Developmental stage specific ANB reference values based on a longitudinal sample of untreated Caucasian subjects

Margaret Hostage,*† Mathew T. Silver,*† Stephanie C. Finn,*† Benjamin Canary,*† Alpdogan Kantarci,+ Veerasathpurush Allareddy,± Negin Katebi* and Mohamed I. Masoud*

Department of Developmental Biology, Harvard School of Dental Medicine, Boston, MA,* Private Practice,† The Forsyth Institute, Cambridge, MA,+ and Department of Orthodontics, University of Illinois College of Dentistry, Chicago, Illinois,± USA

Objectives: The study aimed to assess the longitudinal changes in the ANB angle before and after adolescence, and determine Class I normative values for childhood and adolescent Caucasian patients based on cervical vertebral maturation stages (CVMS) and gender.
Setting and sample population: The sample included 71 (41 females and 30 males) untreated Caucasian subjects who took part in a growth study between 1959 and 1976.
Materials and methods: Lateral cephalometric radiographs were analysed at CVMS1 (childhood) and again at CVMS4-5 (adulthood). A paired sample *t*-test was used to analyse ANB angle differences between the two time points. Subjects who were skeletally and dentally Class I at adulthood (51 subjects) had their radiographs at CVMS1 (childhood) and CVMS2-3 (adolescence) used to establish Caucasian normative values for those stages. Data were also analysed for gender and skeletal classification differences.
Results: There was a statistically significant decrease in ANB value (2.3°) from CVMS1 to CVMS4-5 in the combined sample as well as the skeletal Class I and Class III groups (2.5° and 3.3° for Class I and Class III subjects, respectively). The reduction was smaller and not statistically significant in Class II individuals (1.5°). In Class I individuals, ANB values were 4.68° (SD:1.76°) at CVMS1, 2.86° (SD:1.18°) at CVMS2-3, and 2.13° (SD:0.99°) at CVMS4-5. No significant gender differences were found.
Conclusions: Statistically significant decreases in the ANB angle can be expected between childhood and adulthood in Class I and Class III patients but not Class II untreated subjects. Adult normative values should not be used for children.
(Aust Orthod J 2020; 36: 69-74)

Received for publication: October 2019
Accepted: February 2020

Margaret Hostage: mhostage@gmail.com; Mathew T Silver: MatthewTSilver@gmail.com; Stephanie C Finn: stephcfinn@gmail.com
Benjamin Canary: bcanary1@gmail.com; Alpdogan Kantarci: akantarci@forsyth.org; Veerasathpurush Allareddy: sath@uic.edu;
Negin Katebi: ngkatebi@gmail.com; Mohamed I Masoud: masoudortho@gmail.com

Introduction

Orthodontists use lateral cephalometric radiographs to assist in diagnosis and treatment planning by gathering information regarding a patient's skeletal and dental relationships. Many analyses have been developed to facilitate the evaluation of cephalometric films.[1-4] These analyses use specific landmarks, lines, and angles to provide practitioners insight into the sagittal and vertical positions of the cranial base, jaws, teeth, and their relationship to one another. The radiographs can also offer information regarding skeletal maturity and the timing of peak growth velocity.[5] Cephalometric analyses are therefore a useful tool in determining the possible aetiology of a patient's malocclusion and to enable comparison of individual patient values to establish normative data, thereby identifying the source of a malocclusion.

Most of the cephalometric normative values/standards in current use were developed between 1945–1955, when cephalometrics gained popularity for longitudinal growth studies and as an orthodontic diagnostic aid.[6] Many of the standards developed were based on subjective concepts of what was considered 'normal'. For example, in 1952, Riedel developed normative values for children and adults based on a small sample of individuals with "excellent occlusion".[4] In 1953, Steiner developed his analysis to express the concept of "an average American child of average age".[2] In 1954, Tweed developed norms from 95 cases that he considered had a "face that I thought was pleasing".[3] Despite their imprecise origin, many of these norms have proven reliable over time, including the Caucasian adult normative value for the angle between A point, B point and Nasion (ANB) of 2°.[7]

The ANB angle has been described as the most commonly used parameter in orthodontics.[8] Introduced by Reidel in 1952, the ANB angle provides information regarding the sagittal relationship of the maxilla to the mandible. It is one of the easiest ways to quickly identify the skeletal classification of a patient and, from there, to look at the ANB angle determinants – SNA and SNB – to assess which jaw is responsible for a discrepancy. While there are limitations to the use of the ANB angle, it is not the purpose of this paper to detail its shortcomings. Currently, the Caucasian cephalometric norm for ANB angle is identified as 2°, with greater angles indicating a Class II relationship, and lesser angles indicating a Class III relationship. The ANB angle, like many other normative values, characterises different ethnic groups with an angle of 4° for Black American patients, 4° for Chinese patients, 4° for Japanese patients, and 3° for Israeli patients.[7] Although cephalometric normative values relate to different ethnicities, the same values are utilised regardless of chronologic, skeletal, or dental age and gender. Previous studies have suggested that average cephalometric skeletal values change throughout childhood, adolescence, and adulthood.[9-15] However, these studies have not reported developmental stage specific reference values.

The purpose of the present study was to longitudinally assess changes in the ANB angle before and after adolescence, and determine Class I normative values for childhood and adolescent Caucasian patients based on cervical vertebral maturation stages (CVMS) and gender.

Materials and methods

The study utilised longitudinal data obtained on Caucasian children by the Harvard Orthodontic Program based at The Forsyth Institute between 1959 and 1976. The protocol was approved by the Harvard Medical School Institutional Review Board (IRB #16-0113). In the first part of the study, databases were searched for Class I, Class II, and Class III individuals between the ages of 8 and 18 who had available records. The radiographs were then checked to ensure that all of the subjects at the childhood stage were pre-adolescent (cervical stage: CVMS1) and all of the adult subjects were post-pubertal (cervical stage: CVMS4-5). A power analysis was completed to determine the necessary sample size.[16] With an α error probability of 0.05, 90% power, and effect size of 0.5 (medium effect), the sample size needed for this study was found to be 44 pairs. The sample for the initial part of the study consisted of 71 pairs (41 females and 30 males). The radiographs were analysed, traced, and ANB angles were recorded for both children and adults. A paired sample *t*-test was completed to establish whether a statistically significant difference existed between childhood ANB values and the ANB values found in the same subjects in adulthood. This was done for the entire sample as well as for each adult skeletal classification (Class I, Class II, and Class III based on the ANB angles at the age of 18).

If a statistically significant difference was evident between the children and adults during the initial phase, the project aimed to estimate childhood and adolescent ANB angle normative values for subjects who had Class I ANB angles in adulthood and a Class I dental pattern. For each adult radiograph identified as Class I, two additional radiographs were selected for the same individual at time points representing childhood (CVMS1) and adolescence (CVMS2-3). These radiographs were traced, and descriptive statistics completed to establish new normative values for childhood and adolescence. The data were also analysed by gender, and two-tailed student's *t*-tests were conducted to determine any statistically significant gender differences between the groups.

The radiographs were traced by authors MH, MS, SF and BC. Ten radiographs were randomly selected to be retraced for inter-examiner reliability. All of the ANB values were measured by author MH. Seven random subjects had their ANB angles for all three time points (21 cephalometric radiographs) measured twice by author MH to determine intra-examiner reliability. The intra-class correlation coefficient (ICC) was applied to measure intra- and inter-examiner reliability.

Results

The ICC for inter-examiner reliability for the cephalometric measurements ranged between 0.915 and 0.996 ($p < 0.001$). The ICC for intra-examiner reliability for the ANB measurements was 0.951 ($p < 0.001$).

The power analysis required 44 child-adult pairs (88 in total). Seventy-one child-adult pairs (142 total) were collected. Of the 71 pairs, 41 were female and 30 were male. Table I presents the sample by Class I, Class II or Class III skeletal pattern based on adult ANB values. Fifty-one out of 71 subjects were classified as Class I (72%), 12 out of 71 were classified as Class II (17%) and the remaining seven were classified as Class III (10%). One subject with an adult Class I ANB angle was eliminated from the Class I group due to a Class II dental relationship. The mean ANB angle for children was found to be 4.65° (SD:2.14°). The mean ANB angle for adults was calculated as 2.36° (SD:2.17°). A paired sample *t*-test revealed that the difference in the mean ANB angles in children and adults were statistically significant, with a *P* value of <0.0001. When the sample was grouped according to skeletal classification, the subjects who were skeletal Class I and Class III based on adult ANB angles had childhood ANB angles that were statistically significantly lower than their adult ANB angles. However, subjects who were skeletally Class II had no statistically significant difference between the childhood and adult ANB angles (Table I).

In the second part of the study, 51 individuals were identified who had adult ANB values of 2° (+/- 1.5°) as well as Class I dental findings. Radiographs for these individuals were retrospectively selected at two additional time points: CVMS1 (denoting childhood) and CVMS2-3 (denoting adolescence). The mean childhood ANB was 4.68° (SD:1.76°). The mean adolescent ANB was 2.86° (SD:1.18°). The mean adult (CVMS4-5) ANB was 2.13° (SD:0.99°). A statistically significant difference was present between childhood and adolescent ANB means ($p < 0.001$). Similarly, a statistically significant difference was found between adolescent and adult ANB values ($p < 0.01$) (Table II).

Thirty-one of 51 individuals were female (60.8%), and 20 were male (39.2%). As depicted in Table II, females had ANB values of 4.69° (SD:2.04°), 2.87° (SD:1.27°) and 2.10° (SD: 0.96°) for childhood, adolescence and adulthood, respectively. These values were all statistically significantly different from one

Table I. Mean ANB values for children and adults broken down by skeletal classification and *P* values for paired sample *t*-test.

Group	Mean ANB	SD	N	*P* value (child-adult paired sample *t*-test) / Statistical significance
CVMS 1 (children) all skeletal classifications	4.65°	2.14°	71	*P* < 0.0001 /
CVMS 4-5 (adults) all skeletal classifications	2.36	2.17	71	S
CVMS1 (children) Class I (based on adult ANB)	4.68	1.76	51	*P* < 0.0001 /
CVMS 4-5 (adults) Class I (based on adult ANB)	2.13	0.99	51	S
CVMS1 (children) Class II (based on adult ANB)	6.26	2.13	12	*P* = 0.464 /
CVMS 4-5 (adults) Class II (based on adult ANB)	5.63	1.18	12	NS
CVMS1 (children) Class III (based on adult ANB)	1.64	1.88	7	*P* < 0.001 /
CVMS 4-5 (adults) Class III (based on adult ANB)	-1.66	1.92	7	S

*One male subject with an adult skeletal Class I relationship was eliminated from this group due to a dental Class II relationship.

another. Males had ANB values of 4.68° (SD: 1.22°), 2.83° (SD:1.05°) and 2.32° (SD:0.85°) for childhood, adolescence and adulthood, respectively. Within the male category, statistically significant differences were noted between childhood and adolescence, but not between adolescence and adulthood. There were no statistically significant differences between males and females within any of the three age groups.

Discussion

The aim for the first part of the present study was to determine whether the Caucasian ANB normative value applied to adults also appropriately applied to children. The longitudinal evaluation was consistent with previous literature, which suggested that the ANB angle is significantly different in childhood relative to adulthood.[9-15] Typically, orthodontic populations can provide skewed data; however, the present sample is unique in that it was gathered from a twin registry composed of an untreated Caucasian population. A mean childhood ANB value of 4.65° was found, which is slightly higher than that reported in previous literature.[8-10] This might be explained by differences in the composition of the study sample, with Huang et al. including subjects based solely on a Class I dental occlusion.[9] Nevertheless, the present study adds to the available evidence confirming the pattern that children display larger ANB angle values compared with adults. This may be explained by considering that late mandibular growth would tend to increase the SNB angle, thereby causing a reduction in the ANB measurement. These findings, along with those previously reported, highlight the need to determine more accurate ANB normative values to reflect the patient's skeletal age and developmental status. It was noteworthy that, when the group was subdivided by skeletal classification, the subjects with Class II skeletal patterns did not show a significant change in ANB angle from childhood to adulthood. This is consistent with the finding of Lux et al., who reported that differences between Class II subjects and a control group at age 15 were already present at age seven but to a lesser degree.[8] It is also consistent with the longitudinal findings of Stahl et al., who showed that subjects with untreated skeletal Class II relationships do not self-correct with growth and have a lesser increase in mandibular length during the growth spurt than Class I subjects.[13]

Based on the significant changes observed between childhood and adulthood in Class I subjects, the study went on to report ANB normative values at two time points prior to adulthood; one corresponding with childhood (CVMS1) and one corresponding with adolescence (CVMS2-3). The cervical vertebral method utilised in the present paper was originally developed by Lamparski and was further modified by Baccetti et al. in 2002.[5,17] Baccetti's version differs from Lamparski's in that Baccetti combines Lamparski's CVS1 and CVS2 to make five stages rather than six.[5] Regardless of the method used, the information obtained from these skeletal stages can be applied to either method. CVMS1, denoting childhood, includes individuals for whom peak mandibular growth will occur at least one year after this stage.[5] The ANB angle

Table II. Mean male and female ANB angles in Class I subjects at childhood, adolescence and adulthood, and *P* values for two tailed *t*-test comparing mean ANB angles for each age category within each gender.

	Female (N = 31)	Male (N = 20)	Combined (N = 51)
CVMS1 (childhood) ANB	4.69° (SD 2.04)	4.68° (SD 1.22)	4.68° (SD 1.76)
CVMS 2-3 (adolescence) ANB	2.87° (SD 1.27)	2.83° (SD 1.05)	2.86° (SD 1.18)
CVMS 4-5 (adulthood) ANB	2.10° (SD .96)	2.32° (SD .85)	2.13° (SD 0.99)

Female childhood and adolescence mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$
Female childhood and adult mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$
Female adolescence and adult mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$

Male childhood and adolescence mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$
Male childhood and adult mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$
Male adolescence and adult mean ANB angle difference: Two tailed *t*-test significant with $p = 0.097$

Combined sample childhood and adolescence mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$
Combined sample childhood and adult mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$
Combined sample adolescence and adult mean ANB angle difference: Two tailed *t*-test significant at $p < 0.001$

in the current childhood sample (CVMS1) was 4.68°, which was expectedly larger than the accepted norm of 2° in the adult population because the adolescent mandibular growth spurt has not yet occurred. According to Baccetti et al., the peak mandibular growth stage occurs between stages CVMS2 and 3. For this reason, CVMS2 and 3 have been used to denote the adolescent sample in the present study. The ANB angle in this group was found to be 2.85°, which was statistically significantly lower than the ANB angle at childhood, which was expected given that peak mandibular growth is occurring during this time. In addition, the present study utilised CVMS4-5 to denote adulthood due to the likelihood that peak mandibular growth would have occurred one to two years before this stage.[5] Similar to the established adult ANB angle norm of 2°, the present study found a mean ANB angle of 2.15°, which was statistically significantly lower than the ANB value recorded for childhood.

The current data were also identified by gender in an effort to determine potential differences between males and females for each of the developmental stages. While there were slight variations between the genders with regard to ANB angles in childhood, adolescence, and adulthood, none of these differences were statistically significant. In the present study, males and females had similar mean ANB values related to the developmental age group, and also followed the trend of decreasing ANB values over time. Within the female group, ANB angles decreased significantly from childhood to adolescence, and adolescence to adulthood. Males differed slightly, in that, although the ANB angles were statistically significantly different from childhood to adolescence, there was no significant difference from adolescence to adulthood. This difference could be explained by the fact that the division of the sample by classification and again by gender produced only 20 Class I males, which may not have been sufficient to detect a significant difference between adolescence and adulthood. It is also possible that late mandibular growth in males may continue more steadily even beyond the demarcation of CVMS5, and perhaps a statistically significant difference exists at a later chronologic rather than skeletal age.

The information gathered through this study can be useful when diagnosing and treatment planning patients. Considering an ANB angle of 4.68° as the norm for a child in the developmental stage of CVMS1 may indicate to practitioners that a child at this stage may still grow into a Class I skeletal relationship. For patients presenting in the CVMS2-3 stages, an ANB angle closer to 3° may also indicate that the patient is developing towards a Class I occlusion, and may provide helpful information for practitioners regarding treatment options.

Despite its wide usage, the ANB angle is not without its disadvantages. For example, if a patient has a bimaxillary protrusion, there may be an exaggeration of the ANB angle. Similarly, the ANB angle can be affected if the jaws are rotated clockwise or counterclockwise.[18] Understanding and anticipating growth as it relates to cephalometric measurements may provide additional insight for practitioners in diagnosis and suggest treatment plans based on this data, especially in young children. It is important to consider, however, that cephalometric measurements depict a two-dimensional representation of a three-dimensional object and should always be used in light of other clinical records and exams. Furthermore, the ANB angle has its own inherent limitations. For this reason, ANB is only one piece of diagnostic information that should be used when evaluating the sagittal relationship of the maxilla and the mandible. Other analyses such as the Wits appraisal may deliver a more accurate picture of the sagittal skeletal relationship.

It is suggested that future studies could focus on examining the developmental stage specific normative values for different ethnic groups and different analyses.

Conclusions

1. Statistically significant decreases in the ANB angle (2.3–3.3°) can be expected between childhood and adulthood in Class I and Class III untreated subjects but not Class II untreated subjects.
2. In the present sample, Class I children had an ANB normal value of 4.68°, which dropped to 2.86° during puberty, and finally to 2.13° in adulthood.

Funding sources

- The records used in the study were collected between 1959 and 1976 using NIH funding for the Forsyth Twin Study. Grant/Award Number: (ROI DE 02873).

- The records used in the study were digitised with the support of the American Association of Orthodontists Foundation.

Conflict of interest

The authors declare no conflict of interest related to the information submitted in this manuscript.

Corresponding author

Mohamed I. Masoud
Director of Orthodontics
Department of Developmental Biology
Harvard School of Dental Medicine
188 Longwood Ave
Boston, MA
02115

mohamed_masoud@hsdm.harvard.edu

List of abbreviations

1. ANB: Angle between A point, B point, and Nasion
2. CVMS: Cervical Vertebral Maturation Stage based on Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. Angle Orthod 2002;72:316-23.

References

1. Downs WB. The role of cephalometrics in orthodontic case analysis and diagnosis. Am J Orthod 1952;38:162-82.
2. Steiner CC. Cephalometrics for you and me. Am J Orthod 1953;39:729-55.
3. Tweed CH. The frankfort-mandibular incisor angle (FMIA) in orthodontic diagnosis, treatment planning, and prognosis. Angle Orthod 1954;24:121-69.
4. Riedel RA. The relation of maxillary structures to cranium in malocclusion and in normal occlusion. Angle Orthod 1952;22:142-5.
5. Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. Angle Orthod 2002;72:316-23.
6. Casko JS, Shepherd WB. Dental and skeletal variation within range of normal. Angle Orthod 1984;54:5-17.
7. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. St. Louis, Mo.: Mosby Elsevier, 2007.
8. Lux CJ, Burden D, Conradt C, Komposch G. Age-related changes in sagittal relationship between the maxilla and mandible. Eur J Orthod 2005;27:568-78.
9. Huang WJ, Taylor RW, Dasanayake AP. Determining cephalometric norms for Caucasian and African Americans in Birmingham. Angle Orthod 1998;68:503-11.
10. Hurmerinta K, Rahkamo A, Haavikko K. Comparison between cephalometric classification methods for sagittal jaw relationships. Eur J Oral Sci 1997;105:221-7.
11. Tiwari R, Shyagali TR, Gupta A, Joshi R, Tiwari A, Sen P. Predictability and reliability of different anterio-posterior skeletal discrepancy indicators in different age groups - A cephalometric study. J Clin Diagn Res 2016;10:ZC80-4.
12. Walker GF, Kowalski CJ. The distribution of the ANB angle in “normal” individuals. Angle Orthod 1971;41:332-5.
13. Stahl F, Baccetti T, Franchi L, McNamara JA Jr. Longitudinal growth changes in untreated subjects with Class II Division 1 malocclusion. Am J Orthod Dentofacial Orthop 2008;134:125-37. doi: 10.1016/j.ajodo.2006.06.028.
14. Bishara SE. Class II malocclusions: diagnostic and clinical considerations with and without treatment. Semin Orthod 2006;12:11-24.
15. Ochoa BK, Nanda RS. Comparison of maxillary and mandibular growth. Am J Orthod Dentofacial Orthop 2004;125:148-59.
16. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behav Res Methods 2009;41:1149-60.
17. Lamparski DG. Skeletal age assessment utilizing cervical vertebrae. Am J Orthod 1975;67:458-9.
18. Jacobson A. The “Wits” appraisal of jaw disharmony. Am J Orthod 1975;67:125-38.