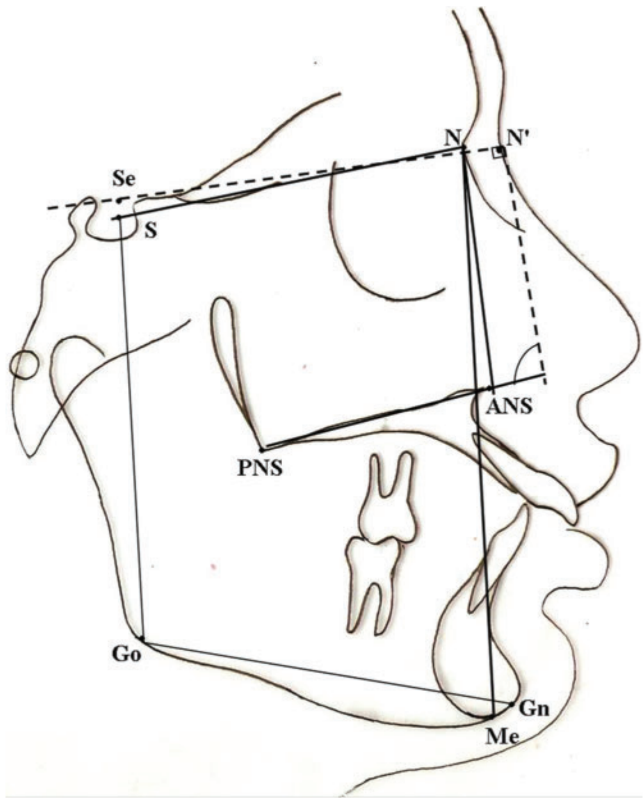

Figure 1 Vertical facial skeletal parameters assessed on lateral cephalogram

Materials and methods

Sample selection

Ethical approval for the study was obtained from the Armed Forces Medical College Ethical Committee (reference no. 2248/AFMC/EC, dated 4 August 2006). The pre-treatment lateral cephalometric radiographs of 190 Indian adults (103 women, 87 men) who had undergone orthodontic treatment at the Department of Orthodontics, Armed Forces Medical College between 2002 and 2006 were selected for this study. Their age ranged 18–27 years. All were in the permanent dentition, and none had any facial congenital anomaly or prior history of orthodontic treatment, surgery or trauma to the face.

Cephalometric analysis

Seven vertical facial skeletal and six nasal soft tissue parameters were identified on the standardized lateral cephalometric radiographs. Tracings of the cephalometric radiographs were made by hand using a sharp 3H pencil on acetate tracing paper in a darkened room by Karan Nehra.

The following vertical facial skeletal parameters were assessed (Figure 1):[37,38]

1. GoGn-SN: the mandibular plane inclination to the cranium;
2. S-Go: posterior facial height;
3. N-Me: anterior facial height;
4. N-ANS: anterior maxillary height;
5. ANS-Me: LAFH;
6. SN-Pp: the angle between the sella-nasion plane and the ANS-PNS line (inclination of palatal plane);
7. Angle of inclination: the angle between the perpendicular drawn from N' on Se-N' line (entry of sella-soft tissue nasion) and the palatal plane.

The following soft tissue landmarks were identified to assess the nose (Figure 2):[37,39]

1. soft tissue nasion (N'): the point of greatest concavity in the midline between the forehead and the nose;
2. pronasale (Pr): the tip of nose (nasal tip);
3. posterior columella point (PCm): the most posterior point of the lower border of the nose at which it

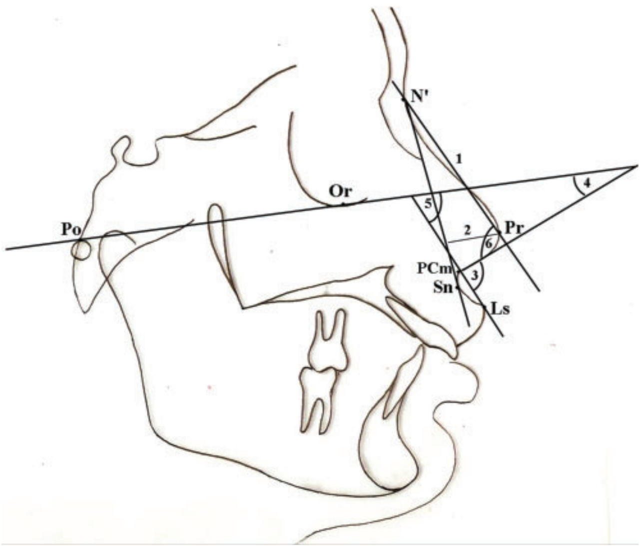

Figure 2 Soft tissue reference planes and variables used to assess nose on lateral cephalogram

begins to turn inferiorly to merge with the philtrum of the upper lip;

4. subnasale (Sn): the deepest point at which the columella merges with the upper lip in the midsagittal plane;
5. labrale superius (Ls): the point indicating the mucocutaneous border of the upper lip.

The following reference planes and variables were used to assess the nose (Figure 2):[36,39]

1. nasal length (N Lth): the distance between N' and Pr;
2. nasal depth (N Dpt): the perpendicular distance between Pr and the line drawn through N' to Sn;
3. nasolabial angle (NLA): the angle formed by the intersection of the PCm tangent (a tangent drawn from PCm along the lower border of the nose at the approximate middle third) and the PCm-Ls line;
4. nasal upward tip angle (UNLA): the postero-inferior angle formed when PCm tangent is extended anteriorly to intersect the Frankfurt horizontal plane/lower border of the nose to Frankfurt horizontal plane;
5. upper lip inclination (LNLA): the antero-inferior angle formed by the PCm-Ls line extended superiorly to intersect the Frankfurt horizontal plane/ inclination of upper lip to Frankfurt horizontal plane;
6. nasal tip angle (NTP): the angle formed by the axis of the dorsum and PCm tangent.

Error analysis

To estimate the reliability of the cephalometric analysis, 35 randomly selected lateral radiographs were traced twice by Karan Nehra at an interval of 1 month. Measurement accuracy was obtained by calculating the error of the method[40] and Houston's coefficient of reliability.[41] Systematic error was calculated with a paired *t*-test between the two sets of measurements and as recommended by Houston[41] significance was determined at the 10% level.

Statistical analysis

To determine whether the soft tissue nasal parameters had a linear correlation with the vertical facial skeletal measurements in this sample, pair-wise Pearson product-moment correlation coefficients were calculated between the seven skeletal measurements and the six nasal parameters. The six nasal parameters were also compared with each other in a similar manner to determine the extent of linear correlation.

Results

The standard deviation of the differences between the two repeated measurements ranged from 0.16 to 0.85 mm for linear measurements and from 0.39 to 1.91° for the angular measurements, Houston's reliability ranged from 0.87 to 0.98 indicating a low random error. There were no significant differences between the two repeated measurements suggesting that there was no systematic error.

Table 1 shows the descriptive data for the vertical facial skeletal and nasal parameters. The Pearson product-moment correlation coefficients between the facial skeletal pattern and the soft tissue nasal parameters are listed in Table 2. Table 3 shows the Pearson product-moment correlation coefficients between the nasal variables.

Significant correlations were seen between the following skeletal and soft tissue nasal variables:

- nasal length (NLth, mean 51.05 SD 4.06 mm) depicted a high positive correlation with three variables; anterior facial height (NMe, $r=0.554$), inclination of palatal plane (SNPp, $r=0.433$) and upper anterior facial height (NANS, $r=0.850$). It also showed a high negative correlation with angle of inclination (AOI, $r=-0.457$), which also represents the inclination of the palatal plane. A statistically significant correlation also existed with the posterior facial height (SGo, $r=0.311$). Within the nasal variables: nasal length had a high positive correlation with nasal depth (N Dpt, $r=0.560$) however a negative correlation was observed with the nasal upward tip angle (UNLA, $r=-0.458$);

- nasal depth (N Dpt, mean 17.30 SD 2.05 mm) depicted a highly significant correlation with upper anterior facial height (NANS, $r=0.465$) and a moderate correlation with anterior facial height (NMe, $r=0.366$) and inclination of the palatal plane (SNPp, $r=0.245$). It also showed a negative correlation with angle of inclination (AOI, $r=-0.264$);
- nasolabial angle (NLA, mean 92.69 SD 11.09) did not show any significant correlation with midface vertical parameters. However it showed a highly significant correlation with inclination of upper lip (LNLA, $r=0.841$) and a significant correlation with nasal upward tip inclination (UNLA, $r=0.407$) and nasal tip angle (NTP, $r=0.427$).
- lip inclination (LNLA, mean 70.55 SD 10.25°) demonstrated moderate correlation with three variables; mandibular plane inclination to the cranium (GoGn-SN, $r=0.238$), upper anterior facial height (N-ANS, $r=0.311$) and inclination of palatal plane (SNPp, $r=0.325$). It also showed moderately negative correlation with angle of inclination (AOI, $r=-0.332$).

Table 1 Mean, standard deviation, maximum value, minimum value and confidence interval of all the vertical facial skeletal parameters and nasal parameters

Cephalometric parameter	Mean	SD	Max.	Min.	Confidence interval (95%)
GoGn-SN	30.3	6.9	50.0	10.0	29.3–31.3
S-Go	77.8	6.3	96.0	63.0	76.9–78.7
N-Me	117.4	6.8	144.0	97.0	116.4–118.3
N-ANS	51.5	3.3	63.0	43.0	51.0–51.9
LAFH	66.0	5.5	86.0	50.0	65.2–66.7
SN-Pp	7.3	3.5	16.5	−3.0	6.8–7.7
AOI	85.8	3.6	95.5	77.0	85.3–86.3
N Lth	51.1	4.1	65.0	40.0	50.5–51.6
N Dpt	17.30	2.1	24.0	11.0	17.0–17.5
NLA	92.7	11.1	132.0	60.0	91.1–94.2
LNLA	70.6	10.3	103.5	45.0	69.1–72.0
UNLA	22.2	6.1	38.0	6.0	21.3–23.0
NTP	76.3	7.2	93.0	56.5	75.2–77.3

Table 2 Correlations of nasal parameters with vertical facial skeletal parameters

	N Lth	N Dpt	NLA	LNLA	UNLA	NTP
GoGnSN	0.143 ($P=0.050$)	0.133 ($P=0.067$)	0.122 ($P=0.093$)	0.238 ($P=0.001$)	−0.178 ($P=0.014$)	0.002 ($P=0.977$)
SGo	0.311 ($P<0.001$)	0.177 ($P=0.015$)	−0.066 ($P=0.365$)	−0.085 ($P=0.246$)	0.022 ($P=0.763$)	0.081 ($P=0.269$)
NMe	0.554 ($P<0.001$)	0.366 ($P<0.001$)	0.054 ($P=0.460$)	0.167 ($P=0.021$)	−0.184 ($P=0.011$)	0.071 ($P=0.332$)
NANS	0.850 ($P<0.001$)	0.465 ($P<0.001$)	0.127 ($P=0.082$)	0.311 ($P<0.001$)	−0.294 ($P<0.001$)	−0.041 ($P=0.573$)
LAFH	0.183 ($P=0.012$)	0.178 ($P=0.014$)	−0.008 ($P=0.909$)	0.023 ($P=0.755$)	−0.054 ($P=0.461$)	0.113 ($P=0.121$)
SNPP	0.433 ($P<0.001$)	0.245 ($P<0.001$)	0.047 ($P=0.517$)	0.325 ($P<0.001$)	−0.462 ($P<0.001$)	−0.197 ($P=0.006$)
AOI	−0.457 ($P<0.001$)	−0.264 ($P<0.001$)	−0.074 ($P=0.311$)	−0.332 ($P<0.001$)	0.427 ($P<0.001$)	0.185 ($P=0.011$)

Table 3 Correlations between nasal parameters

	N Lth	N Dpt	NLA	LNLA	UNLA	NTP
N Lth	1	0.560 ($P<0.001$)	−0.023 ($P=0.750$)	0.246 ($P=0.001$)	−0.458 ($P<0.001$)	−0.176 ($P=0.015$)
N Dpt		1	0.061 ($P=0.404$)	0.242 ($P=0.001$)	−0.297 ($P<0.001$)	−0.235 ($P=0.001$)
NLA			1	0.841 ($P<0.001$)	0.407 ($P<0.001$)	0.427 ($P<0.001$)
LNLA				1	−0.152 ($P=0.036$)	0.108 ($P=0.137$)
UNLA					1	0.597 ($P<0.001$)
NTP						1

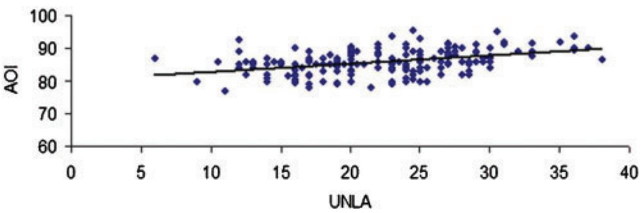

Figure 3 Correlation between UNLA and AOI

- nasal upward tip angle (UNLA, mean value 22.20 SD 6.10) depicted a moderate negative correlation with upper anterior facial height (NANS, $r=-0.294$) and a statistically significant high negative correlation with inclination of palatal plane (SNPp, $r=-0.462$). It also showed high positive correlation with angle of inclination (AOI, $r=0.427$, Figure 3) which again represents inclination of palatal plane in vertical dimension.

Discussion

The improvement of facial aesthetics is an intrinsic objective of orthodontic treatment and because the nose occupies the most prominent position on the face it influences the facial aesthetics considerably. Nasal features vary from race to race and based on their characteristic size and shape, a given nose is often termed as caucasoid (medium to long), negroid (broad and flat), mongoloid (medium to broad) etc. Population norms for the nasolabial angle differ considerably in the Indian population from those found in white Europeans[42] In fact a nasolabial angle approaching the white European normal values is seen in very few Indian patients. A higher UNLA has often been observed to be associated with a short nose in this ethnic group.

Subtelny[12] first documented the downward and forward growth of the nose that occurs during maturity. He concluded that the nose grows more vertically when compared to its growth in the sagittal dimension and this vertical growth continues until 16 years in females and 18 years in males. These findings were supported in later studies by Meng *et al.*[13] and Posen *et al.*;[14] however long term studies by Behrents[18] have proposed that a considerable amount of nasal growth occurs even after puberty.

The nasolabial angle is an important constituent of the soft tissue profile and remains an excellent clinical and cephalometric parameter to reveal the anteroposterior position of the maxillary dentition. Lo and Hunter[35] were the first to divide the nasolabial angle into its two contributing angles (the inclination of the upper lip and the inclination of the lower nose) and to study the changes during incisor retraction.

Fitzgerald *et al.*[36] extensively studied the nasolabial angle and its relation with the underlying facial structures. Although they divided the nasolabial angle into the two components of inclination of the upper lip and inclination of the lower nose and investigated their relation with sagittal and vertical facial parameters, the relation with vertical maxillary skeletal pattern was not studied. No investigation has ever been carried out to determine if a relationship exists between these two components of nasolabial angle and vertical maxillary skeletal pattern. The results of our study demonstrated a strong relation between the UNLA and the vertical maxillary skeletal pattern. The highly significant negative correlation between the UNLA and the inclination of the palatal plane indicated that the nose tends to get more upturned as the maxilla rotates anticlockwise, thereby decreasing the upper anterior facial height. This fact was further supported by an increase in the AOI with increase in UNLA. All these findings strongly suggest that if an adult patient presents with an upturned nose during the clinical examination, then it might indicate that the maxillary plane is tipped anticlockwise.

The hypothesis of Scott[21] suggests that the nasal septum is the determinant of midface growth. Latham,[43] in a modification to this theory, suggested that the nasal septum acted as a starter mechanism, pulling the premaxillae and maxillae forward via the so-called septo-premaxillary ligaments. In a study on identical twins, Grymer *et al.*[24] reported that deficient nasal septum growth along with decreased anteroposterior growth of the maxilla leads to an upward displacement of the anterior part of the maxilla indicating a strong relationship between nasal growth and inclination of the maxillary plane. Our study supports the above literature that the nasal morphology and inclination of maxilla are significantly correlated.

One of the first studies determining the association between nasal and skeletal parameters was done by Robison *et al.*[28] Their cephalometric study on the relationship between skeletal facial pattern and soft tissue nasal form concluded that nasal shape followed the underlying skeletal pattern very closely in the sagittal dimension; however no association between nasal morphology and vertical maxillary skeletal pattern was studied.

Gulsen *et al.*[29] investigated the relationship between craniofacial structures and the nose in an adult Anatolian Turkish population. They studied the relationship of the nasolabial angle with facial skeletal parameters and found no significant correlation between them, which is contrary to the findings if this study. However, our study does agree with their findings of an association between the nasal base angle and the inclination of palatal plane. The former is a parameter which also depends upon the growth of the nose and its angulation.

This study highlights the importance of close association between the vertical maxillary skeletal framework and nasal growth. It is common that the nasolabial angle studied is more often associated with proclined or retroclined maxillary dentition and the inclination of the columella of the nose is overlooked.

Findings of an upturned nose especially in an individual from the Indian subcontinent may indicate a deficient descent of the anterior palatal plane manifesting as a counter clockwise rotation of the maxilla. However as multiple tests are being performed in this study, the probability of significant results occurring by chance increases and the significance level of correlation coefficients should be interpreted with caution.

Similar data are not available for other major ethnic and racial groups and further work on different populations may prove useful from a diagnostic and treatment planning perspective.

Conclusions

- Nasal length was seen to be significantly correlated to upper anterior facial height and inclination of palatal plane.
- An upturned nose in an adult individual was significantly correlated with anti-clockwise rotation of maxilla.

Contributor statement

Mr Karan Nehra was responsible for data collection, drafting, critical revision and technical support of the article.Mr Vineet Sharma was responsible for study design, critical revision and final approval of the article.Mr Karan Nehra is the guarantor and, as such accepts full responsibility for the study, has access to the data and controlled the decision to publish.

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