2018

Heritability of nasal characteristics using lateral cephalograms

BOSTON UNIVERSITY

HENRY M. GOLDMAN SCHOOL OF DENTAL MEDICINE

THESIS

HERITABILITY OF NASAL CHARACTERISTICS USING LATERAL CEPHALOGRAMS

RAMANDEEP SAMRA

B.Sc. York University, 2011

D.M.D. Henry M. Goldman School of Dental Medicine, 2015

Submitted in partial fulfillment of the requirements for the degree of

Master of Science in Dentistry
In the Department of Orthodontics and Dentofacial Orthopedics

2018

Approved by

First Reader ______________________________

Dr. Motro, DDS, PhD

Clinical Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics

Second Reader ______________________________

Dr. Khiem, DMD, MSD

Clinical Associate Professor, Department of Orthodontics and Dentofacial Orthopedics

Third Reader ______________________________

Dr. Leslie A. Will, DMD, MSD

Program Director, Division of Graduate Orthodontics

Department Chair, Department of Orthodontics and Dentofacial Orthopedics

ACKNOWLEDGEMENTS

I would like to thank my mentor, Dr. Leslie Will, for her continued support over the past three years. Throughout this entire project her guidance and words of encouragement pushed and motivated me to create a thesis I am proud of, and I greatly appreciate her efforts.

I would also like to thank the Forsyth Institute as well as the American Association of Orthodontists for allowing access to the Twin Study sample and funding this research. Without these samples and funding, this study would not have been possible.

I would also like to thank Dr. Motro for all of his mentorship throughout the past three years. I am grateful to have had his help within the scope of this project and for his effort to always to meet with me, whenever I had any questions or concerns.

I would also like to thank Dr. Ahmed Alsulaiman for his tremendous help with this project. His research design and countless hours of help made this project possible. My never-ending questions have finally come to an end!

Finally, I would like to thank all of my close friends and family, and specifically my parents, grandparents, my brother and my fiancé, for their never-wavering love and support. They have always and continue to support me in all I do and I am beyond grateful to have them in my life.

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RAMANDEEP SAMRA

Boston University, Henry M. Goldman School of Dental Medicine, 2018

Major professor: Leslie A. Will, DMD, MSD, Department Chair, Department of Orthodontics and Dentofacial Orthopedics

IRB NUMBER: H-34719

ABSTRACT

Background: Growth of the cranial base and its structures are of particular interest to the orthodontic community. The midface and nasal bones have a significant influence on facial esthetics and thus pattern recognition of facial growth from parental data can influence orthodontic treatment plans. We aimed to determine if there is a similarity in midface and nasal bone and soft tissue growth between a child and either parent.

Materials and Methods: This cross-sectional study was comprised of forty-seven western European families from the Forsyth/Moorrees Twin Study. The lateral cephalograms of each parent and post pubertal child, who were at least 2 years past peak growth (age $\geq$ 16 yrs for females and $\geq$ 17 yrs for males) were evaluated on fourteen cephalometric variables. The radiographs were digitized and analyzed using the Mimics™ software program (Materialise, Leuven, Belgium) by a single investigator. A linear regression analysis was used to correlate linear and angular measurements to one another. An ANOVA with multiple comparisons (TUKEY) was performed to test for the differences between family members controlling for the effect of the individual family (as each family has a trend within itself). Age and gender interactions were tested for in the models. Statistical significance was set at $p < 0.05$.

Results: Twenty-five male and twenty-two female children and their parents were studied. When comparing the fourteen parameters between the mean of the child and both parents, a significant difference ($p < 0.05$) was found between the child and the father but not the mother in six measurements. These included the ratio of nasal height to total face height, angle of nasal bone to SN, distance from rhinion to pronasale (mm), distance from ANS to pronasale (mm), projection of nose (mm) and nasal length (mm). A significant difference was also found between the child and the mother, but not the father for rhinion to ANS (mm). A significant difference was found between the child and both parents for nasal height (mm). When controlling for family and isolating the gender of the child, males and females were not significantly different from their fathers for ratio of nasal height to total face height. For angle of nasal bone (S-N-Rh) and nasal length (N'-vertical line from Pro), females but not males were significantly different from the father. Both girls and boys were still significantly different from the father in the rhinion to pronasale and ANS to pronasale distances, projection of nose and nasal heights.

Only males showed a significant difference from the mother for rhinion to ANS and nasal height when isolated for by gender.

Conclusion: Statistically significant differences were found between the child and father and not the mother for six out of our fourteen measurements of interest. Two measurements of interest showed a difference between the child and the mother and not

the father and one showed a significant difference from both parents. From this study we conclude that children tend to be morphologically less similar to their fathers when comparing midface and nasal soft and hard tissue parameters.

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REVIEW OF THE LITERATURE

Background

A child's physical attributes often resemble a particular parent or are combination of both parents. Genetically, we are derived from an equal number of cells from each parent; however, expressivity and environmental factors can influence our external features. Parental characteristics often act as a starting point when predicting potential features in the child. Growth is one example where children are compared to their parents throughout childhood and adolescence. Within the realm of orthodontics, the growth of the cranial base and its structures can influence form, function and esthetics. It is for these reasons that we must consider growth during treatment plan considerations.

Although past research has helped develop average growth curves in relation to height and weight, a standard for the pattern of growth for the cranial base has not yet been established, since there is high individual variance. Studies have attempted to gather patterns of growth from the same subject, but have sparsely used parental data. In order to have an accurate representation of the growth potential of a child, having parental information can be quite valuable. This provides an outcome to which the possibilities of growth can be compared to and help direct treatment plan considerations in the right direction.

As orthodontists, our main focus is on intraoral concerns. However, it's the extraoral features that are exposed in an everyday environment. Therefore, the hard and soft tissues surrounding the teeth must be considered as part of a complete diagnosis and treatment plan. The midface and nasal bone structures have a dramatic influence on facial esthetics, both from the frontal and profile orientations. Therefore, the prediction of growth of these bones can help influence orthodontic treatment, primarily on retraction or non-retraction mechanics as the majority of the nose stops growing after routine orthodontics is often completed. It has been said that the upper lip, by virtue of its attachment to the nose, may be affected in its thickness and position by growth tendencies of the nose itself. Therefore, it would seem important to consider the growth of the nose and its influence on the soft tissue profile.[1] This study will focus on using lateral cephalometric radiographs of parents to predict the growth pattern of midface and nasal hard and soft tissues of their children. The null hypothesis to be tested is that there is no relationship in mid-face and nasal bone and soft tissue growth pattern between both the parents and the corresponding children.

Literature Review

Parental genetic influences on a child's characteristics have long been discussed in research studies. Although there is a tendency to rely on growth curves and normative values of the population, Suzuki and Takahama suggested otherwise. Studying 250 Japanese families, they found that the correlation of craniofacial form between a child and parent becomes closer with growth, suggesting that the use of parental information can be more informative than of population norms. The study showed that if the craniofacial form of a young child resembles that of either parent, it will continue to resemble that parent into adulthood, as the phenotype of facial appearance does not change with age.[2] In the same regard, Nakata et al., used the Indiana University twin sample of sixty-four families to estimate heritability patterns. The study found that the father-child heritability patterns with regards to certain lateral cephalometric measurements, particularly involving mandibular structures, such as articulare to menton distance and gonial angle, were more closely related than that of the mother and child.[3] This supported the findings from a study conducted by Hunter et al., who looked at thirty-one families consisting of parents and their adult children (17-21 years of age) of European descent. They found linear skull measurements of the child, again mostly related to the mandible (articulare to gonion, articulare to gnathion and gonion to menton distances) to be more related to that of the father than the mother.[4] A study conducted by Stein et al., which focused on general lateral cephalometric angular measurements also confirmed this paternal-child correlation.[5] These studies focused on overall growth of the craniofacial structures, but nasal bone and midface structures were not highlighted.

Since skeletal tissue serves as the foundation over which the soft tissue is draped, it is important to understand the transition that will take place in the underlying cranial features from a young age to adulthood. According to Scott, the cranium undergoes an early rapid expansion to accommodate the growth of the brain, while the face shows sustained growth of a longer duration, in relation to dental development. He believed that most growth in length of the nasal bones occurred at the frontonasal suture, and no substantial amounts of growth took place at this suture after the first few years of life. Therefore, Scott believed that the forward positioning of the nasal bones later in life occurred due to the forward growth of the supporting nasal septal cartilages.[6] However, it is known from the studies of Sicher and Weinmann that the frontomaxillary, zygomaticomaxillary, zygomaticotemporal and pterygopalatine sutures all exhibit growth and since these structures are parallel to one another and are directed downward and forward, they cause this downward and forward shifting of the maxillary complex; which occurs later in life after the frontonasal suture has closed.[7] Bjork confirmed these results stating that growth of the craniofacial skeleton follows a general downward and forward growth pattern with varying degrees of rotation.[8] The nasal bone and soft tissue seem to follow this downward and forward growth into early adulthood and the degree of increase is expected to be equivalent for males and females. With age, the nose becomes more inclined in the forward direction and the tip of the nose, formed by a continuation of the bridge and the columella, will cause the nasolabial angle to become more acute during the later stages of development in a normal growing individual. In terms of spatial relationships, the nose itself grows in a forward direction to a proportionately greater degree than the other soft tissues of the face, increasing its projection relative to the total facial profile. It tends to grow more in the vertical direction than horizontally, and in the horizontal or anterior-posterior direction, a sex difference can be noted between males and females. Females will often show a greater overall increase in the depth of the nose than will males at the same age.[1] In general, the path of growth of the soft tissue nose seems to be related to the path of growth of the nasal bone.[9] It is understood that after initial downward and forward growth of the nose, at some point in development, the nose tip does not grow to the same extent as the nasal bone. This results in a straightening or humping of the nasal dorsum.[10] An interesting finding from an article by Genecov who looked at cephalometric radiographs of 64 untreated persons who exhibited class I and class II skeletal patterns from the mixed dentition stage to early adulthood found that in skeletal class II patients, greater elevation and projection of the nasal bone, at the level of rhinion is seen, resulting in a dorsal nasal hump. [11] Robison et al, explained that 85% of patients in their sample of 123 demonstrated a correlation of nasal shape with specific skeletal groupings. Straight profiles tended to have straight noses, convex profiles accompanied convex nasal shapes and concave profiles had concave nasal shapes.[12] This parallels the theory which states that people with more anterior and superior rotational patterns of lower facial growth will exhibit a similar rotational pattern of the nasal dorsum as influenced by rhinion.[13]

Growth of the nose has been reported to continue into early adulthood increasing 1- $1^{1/3}$ millimeters in overall length per year.[1] From a study involving a sample of thirty Caucasian children, Posen found that the nasal bone (nasion - rhinion distance) increased in length an average of 12.36 mm from ages 3 months to 18 years of age, 90% of which was accomplished by the age 13. On the other hand, only 58% of the total nasal bone angulation (measured from basion – nasion - rhinion) was accomplished by age 13. As we age, it appears that the prime factor in determining nose shape is the angular change in the nasal bone as related to the changes in the nasal dorsum and the tip of the nose.[10]

It is important to acknowledge that there may be differences in growth patterns between males and females. Looking at the course of nasal development and the relative position of the nose to the rest of the soft tissue, Genecov et al., searched for associations between the patterns of hard and soft tissue development using longitudinal data. They studied both male and female subjects at 7, 12 and 17 years of age. In terms of angular measurements of the nasal bone (sella – nasion - rhinion), they found that the anterior projection increased from ages 7-17 in both sexes (7 and 10 degrees in females and males respectively). However, in the anterioroposterior dimension as defined by soft and hard tissue landmarks to a vertical line from the tip of the nose, and vertical positions of the nose, from soft tissue nasion to subnasale, they found that females completed a large portion of their hard and soft tissue development by age 12, whereas males continued until the age of 17. Overall, they found a considerable dichotomy to occur between the sexes from 12-17 years of age.[11] Therefore, when evaluating treatment plan, it must be understood that males and females have differential growth remaining at certain age points. Subtelny's longitudinal study of males and females from 1-18 years of age found no difference in the degree of increase in nasal length (nasion to pronasale), but did note that males on average had greater values than females.[9] Begg's cross-sectional study of 50 untreated dental school students with a mean age of 21 for males and 20.2 for females found similar results, but also added that men had taller noses (soft tissue nasion – subnasale) that projected further from the face (soft tissue nasion vertical to pronasale), longer dorsa (soft tissue nasion – pronasale) and straighter noses (per smaller supra-tip beak angle – dorsal nose plane to supra-tip plane)) than women.[14] For males, it is also known that a growth spurt between ten and sixteen will show forward positioning of the nasal bone and subsequent elevation of the bridge of the nose.[1] Behrents confirmed the results above as he looked at nasal changes from childhood into late adulthood. He stated that males on average have larger noses, but angular measurements did not differ amongst sexes. The nasal tip moved downward with increasing age, but was less prominent in females. [15]

The age at which nasal bone growth is completed has also been extensively looked at for cosmetic considerations, such as rhinoplasty procedures. A systemic review conducted by Heijden et al., stated that in 98 % of adolescent girls the nose is mature at the age of 15.8 years. For 98 % of adolescent boys, this age is 16.9 years. Because the results of nasal interventions performed after the age of maturation are not likely to be disturbed by nasal growth, a rhinoseptoplasty can be performed safely, in most cases, in adolescent girls the age of 16 years and in adolescent boys after the age of 17 years.[16] Previous articles have speculated the maturation of the nose to occur as early as 12-13 for females.[10,11] Others have indicated that female noses are close to complete by 15, but male noses continue growth even past the age of 18.[17] This is crucial to our study, as our lateral cephalometric radiographs of the children must be older than the age stated above.

The degree of resemblance between a parent and child regarding nasal bone and midface growth has only been touched upon in the past. However, my research will go into depth pertaining to this and attempt to focus on whether or not facial patterns resemble one parent or are a hybrid of both when pertaining to nasal bone and midface growth.

Hypothesis and Objectives

1. The first objective of this study was to determine if there is a difference in midface and nasal bone and soft tissue growth between a child and either parent
    - The null hypothesis is that there is no difference in midface and nasal bone and soft tissue growth between either parent and their child
2. The second objective of this study was to determine if there was a difference between male or female children in the extent of their similarity to either parent
    - The null hypothesis is that there is no difference between males or females in the extent of their similarity to their mothers or fathers

MATERIALS AND METHODS

Sample Selection

The initial power analysis for this retrospective study showed that for a power of 95%, 40 families would be adequate to determine statistically significant correlations. The approval of the Institutional Review Board (IRB) of the Boston University Medical Campus was obtained (IRB: H-34719). Subjects were selected from the Forsyth/Moorrees Twin Study, which contains orthodontic records from roughly 500 families with twins or triplets taken at the Forsyth Infirmary for Children in Boston, Massachusetts from 1959-1975. Lateral cephalograms of children and parents from this database were screened using the inclusion criteria below. All lateral cephalograms were taken using the same machine and settings. The films were digitally scanned using an Epson Expression 11000XL – Photo Scanner (Epson America, Inc., Long Beach, CA) with the settings: Professional Mode, Film, Positive Film, 16-bit Grayscale, 300 dpi. All subjects were selected for quality of films, families of post pubertal children, and parents with posterior occlusal stops. Siblings, twins and triplets were not included in this study.

Inclusion Criteria

Quality of films

Films had to be of sufficient quality (including contrast and clarity) to identify landmarks and trace the lateral cephalograms to be included. Under or overexposed films, films containing objects blocking landmarks (e.g. jewelry), or blurry films were excluded from this study. Films from which nasal soft tissue was not visible also were excluded from the study.

Families of post-pubertal children

The children were selected based on the availability of lateral cephalogram radiographs of both parents. If the family consisted of multiple post-pubertal children with radiographs of diagnostic quality, the child with the best quality radiograph was taken. Selection of gender was not known during sample selection, so the ultimate sample of 25 males and 23 females occured at random (ages 17-19). Post-pubertal status was indicated by cervical vertebral maturation stage of CS5, indicating that peak growth occurred at least 2 years ago.[18] Hand wrist radiographs were not available for all the children, so the Fishman Skeletal Maturity Assessment could not be used [19].

Parental posterior occlusal stops

Families were only included if both parents had posterior occlusal stops. Since a lack of vertical dimension of occlusion (VDO) can influence soft tissue support, including that of the nose, it was important that occlusal stability was present in all subjects.

Landmark Selection and Identification

After screening, 47 families consisting of both parents and one child were selected for this study. Each subject's lateral cephalograms were digitized and anatomical landmarks were identified using the MIMICS (Materialise's Interactive Medical Image

Control System; Leuven, Belgium) software program (Version 19.0). The original scanned radiographs were converted to a file (JPEG to TIFF) that could be analyzed by the software program. This caused a 0.5 mm source of error in all linear values due to a difference in pixilation and magnification; however, this did not affect our results as the same 0.5mm difference was found across all radiographs. Because of this discovery, these values were controlled for in the final design of the project. A secondary source to confirm millimetric values was a radiopaque ruler in the Bolton Cephalostat, allowing for an additional means of evaluating reliability of measurements.

Fourteen parameters were studied, including hard tissue, soft tissue and hard-to-soft tissue measurements. The landmarks and measurements used to study linear and angular characteristics in tables 1 and 2 were selected from previous studies [15,10,20,14,21,22,23] and were chosen because as a group they are able to provide a detailed description of hard and soft tissue nasal characteristics that are important to us from the lateral view.

Region Selection and Delineation

Regions of interest included the cranial base, midface and nasal hard and soft tissues. The regions of interest were further divided into hard tissue, nasal bone and face height, soft and hard tissue and soft tissue measurements of interest. All of the lateral cephalograms were adjusted to the natural head position to standardize the position of the radiograph. A list of all landmarks that connect and delineate each region is shown in table 2.

Table 1. Lateral cephalogram landmarks

Landmar	Definition	
1	A (A point)	Most concave point of anterior maxilla
2	ANS (anterior nasal spine)	The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening
3	B (B point)	Most concave point on mandibular symphysis
4	Cm (Columella)	The most anterior soft tissue point on the columella of the nose
5	Ls (labialis superior)	Most prominent portion of the upper lip
6	L1 (tip of lower central incisor)	Most labial portion of the lower incisor
7	Me (Menton)	Lowest point on mandibular symphysis
8	N (Nasion)	Most anterior point on frontonasal suture
9	N'(Soft tissue nasion)	Point on soft tissue over nasion
10	Pg (Soft tissue Pogonion)	Soft tissue over pogonion
11	P (Pronasale)	Pronasale: Most prominent point of the nose
12	Rh (Rhinion)	The anterior tip at the end of the suture of the nasal bones
13	Sn (Subnasale)	In the midline, the junction where base of the columella of the nose meets the upper lip
14	S (Sella)	Midpoint of sella turcica
15	U1 (tip of upper central incisor)	Most lingual portion of the tip of the upper incisor

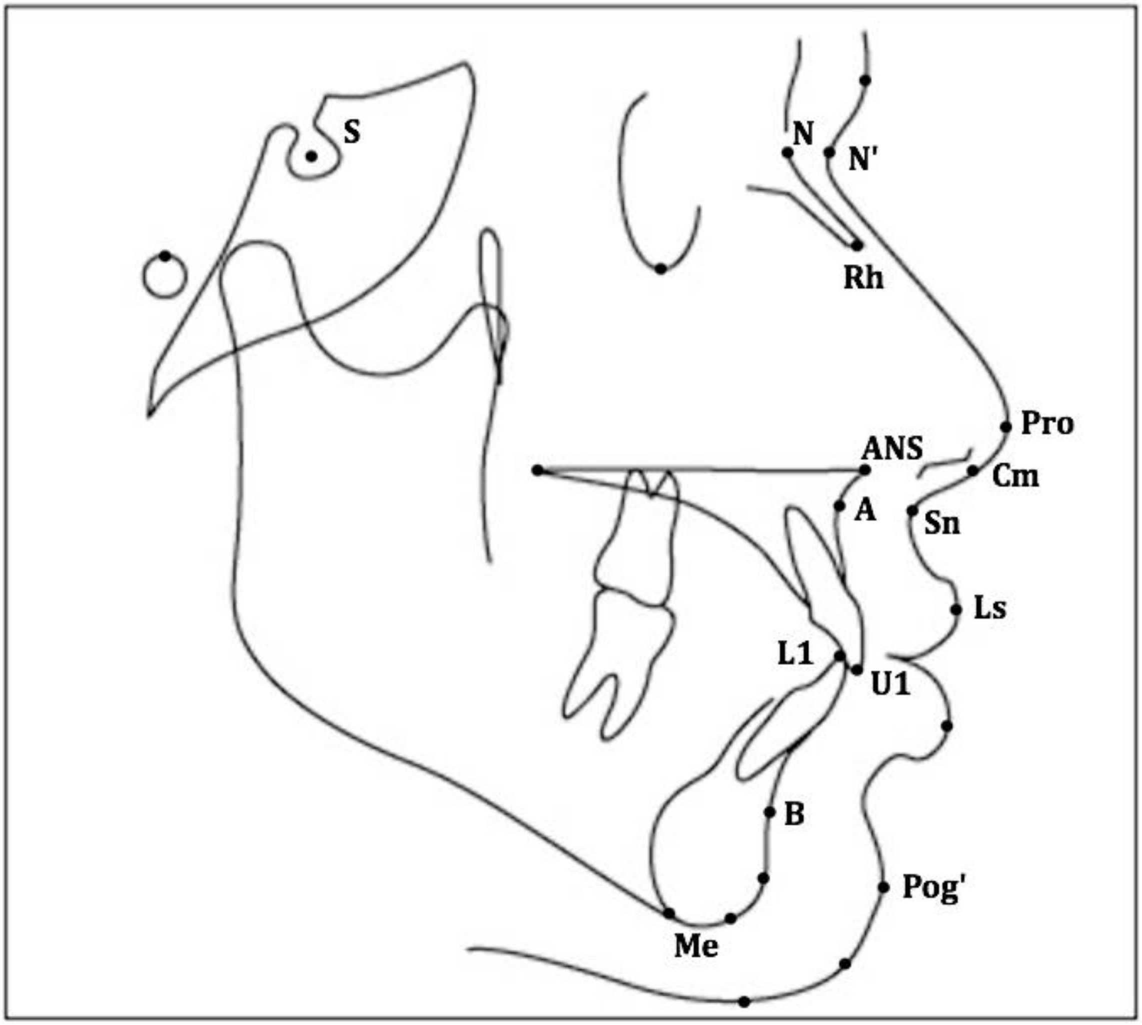

Figure 1: Diagram of landmarks

Table 2: Measurements of interest

Measurement of interest	Landmarks
Hard tissue	
ANB (degrees)	A point – N – B point
Overjet (mm)	U1 –L1 (mm)
Nasal bone and face height	
Ratio of nasal height to total face height	(N-ANS/N-Me)
Angle of Nasal bone to SN	S-N-Rh
Nasal Bone length (mm)	N-Rh
Distance from Rhinion to ANS (mm)	Rh-ANS
Angle of anterior nasal spine relative to Sella-Nasion	S-N-ANS
Hard and Soft tissue	
Rhinion to Pronasale (mm)	Rh-Pro
Anterior Nasal Spine to Pronasale (mm)	ANS-Pro
Soft tissue	
Nasolabial angle	Cm-Sn-Ls
Projection of nose (mm)	Sn-Pro
Soft tissue convexity angle with the nose	N'-Pro-Pog'
Nose Height (mm)	N'-Sn
Nose Length (mm)	N'-Vertical line from Pro

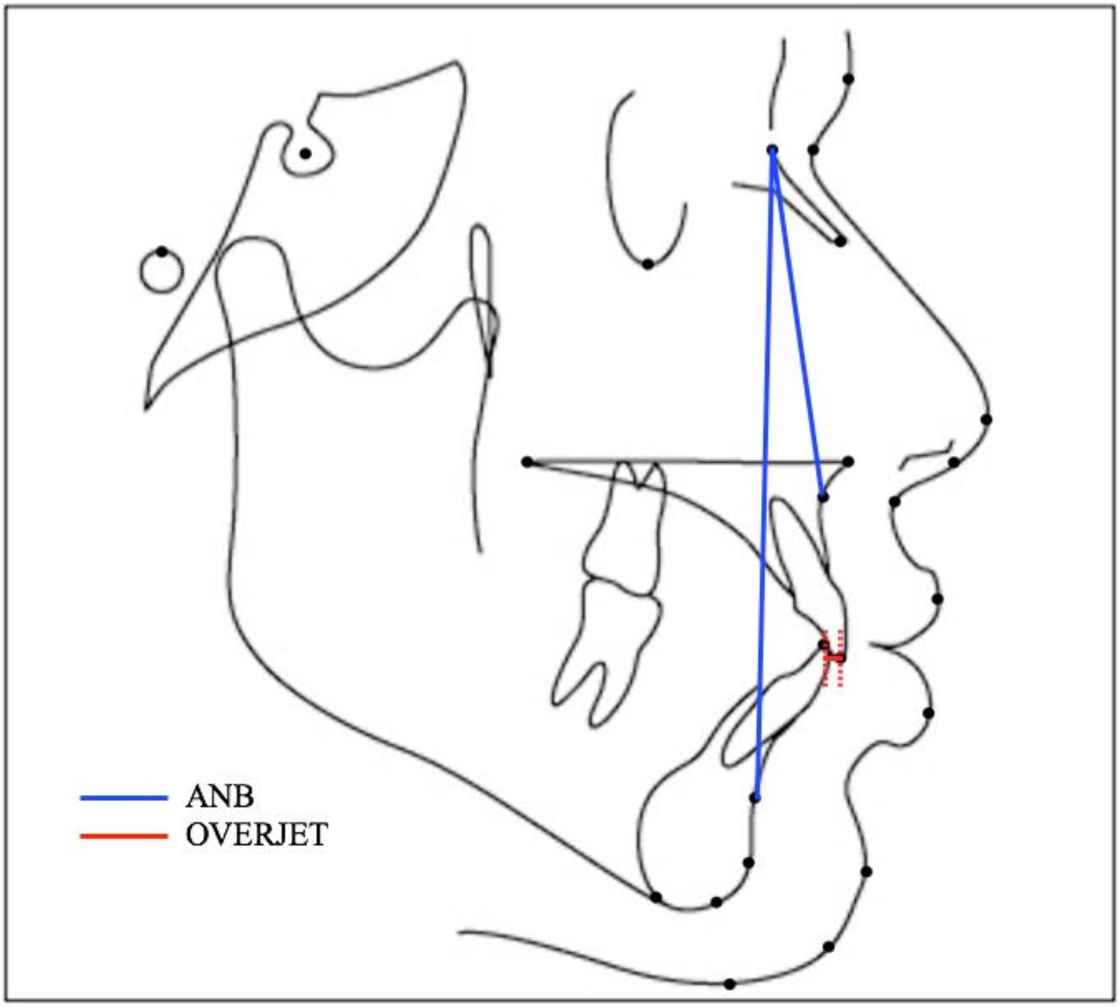

Figure 2: Measurements of interest, hard tissue

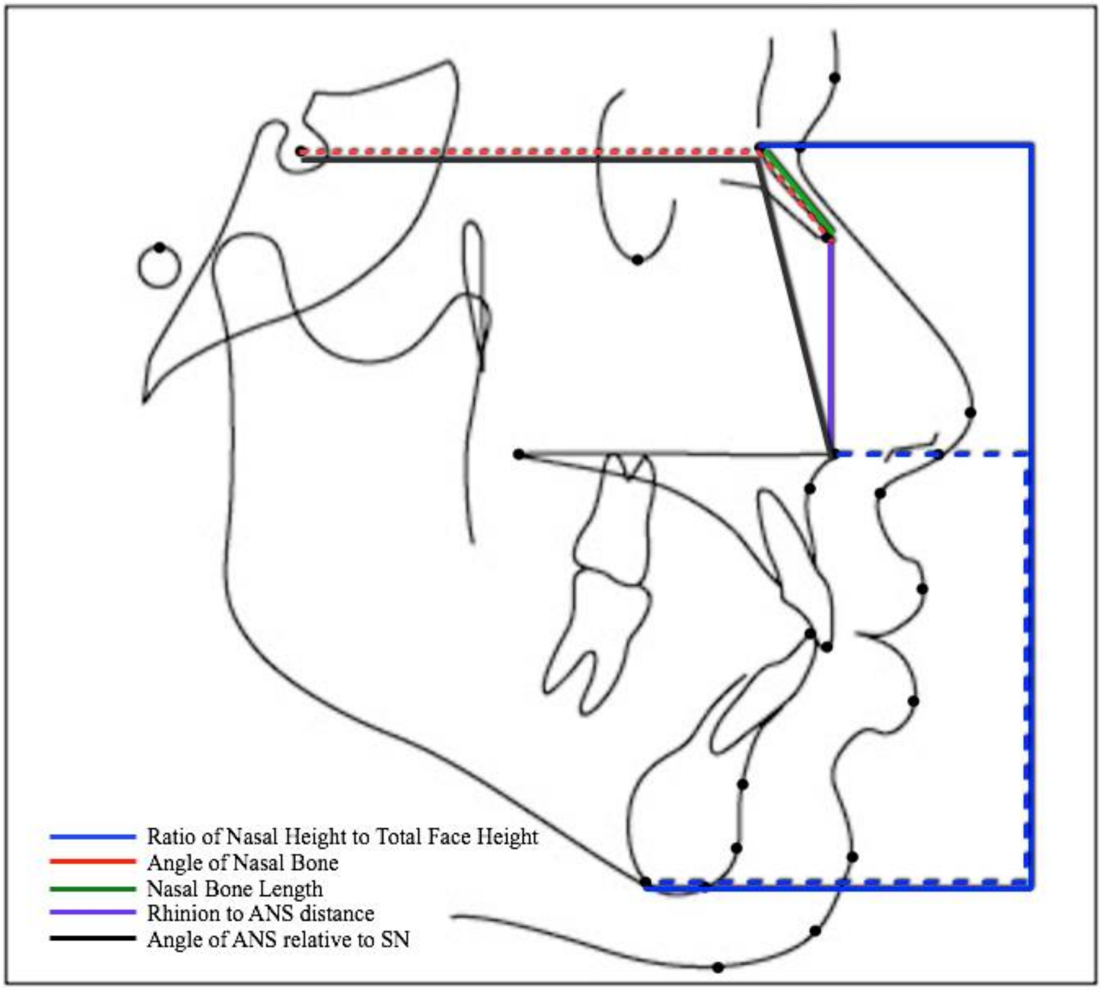

Figure 3: Measurements of interest, nasal bone and face height

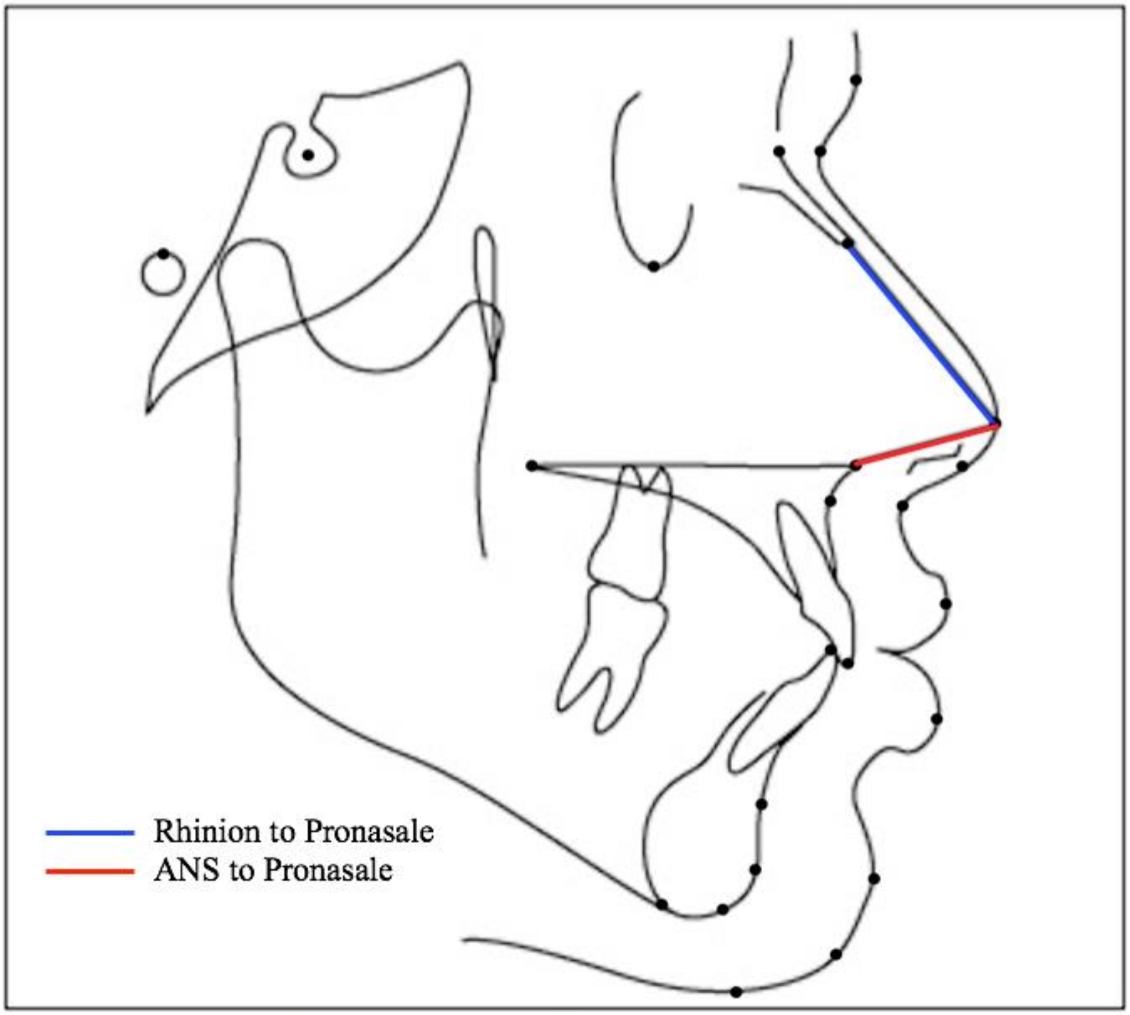

Figure 4: Measurements of interest, hard and soft tissue

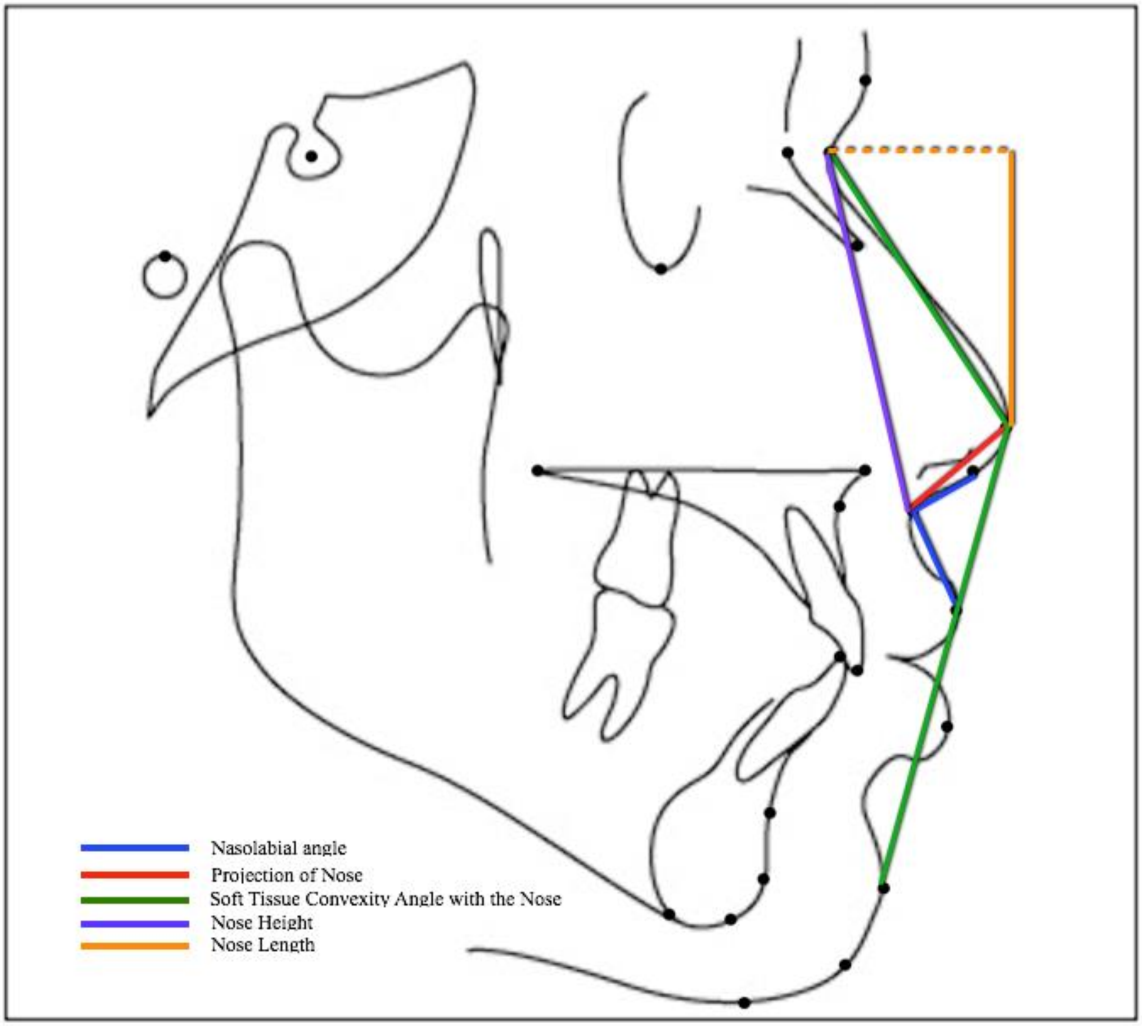

Figure 5: Measurements of interest, soft tissue

Statistics

An ANOVA with multiple comparisons (TUKEY) was performed to test our hypothesis, taking into account the effect of family in the analysis. Age and gender interactions were included in the models if they were significant. Stratified analysis was performed if the interaction terms were significant.

RESULTS

Intra-examiner Error

The tracings from ten of the first families (including both sets of parents and the child) were re-traced and scaled in MIMICS two weeks later by the same examiner. An Intraclass correlation coefficient (ICC) analysis was performed to show the reliability between the two readings for all landmarks and it showed excellent reliability (Table 3).

Table 3: Intraclass correlation coefficient table

Characteristics	ICC (Intraclass Correlation Coefficient)
Hard tissue	
ANB (degrees), mean ± SD	0.98
Overjet (mm), mean ± SD	0.97
Nasal bone and face height	
Ratio of nasal height to total face height, mean ± SD	0.96
Angle of Nasal bone, mean ± SD	0.97
Nasal Bone length (mm), mean ± SD	0.94
Distance from Rhinion to ANS (mm), mean ± SD	0.97
Angle of anterior nasal spine relative to Sella-Nasion, mean ± SD	0.95
Hard and Soft tissue	
Rhinion to Pronasale (mm), mean ± SD	0.97
Anterior Nasal Spine to Pronasale (mm), mean ± SD	0.98
Soft tissue	
Nasolabial angle, mean ± SD	0.99
Projection of nose (mm), mean ± SD	0.91
Soft tissue convexity angle with the nose, mean ± SD	0.91
Nose Height (mm), mean ± SD	0.97
Nose Length (mm), mean ± SD	0.95

Objective 1

When comparing the fourteen parameters from Table 2 between the child and each parent, a significant difference ($p < 0.05$) was found between the child and the father but not the mother in six measurements (see Table 4). These included, ratio of nasal height to total face height, angle of nasal bone to SN, distance from rhinion to pronasale (mm), distance from ANS to pronasale (mm), projection of nose (mm) and nasal length (mm). A significant difference was also found between the child and the mother, but not the father for rhinion to ANS (mm). A significant difference was found between the child and both parents for nasal height (mm).

Table 4: Measurement of interest and comparison of the child to the mother and father

Characteristics	Child	Mother	Father	Child vs. Mother	Child vs. Father
Age, mean ± SD*	17.9 ± 0.6	39 ± 5.6	41.7 ± 5.6	-	-
Hard tissue					
ANB (degrees), mean ± SD	3.5 ± 2.3	3.4 ± 2.2	2.5 ± 2.2	*	*
Overjet (mm), mean ± SD	2.7 ± 2.2	3.1 ± 2.1	2.2 ± 2.4	*	*
Nasal bone and face height					
Ratio of nasal height to total face height, mean ± SD	45 ± 2.4	43.8 ± 2.7	43.4 ± 2.5	*	-
Angle of Nasal bone, mean ± SD	114.2 ± 6.7	114.9 ± 5.0	118.1 ± 5.6	*	-
Nasal Bone length (mm), mean ± SD	24.2 ± 2.8	23.5 ± 2.9	25.4 ± 3.9	*	*
Distance from Rhinion to ANS (mm), mean ± SD	36.7 ± 3.0	34.6 ± 2.4	37.9 ± 2.8	-	*
Angle of anterior nasal spine relative to Sella-Nasion, mean ± SD	85.4 ± 5.5	84.8 ± 3.4	85.2 ± 4.3	*	*
Hard and Soft tissue					
Rhinion to Pronasale (mm), mean ± SD	33.5 ± 3.8	32.8 ± 2.8	37.5 ± 3.2	*	-
Anterior Nasal Spine to Pronasale (mm), mean ± SD	30.5 ± 2.7	30.4 ± 2.5	34.8 ± 3.5	*	-

SD = standard deviation

(*) p-value > 0.05 represents similarity

(-) p-value < 0.05 represents significant difference

Table continued on next page.

Table 4 (continued): Measurement of interest and comparison of the child to the mother and father

Characteristics	Child	Mother	Father	Child vs. Mother	Child vs. Father
Soft tissue					
Nasolabial angle, mean ± SD	112.4 ± 9.8	108.3 ± 8.8	109.7 ± 10.4	*	*
Projection of nose (mm), mean ± SD	22.5 ± 2.5	23.5 ± 1.7	25.2 ± 2.6	*	-
Soft tissue convexity angle with the nose, mean ± SD	130.9 ± 5.2	129.8 ± 5.2	130.3 ± 5.3	*	*
Nose Height (mm), mean ± SD	62 ± 4.1	59.9 ± 3.4	65.5 ± 3.7	-	-
Nose Length (mm), mean ± SD	26.5 ± 4.0	26.8 ± 3.1	28.8 ± 3.7	*	-

SD = standard deviation

(*) p-value > 0.05 represents similarity

(-) p-value < 0.05 represents significant difference

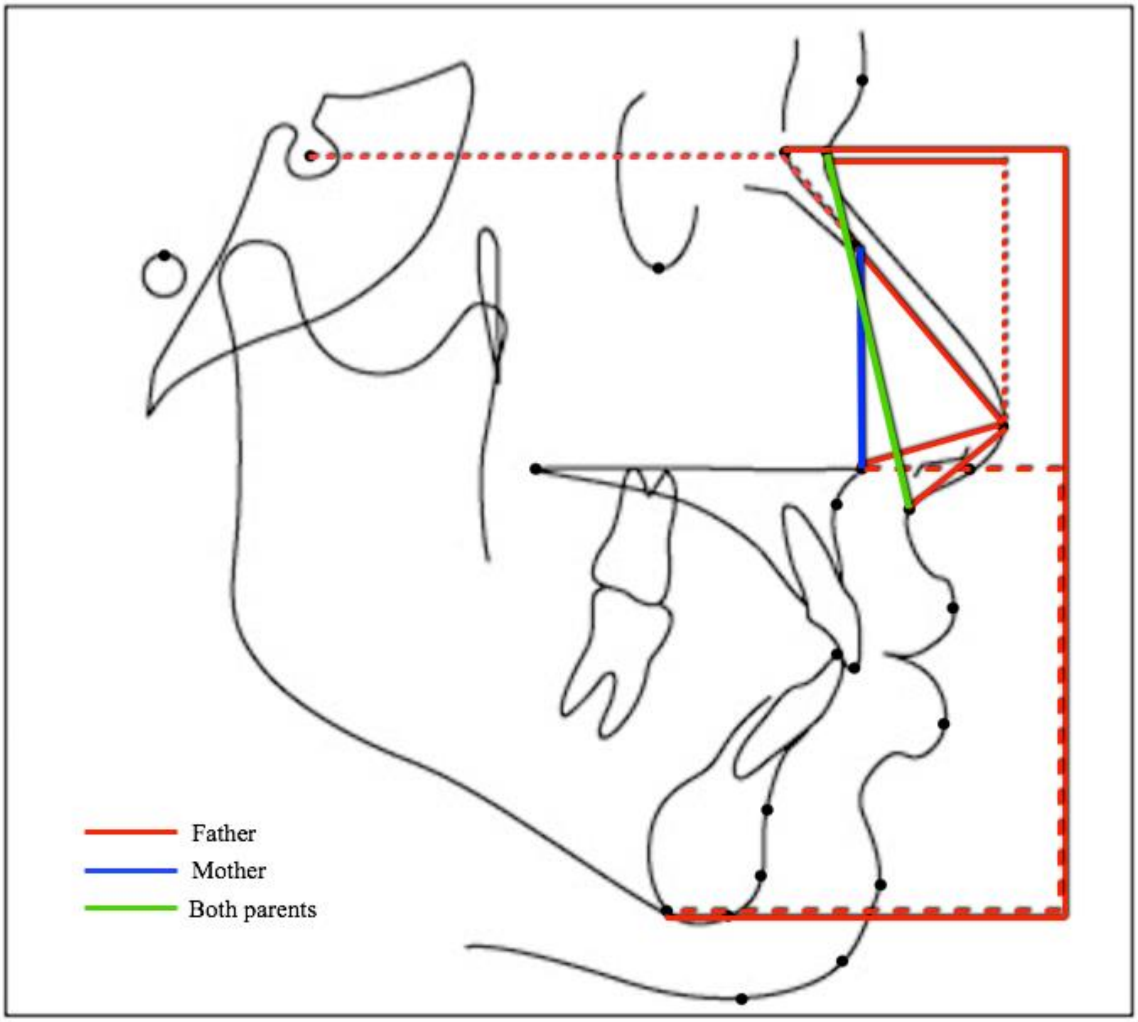

Figure 6: Measurements of interest yielding significantly different results with children as a whole

Objective 2

When controlling for family and isolating the gender of the child, some differences were found from the mean child results. For ratio of nasal height total face height, males and females were not significantly different from their fathers when looked at as groups of girls versus groups of boys. For angle of nasal bone and nasal length, although the overall results showed that children as a whole were different than their fathers, individually, only females showed a significant difference from the father when isolated for by gender. This implies that there is a significant interaction ($p < 0.05$) between gender and the measurement of interest. The measurements of interest, rhinion to pronasale, ANS to pronasale, projection of nose, nasal height all were still significantly different between the father and the mean of the boys as well as the mean of the girls.

For both the distance from rhinion to ANS and nasal height, although the overall results showed that children as a whole were different than their mothers, individually, only the mean of the males showed a significant difference from the mother when isolated for by gender. This once again implies that there is a significant interaction ($p < 0.05$) between gender and the measurement of interest.

Table 5: Measurement of interest and comparison of the male child to the mother and father

Characteristics	Male	Mother	Father	Male vs. Mother	Male vs. Father
Age, mean ± SD*	17.9 ± 0.5	40.5 ± 5.8	43.2 ± 5.7	-	-
Hard tissue					
ANB (degrees), mean ± SD	4.2 ± 2.2	3.9 ± 2.3	2.8 ± 2.4	*	*
Overjet (mm), mean ± SD	3.1 ± 2.6	3.1 ± 2.0	1.7 ± 2.0	*	*
Nasal bone and face height					
Ratio of nasal height to total face height, mean ± SD	45.0 ± 2.3	44.1 ± 2.5	43.7 ± 2.6	*	**
Angle of Nasal bone, mean ± SD	116.9 ± 5.9	114.7 ± 4.7	117.3 ± 5.1	*	**
Nasal Bone length (mm), mean ± SD	24.5 ± 3.4	23.7 ± 3.1	25.6 ± 3.9	*	*
Distance from Rhinion to ANS (mm), mean ± SD	38.1 ± 2.4	34.7 ± 2.6	37.9 ± 2.7	-	*
Angle of anterior nasal spine relative to Sella-Nasion, mean ± SD	87.6 ± 5.1	85.5 ± 3.4	85.6 ± 4.4	*	*

SD = standard deviation
(*) p-value > 0.05 represents similarity
(-) p-value < 0.05 represents significant difference
(**) different results than when child was looked at as a whole (male + female)
Table continued on the next page.

Table 5 (continued): Measurement of interest and comparison of the male child to the mother and father

Characteristics	Male	Mother	Father	Male vs. Mother	Male vs. Father
Hard and Soft tissue					
Rhinion to Pronasale (mm), mean ± SD	34.9 ± 3.3	33.2 ± 3.2	37.9 ± 3.1	*	-
Anterior Nasal Spine to Pronasale (mm), mean ± SD	31.3 ± 2.9	30.2 ± 2.6	34.4 ± 3.6	*	-
Nose Length (mm), mean ± SD	28.3 ± 3.9	27.3 ± 3.5	29.3 ± 3.7	*	**
Soft tissue					
Nasolabial angle, mean ± SD	112.5 ± 10.2	107.6 ± 9.7	110.5 ± 9.7	*	*
Projection of nose (mm), mean ± SD	23.0 ± 2.6	23.5 ± 2.0	25.5 ± 2.8	*	-
Soft tissue convexity angle with the nose, mean ± SD	128.7 ± 4.9	128.5 ± 5.1	129.6 ± 5.3	*	*
Nose Height (mm), mean ± SD	63.3 ± 3.7	60.6 ± 3.9	66.1 ± 3.9	-	-

SD = standard deviation

(*) p-value > 0.05 represents similarity

(-) p-value < 0.05 represents significant difference

(**) different results than when child was looked at as a whole (male + female)

Table 6: Measurement of interest and comparison of the female child to the mother and father

Characteristics	Female	Mother	Father	Female vs. Mother	Female vs. Father
Age, mean ± SD*	17.5 ± 0.6	37.2 ± 4.8	40.0 ± 5.1	-	-
Hard tissue					
ANB (degrees), mean ± SD	2.7 ± 2.1	2.8 ± 1.9	2.0 ± 2.0	*	*
Overjet (mm), mean ± SD	2.2 ± 1.3	3.1 ± 2.3	2.9. 2.7	*	*
Nasal bone and face height					
Ratio of nasal height to total face height, mean ± SD	45.0 ± 2.6	43.84 ± 3.0	43.1 ± 2.4	*	**
Angle of Nasal bone, mean ± SD	111.2 ± 6.3	115.2 ± 5.4	119.0 ± 6.2	*	-
Nasal Bone length (mm), mean ± SD	23.9 ± 1.7	23.2 ± 2.8	25.3 ± 3.9	*	*
Distance from Rhinion to ANS (mm), mean ± SD	35.1 ± 2.9	34.5 ± 2.2	37.9 ± 3.0	**	-
Angle of anterior nasal spine relative to Sella-Nasion, mean ± SD	83.0 ± 4.9	84.0 ± 3.3	84.8 ± 4.2	*	*

SD = standard deviation
(*) p-value > 0.05 represents similarity
(-) p-value < 0.05 represents significant difference
(**) different results than when child was looked at as a whole (male + female)
Table continued on the next page.

Table 6 (continued): Measurement of interest and comparison of the female child to the mother and father

Characteristics	Female	Mother	Father	Female vs. Mother	Female vs. Father
Hard and Soft tissue					
Rhinion to Pronasale (mm), mean ± SD	31.9 ± 3.8	32.3 ± 2.3	37.0 ± 3.3	*	-
Anterior Nasal Spine to Pronasale (mm), mean ± SD	29.6 ± 2.2	30.6 ± 2.5	35.3 ± 3.4	*	-
Soft tissue					
Nasolabial angle, mean ± SD	112.3 ± 9.6	109.2 ± 7.8	108.8 ± 11.2	*	*
Projection of nose (mm), mean ± SD	21.9 ± 2.2	23.5 ± 1.5	24.8 ± 2.3	-	-
Soft tissue convexity angle with the nose, mean ± SD	133.3 ± 4.5	131.3 ± 4.9	131.1 ± 5.2	*	*
Nose Height (mm), mean ± SD	60.4 ± 4.1	59.2 ± 2.7	64.8 ± 3.5	**	-
Nose Length (mm), mean ± SD	24.4 ± 2.9	26.2 ± 2.6	28.2 ± 3.7	*	-

SD = standard deviation

(*) p-value > 0.05 represents similarity

(-) p-value < 0.05 represents significant difference

(**) different results than when child was looked at as a whole (male + female)

DISCUSSION

When comparing the fourteen parameters from Table 2 between the mean of the child and mean of each parent, a significant difference ($p < 0.05$) was found between the child and the father but not the mother in six measurements (see Table 4). These included, ratio of nasal height to total face height, angle of nasal bone to SN, distance from rhinion to pronasale (mm), distance from ANS to pronasale (mm), projection of nose (mm) and nasal length (mm). A significant difference was also found between the child and the mother, but not the father for rhinion to ANS (mm). A significant difference was found between the child and both parents for nasal height (mm). When looking at these findings as a whole, one can suspect that with the exception of nasal height to total face height, all measurements found to be significantly different than the father were those involving the depth of the nose in the anterior-posterior direction with a combination of vertical and horizontal components. On the contrast, rhinion to ANS distance, which is a vertical measurement, showed significant difference from the mother. Nasal height, which also encompasses a vertical component, showed significant difference from both parents. Therefore, we can reject the null hypothesis of no difference in midface and nasal bone and soft tissue growth between both the parents and the corresponding child for the above measurements of interest only.

When controlling for family and stratifying these results for gender, some differences were found from the overall child results. For ratio of nasal height total face height, males and females were not significantly different from their fathers when looked at individually. For angle of nasal bone and nasal length, although the overall results showed that children as a whole were different than their fathers, individually, only females showed a significant difference from the father when isolated for by gender. This implies that there is a significant interaction ($p < 0.05$) between gender and the measurement of interest. The measurements of interest, rhinion to pronasale, ANS to pronasale, projection of nose, nasal height all were still significantly different between the father and each individual child, when the gender was stratified. Therefore, when looking at angular measurements (angle of nasal bone) and those of a horizontal component (nasal length), females showed significant differences than their fathers, whereas males did not. When studying measurements involving both horizontal and vertical components (rhinion-pronasale, ANS-pronasale and projection of nose), both males and females were different than their fathers. As a result, when looking at treatment planning considerations, from this data we can assume that for most measurements, males and females will more closely resemble their mothers as they are significantly different than their fathers. This is with the exception of rhinion to ANS distance (vertical) and nasal height (vertical), where males tend to be different than their mothers. So in terms of predicting nasal patterns of children from parental information, as clinicians we should assume; that for vertical measurements, males will resemble more closely their fathers, for horizontal and vertical components, both males and females will resemble more closely their mothers, and for angular measurements males will resemble a combination of both mothers and fathers whereas females will more closely resemble their mothers. Therefore, we can reject the null hypothesis of no difference between either males or females to the extent of their similarity to their mothers and fathers for the measurements of interest that yielded significant results. However, for all other measurements of interest, we have to accept the null hypothesis.

Based on our study and from the results obtained, we are able to reject both null hypotheses for certain parameters and show that there is statistically significant tendency for certain genders to be significantly different from either or both parents depending on the measurements of interest in regards to the midface and nasal hard and soft tissue area.

This study was unique in the sense it was the first to focus solely on midface and nasal hard and soft tissue parameters of both parents and the post-pubertal child. Previous studies have looked at general facial characteristics and measurements, but none with this data have attempted to solely focus on the nose.

A study by Bishara and Jacobsen which studied 35 subjects on 48 descriptive parameters demonstrated that 77% of people maintained their facial types (long, average or short) from ages 5 to 25.5 years of age.[24] This obviously does not specify soft tissue and nasal changes, but overall facial pattern can be described without parental information more than ¾ of the time.

Two Nakata and Takahama studies used parental information in the hopes of gathering heritability patterns of the post-pubertal child. They found a high correlation between the craniofacial form of the child and that of his or her parents, noting that the relationship becomes closer with growth from childhood to adulthood.[2,3] This supported our notion that parental information is better than average growth curves when craniofacial form is to be determined. However, both studies failed to focus on nasal parameters and instead focused on reference planes and overall facial measurements.

A study by Hunter looked at parents and children that were reported to be past their pubertal growth spurt (17-21 years of age). By using 21 males and 27 females, they found a stronger correlation between the father and child than the mother and child, but also lacked the inclusion of nasal characteristics (mainly focusing on mandibular measurements).[25] Facial height, the only relevant measurement to our study, was shown to resemble both parents. Unfortunately, this study did not use the measurements we included in our study, so our results could not be compared with theirs.

Saunders stated that multiple measurements from both parents give the best results when attempting to predict a child's craniofacial dimensions, indicating that parental information can be quite useful in clinical orthodontic treatment planning. This study by Saunders, which utilized the Burlington Growth Center sample where 90% of the children had records at 20 years of age, found that the father's information was slightly better than data from the mothers in predicting the son's measurements. However, these results primarily addressed mandibular changes. When focusing on cranial base, and a combination of maxillary and mandibular measurements, mid-parent (average) values increased the predictability of the child's values.[26] This study however, did not include midfacial and nasal parameters, and thus, no actual comparison can be made.

Alkhudhairi and Alkofide in Saudi Arabia looked at 4 members of the family; mother, father, son and daughter. 24 families with children aged 17 years or older were studied and a significant correlation between the father-child groups was found more than the mother-child groups. The daughters resembled more their fathers in all variables (angular, linear and proportional).[27] Unfortunately, different parameters were examined so that this study could not be compared with ours. An interesting matter that was brought up with this study was the concept of co-habitual effect, which causes family members to share similar traits due to a shared environment, in addition to genetics. This can also be an important consideration when looking at such studies where two siblings are compared to their parents.

A study on 45 Northern Irish families with boys and girls over the mean age of 18.4 years by Houston and Brown focused on family likeness as a basis of facial growth. This study did examine a similar measurement to ours, nasal height (N-ANS, but did not compare it to total face height), and they found no definitive pattern and the values were generally consistent with the polygenic mode of inheritance.[28] Polygenic inheritance describes the inheritance of traits that are determined by more than one gene, indicating that neither parent contributes more to nasal height.[26] These results were different than ours because of the difference in measurement used as well as that our sample did not contain only Northern Irish families.

Johannsdorrit et al., looked 363 Icelandic children at ages 6 and 16 and compared them to their parents using lateral cephalograms. The two sexes were further categorized to include the 6 and 16-year-old males with both parents and the 6 and 16-year-old females with both parents. When comparing nasal bone length (nasion - rhinion) to their parents, the heritability was statistically significant for all groups except the 16-year-old daughter-mother group and the 16-year-old son-father group.[29] In comparison to our study, we found no significant difference from either parent for nasal bone length. This could have been because of our smaller sample size and also that the latest radiographs taken for this sample was at 16 years of age, whereas our mean for the children was 17.7 years of age. For nasal prominence, which was equivalent to our angle of nasal bone (sella – nasion - rhinion), only the 16-year-old daughter-father group failed to reach statistical significance, meaning that these two were different.[29] This agrees with our results, where females were different than their fathers but not their mothers ($p < 0.05$).

Shetty et al., studied pre and post orthodontic treatment linear and angular measurements of 36 patients 16 years of age or older. This was an interesting study as it helped correlate orthodontic tooth position and the nasal effects. They found that nasal bone angle (sella - nasion- rhinion) changed in accordance to the changes in the maxilla, especially A point. A decrease in SNA resulted in the movement of the nasal bone in a clockwise direction and vice versa. In essence, incisor angulation also had an indirect effect on rhinion because of the effect that incisor angulation can have on the position of A point.[21] Tipping of the incisors facially moves A point distally.[30] Thus, as the incisors were proclined and A point moved backwards, rhinion seemed to move backwards giving a clockwise tilt to the nasal bone. Conversely, if A point moved forward, rhinion also moved forward, resulting in a counterclockwise tilting of the nasal bone. The one flaw in this study was that there was no growth sample included as a control for the results achieved. However, in conclusion, the actual changes in the nasal bone after orthodontic treatment were considered negligible. It was also noted that two situations can thus give the nose an upturned appearance (counterclockwise) rotation: maxillary advancement and forward movement of A point via incisor retroclination.[21] Our study avoided both of these situations, as the sample was from an untreated group.

Foley's study on soft tissue profile changes only looked at male adolescents from 14-20 years of age, divided into 3 categories of 2 years each (14-16, 16-18, 18-20). This study found a 8mm increase in nasal tip measurements (pterygoid vertical to pronasale), the largest change in soft tissue characteristics studied. The largest increase of 4.5mm was observed in the age period of 14-16, but the increase diminished by about 50% over each successive age period. Nasal tip changes were seen up to 20 years of age in males and about 1mm was seen from ages 18-20, meaning that treatment planning and management of any potential soft tissue nasal changes can be effected by both nasal growth and the effect of treatment on nasal shape.[31] This study supported the evidence of Behrent's that changes in soft tissue are apparent throughout life, and can continue into adulthood.[15] So although we took post-pubertal radiographs of the children, it is important to note that growth changes in soft tissue and cartilage can still occur, also potentially altering the parental influence. However, as noted by Van Loosen et al., after the age of 35, both male and female nasal soft tissue characteristics, including septal cartilage remains relatively stable, so parents chosen after this age will not differ much in their facial profile.[32] The mean age of our parents were 41 for fathers (range 32-56, SD = 5.59) and 39 for mothers (range 28-49, SD = 5.56).

Since our study was to encompass a complete evaluation of the hard and soft tissues that make up the nose, it was important to choose rhinion (the anterior tip at the end of the suture of the nasal bones) to ANS distance. This distance represents the scope of non-hard tissue dictating the size of the nose, as there is only cartilage and soft tissue between these two hard tissue points. Thus, this measurement gives us a good representation of other factors that might contribute to nasal changes. In our study we found that when stratifying the results, males were different than their mothers and females were different than their fathers. This is very interesting as there may be a sex predilection in terms of the amount of cartilage and soft tissue growth both genders experience.

Strengths

Our study aimed to improve upon original studies of craniofacial growth and predictability using parental data by using more landmarks and regions related to the nasal hard and soft tissues. Additionally, the effects for family were controlled for to account for any mean averages in age, which may alter the results. Using a combination of measurements gathered from multiple studies, we were able to gain a comprehensive look at the mid-face and nasal features. The subjects chosen from this sample were picked at random, resulting in 25 males and 22 female children, further increasing the validity of this study with an unbiased approach. Unlike previous studies which looked at craniofacial structures of patients in the pre-pubertal or immediately post-pubertal time points, this study allowed for radiographs up to 2 years post pubertal, allowing for additional growth following the growth spurt to take place before the collection of our data points.

One benefit of using parental data for prediction of children's characteristics is that it can be applied to patients with growth disturbances or deformations from trauma or early surgery. Knowing which characteristics may resemble which parent can help the surgeon estimate the natural growth which may have occurred in the patient if the insult had not occurred.

Limitations

Our study utilized lateral cephalograms from 1959-1975, and it is unknown if the same technician took all of the films orienting the subject's heads in the same position at each subsequent visit. Very accurate head position is required and can be subject to a patient's anatomy. Small changes in head rotation can produce changes in linear and angular measurements especially in terms of recognizing that there are two nasal bones and alterations in head posture can effect correct identification.[33] Out of roughly 500 families available for this study, only 47 were chosen due to the low quality and availability of radiographs. It has been shown via Witsh and Böe that soft tissue landmarks tend to be less sharply defined than hard tissue landmarks and this can create problems with identifications and reproducibility.[34] Many of the families did not have radiographs of the parents and many parents had edentulous arches causing a lack of posterior occlusion. This could be attributed to the lack of fluoridated water, causing decay and the need for extractions of posterior teeth before the time that the data was collected. Fluoridation of water began the USA (Grand Rapids, Michigan) in 1945 but was not implemented in all cities at this time.[39]

As more than one examiner could have taken these radiographs, it must also be known that since our research is focused on soft tissue anatomy, facial expressions or movement can alter some of our results. Posen mentioned that we must recognize the great changes that small variations in facial expressions can produce on soft tissue profile.[10] Fiagallo and Acosta noted that although there are eight nasal muscles, only two, the procerus and nasalis, are in a position to impact the nasal profile, and either of these could have affected our findings.[22] Vig, Cohen and Mamandras discussed this important problem associated with soft tissue studies since voluntary and involuntary muscle activity can affect the contours being studies.[35,36]

We know that some changes occur with soft tissues and cartilage as the patient ages.[1,15] Therefore, when evaluating our results, even though parental information is included, we must consider that parental changes may also have occurred after peak growth but before these radiographs were taken. Drooping of the nasal cartilage, loss of elasticity and tonicity of muscle activation and loss of vertical dimension of occlusion due to tooth wear and loss of posterior stops can all influence the appearance and structure of the nose and its surrounding tissues. We were careful to select parents who had posterior occlusal stops but could not determine whether other post peak growth changes had occurred. In addition, Nanda et al., stated that in terms of nasal depth, growth curves between males and females started to diverge from ages 16-18 where males showed more acceleration compared to the female group (nearly 3mm from 17-18). They found that at 18 years of age, males showed some change in lower nose height, nose depth and upper nose inclination.[17] Therefore, soft tissue changes may have continued, possibly past some of the time points that we had measured (in our sample).

This study was also only taken from patients of largely western European descent. We know that different ethnicities may have different hard and soft tissue characteristics. More recently, there is also an increase in interracial relationships, thus further diversifying the genetic makeup of the child. Future studies would need this longitudinal information from different ethnic groups in order to confirm whether the results applied to different racial or ethnic groups.

Our research results yielded large standard deviation values and thus this has the tendency to increase the likelihood that the results would indicate similarity due to the increased variability of the data. Due to this higher variability, although significance was found in the results, it does not mean that the results were necessarily clinically significant. If a child's measurements were significantly different from one parent, this does not mean that the child's measurements were noticeably similar to the other parent. As orthodontists, we have the obligation to also focus on clinical importance within our research. A future study may want to also incorporate a layperson's opinion of an esthetic nose from the profile view. This could also be combined with using all three lateral cephalograms as silhouettes and having a layperson choose which parent the child resembles more. This will help guide clinicians in clarifying what an esthetic nose may be to an average individual.

Recommendation and Future studies

Future studies should focus on obtaining a larger sample size with radiographs of diagnostic quality. This would inherently improve the research design and offer a smaller source of bias. With the advent of 3-D imaging, we now have the resources to study structures to a much higher degree than what was previously available with 2D radiographs. Therefore, analysis of 3D imaging from multiple views (sagittal, coronal and transverse) can only further our understanding in proper diagnosis and treatment planning.

Since nasal shape is not linear, using a measurement to examine its shape and distance along its soft tissue portion along its curvature may provide more information than some linear and angular measurements. A future study may want to consider examining the overall circumferential shape of the nose and compare the pattern of the nose to that of the parents.

Given that the nose is such a prominent feature of the face, one's perception of the nose can influence what they may perceive as esthetic or not. Future studies could use parental and child data to see which nose is “esthetic” by using silhouettes of the lateral cephalograms, as well as use the parental silhouettes to see which parent the child resembles more.

Conclusion

This study concluded that resemblance of nasal characteristics of children to parents varies depending on the measurements of interest. As clinicians we can assume that for vertical measurements, males will resemble more closely their fathers; for horizontal and vertical components, both males and females will resemble more closely their mothers; and for angular measurements males will resemble a combination of both mothers and fathers whereas females will more closely resemble their mothers. Although the nose occupies almost half of the total face, orthodontists pay little or no attention to it during diagnosis and treatment planning. The changes we make to the jaws and teeth can affect profile, muscle tonicity and vertical relationships of the face, all of which have an indirect effect on the appearance of the nose. Using parental data can give us a better understanding of the general pattern of the nose that might occur in the child. Although Behrents points out that even in adulthood, biology is never static, and the nose can change with age, at the time of treatment planning, we as orthodontists have the obligation to provide focus on the entire face, as opposed to solely focusing on the esthetics of teeth.[15]

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List of Journal Title Abbreviations

Am J Orthod..American journal of orthodontics

Am J Orthod Dentofac Orthop..

....American journal of orthodontics and dentofacial orthopedics

Am J Phys Anthropol....................................... American journal of physical anthropology

Angle Orthod .... Angle orthodontist

Arch Oral Biol... Archives of oral biology

Arch Otolaryngol Neck Surg .... Archives of otolaryngology--head & neck surgery

Craniofacial Growth Ser .... Craniofacial growth series

Eur J Orthod.. European journal of orthodontics

Forensic Sci Int ....Forensic science international

J Anat ....Journal of anatomy

J Oral Maxillofac Surg.. Journal of oral and maxillofacial surgery

Nat Commun... Nature communications

PLoS Genet .... PLoS genetics

CURRICULUM VITAE

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