Original Article

Evolution of ANB and SN-GoGn angles during craniofacial growth: A retrospective longitudinal study

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Abstract

Objective: The aim of this study is to describe the evolution of the ANB and SN-GoGn angles throughout development, in a longitudinal sample of Caucasian patients. **Materials and Methods:** Historical cephalometric records from North American individuals available at the American Association of Orthodontists Foundation Craniofacial Legacy Growth Collection website were used to carry out an exploratory longitudinal study. Lateral cephalometric radiographs of orthodontically untreated males and females were included. Individuals with three or more longitudinal cephalometric records at pre- and post-pubertal stages, with at least one postpubertal radiograph available in vertebral cervical maturation stage (cervical vertebral maturation) 5 or 6, were selected. Seventy-one individuals met the inclusion criteria. ANB, SNA, SNB, and SN-GoGn angles were measured. Individuals were classified according to the latest postpubertal ANB angle available and grouped by CVM. Descriptive statistics were obtained for the cephalometric variables, and differences between genders were analyzed. **Results:** Forty-five individuals were classified as skeletal Class I at the end of growth, 17 as Class II, and 9 as Class III. ANB values decrease as growth occurs in every group (average ANB decrease between the stages CVM 1 and 6: Class I - 1.5°, Class II - 0.7°, and Class III - 3.1°). For SN-GoGn angle, a constant reduction was observed as skeletal maturation increased (Average SN-GoGn decrease between the stages CVM 1 and 6: Class I - 4°, Class II - 2.5°, and Class III - 4.9°). **Conclusions:** ANB and SN-GoGn angles decrease during growth. The magnitude varies depending on individual sagittal characteristics, Class III individuals displaying the greatest reduction, and Class II individuals the least.

Key words: ANB angle, craniofacial growth, SN-GoGn angle

INTRODUCTION

Sagittal malocclusions are highly prevalent[1] and have functional, esthetic, and social implications[2,3] that make them a public health issue. Their prognosis and clinical expression at adulthood are determined by facial growth.

Facial growth is a complex phenomenon characterized by the differential development of the jaws.[4] Therefore, the sagittal intermaxillary relationship varies gradually between an early age and adulthood where normal young individuals have a greater facial convexity than adults.

Access this article online	
Quick Response Code:	Website: www.apospublications.com
	DOI: 10.4103/2321-1407.194796

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How to cite this article: Oyonarte R, Hurtado M, Castro MV. Evolution of ANB and SN-GoGn angles during craniofacial growth: A retrospective longitudinal study. APOS Trends Orthod 2016;6:295-301.

A cephalometric measurement routinely used to diagnose sagittal skeletal dysplasias is the ANB angle.[5,6] Its use is widespread among orthodontists because of its ease of use and its consistency with the clinical presentation in most cases. It also performs well as a diagnostic test, with high specificity and sensitivity assessing sagittal intermaxillary discrepancies.[7-9]

Longitudinal cephalometric studies using historical records of North American individuals have reported that maxillary and mandibular sagittal development takes place with increases in SNA and SNB angles throughout growth, while ANB decreases.[10-14] This ANB angle reduction has been reported to be significant in individuals between 7 and 15 years of age[15] and has been consistently reported in different studies as a result of a relative dominance of sagittal mandibular growth.[4,10-17] It is, thus, expected that ANB angle may diminish during development.[10,11,13,15,16,18-20]

Clinically, the ANB angle is frequently used considering an average value of 2° and a standard deviation of 2°.[6] However, this diagnostic approach does not take into account the maturational status of an individual, nor does it consider the possibility of a variation in the sagittal intermaxillary relationship during facial development. An early assessment, which fails to consider the above-mentioned developmental pattern, could incorrectly classify an individual, eventually leading to a wrong diagnosis and orthodontic treatment plan. Further, even knowing that a reduction in ANB is expected with growth, the amount of this reduction remains unclear. This is highly relevant in growing patients who carry Class II or Class III malocclusions.

Vertical development is also relevant in the sagittal plane. The maxillomandibular complex usually displays a counterclockwise rotation during the development.[18] The SN-GoGn angle allows for the identification of variations between the mandibular plane and the cranial base.[6,21] Its serial use can record the mandibular vertical developmental trend as it identifies the direction of mandibular growth rotation.

Maturational status is a key factor in facial growth evaluation. Different studies have assessed chronological age,[10,16] which is a less desirable indicator than skeletal maturation, either analyzed in hand-wrist X-rays[18,22] or at the cervical vertebrae.[23] Given the progressive nature of development, the cephalometric values of ANB and SN-GoGn angles, analyzed relative to individual maturation, can provide useful information about dynamic phenomena in facial development, orthodontic diagnosis, and treatment planning.

The aim of this study is to describe the evolution of the ANB and SN-GoGn angles during the development, in a longitudinal sample of Caucasian patients classified according to the latest postpubertal ANB angle available and grouped by cervical vertebral maturation (CVM) stage.

MATERIALS AND METHODS

Historical cephalometric records from North American craniofacial growth centers were used to carry out an exploratory longitudinal study. The data for this study were obtained from the American Association of Orthodontists Foundation (AAOF) craniofacial legacy growth collection files, available on the internet. This collection contains radiographic longitudinal records of Caucasian individuals from ten growth centers in North America (Bolton-Brush, Burlington, Denver, Fels Longitudinal, Forsyth Twin, Iowa, Mathews, Meharry, Oregon, and Michigan Growth Studies).

AAOF craniofacial legacy growth collection files were reviewed for longitudinal records of individuals with pre- and post-pubertal lateral cephalometric X-rays, regardless of their sagittal classification. Clear lateral cephalometric radiographs in occlusion of orthodontically untreated male and female individuals with pre- and post-pubertal records were included in the study with three or more longitudinal cephalometric records. At least one postpubertal radiograph in vertebral cervical maturation (CVM) stage 5 or 6 had to be available. Following the inclusion criteria described above, from a total of 134 individuals and 1362 radiographs belonging to the online database with open access of the AAOF in August 2010, 71 individuals were selected for the study.

Longitudinal records were divided by gender and classified according to their skeletal developmental status using the CVM Method according to Baccetti *et al.*,[23] [Table 1] with six maturational stages (cervical vertebral stage [CVS]). If one individual had several lateral radiographs displaying the same cervical maturation stage, the latest radiograph was selected to represent that given stage of maturation.

Cephalometric measurements were performed by a calibrated researcher using morphometric software (SigmaScan Pro 5.0, SPSS Science, Chicago, USA). After identifying points Sella (S), Nasion (N), A, B, Gonion (Go) and Gnation (Gn), ANB, SNA, SNB and SN-GoGn angles were measured in each radiograph for every individual. The individuals were classified based on their maxillomandibular sagittal relationship, according to the ANB angle at the latest postpubertal record available (CVS 5 or 6). Three groups were established, with Class I defined as those individuals with an ANB angle between 0 and 4 degrees. Values above or below this range were included in the Class II and Class III groups, respectively. Cephalometric angles were then recorded for every individual at each stage of skeletal maturation.

Statistical analysis

Descriptive statistics were obtained for the cephalometric variables, and the sampling distribution of the data was assessed using the Shapiro–Wilk test, establishing the normal distribution of the data for both males and females ($P > 0.05$), in each of the stages of skeletal maturation studied. The Student's *t*-test was used to explore the differences in variables between male and female samples for each stage of skeletal maturation. Statistical analysis was performed using STATA 10.0 statistical software (StataCorp, TX, USA) for personal computer.

RESULTS

The sample included 71 individuals between 6- and 18-year-old, totaling 343 lateral radiographs (46% female), as shown in Table 2.

CVM progressed with increasing chronological age. No statistically significant (SS) differences were observed between genders (*t*-test $P > 0.05$). Data from males and females were grouped according to skeletal maturation and then analyzed together [Table 2].

Cephalometric measurements

Table 3 summarizes the descriptive variables for each group of CVM and divides them according to final skeletal class. Forty-five individuals were classified as skeletal Class I at the end of growth, 17 as Class II, and 9 as Class III.

ANB values are in a range between −4.2° and 9.0°. It was observed that ANB values tend to decrease as growth occurs in every group. For Class I, an average ANB decrease of 1.5° was observed between the stages CVS 1 and 6. In Class II, the reduction was 0.7°, and 3.1° in Class III individuals [Table 3 and Figure 1].

Both SNA and SNB angles increase as growth occurs while the SN-GoGn angle decreases [Table 3]. For the SNA angle, the highest values were recorded for Class II patients and the lowest for those in Class III [Table 3]. For angle SNB, the values are similar between Class I, II, and III. The lowest values are observed for Class II individuals [Table 2].

For the SN-GoGn angle, the values were similar between skeletal classes in the same CVS [Table 3]. A constant reduction of this value was observed as skeletal maturation

Table 1: Cervical vertebral maturation method to determine skeletal maturation

Stages of CVM	Anatomical features	Time of mandibular growth peak
CVS 1	Bottom edges of C2-C4 vertebrae are flat. Bodies of C3 and C4 are trapezoidal	At least 2 years after
CVS 2	There is a concavity in the bottom edge of C2. Bodies of C3 and C4 are trapezoidal	1 year after
CVS 3	There are concavities in the bottom edges of C2 and C3. Bodies of C3 and C4 are trapezoidal or rectangular horizontal	Within 12 consecutive months
CVS 4	There are concavities in the bottom edges of C2-C4. Bodies of C3 and C4 are horizontal rectangular	Within the previous year
CVS 5	Concavities are present on bottom edges of C2-C4. At least one of the bodies of C3 or C4 is square	At least 1 year previous
CVS 6	Concavities are present on bottom edges of C2-C4. At least one of the bodies of C3 or C4 is vertical rectangular	At least 2 years previous

CVS – Cervical vertebral stage; CVM – Cervical vertebral maturation

Table 2: Description of age according to cervical vertebral maturation for the total sample of radiographs

Stages of CVM by gender	Average age	SD	Minimum	Maximum	*n*
Females					
1	8.2	1.1	6	11	28
2	9.9	1.2	7	12	30
3	11.2	1.3	8	13	30
4	12.2	1.3	10	15	23
5	13.7	1.2	12	16	22
6	16.2	1.2	13	18	26
Males					
1	8.1	1.7	6	12	31
2	10.2	1.8	6	14	33
3	11.7	1.5	7	14	30
4	13.4	1.4	9	16	29
5	15.4	1.3	11	18	35
6	17.0	1.0	15	18	26
Males and Females					
1	8.1	1.4	6	12	59
2	10.0	1.5	6	14	63
3	11.5	1.4	7	14	60
4	12.9	1.5	9	16	52
5	14.8	1.5	11	18	57
6	16.6	1.2	13	18	52

SD – Standard deviation; *n* – Number of radiographs; CVM – Cervical vertebral maturation

Table 3: ANB, SNA, SNB, SN-GoGn angles description according to cervical vertebral maturation for each skeletal class

CVS	Class I					Class II					Class III				
	ANB	SD	Minimum	Maximum	*n*	ANB	SD	Minimum	Maximum	*n*	ANB	SD	Minimum	Maximum	*n*
1	3.9	1.8	1.1	7.9	37	5.8	1.8	3.7	9.0	16	1.4	1.7	−0.8	3.3	6
2	3.4	1.4	0.9	7.3	41	5.9	1.6	3.2	8.2	15	−0.4	1.4	−2.6	2.1	7
3	3.0	1.3	0.6	6.4	40	5.7	1.7	3.1	8.5	16	−0.7	1.3	−2.4	0.7	4
4	2.8	1.3	0.8	5.1	34	5.3	1.6	2.9	7.9	14	−1.8	1.4	−3.1	0.2	4
5	2.4	1.3	0.1	5.0	36	5.4	1.3	3.4	7.5	13	−1.4	1.5	−4.2	0.1	9
6	2.4	1.2	0.0	3.9	35	5.0	0.9	4.2	7.5	14	−1.7	1.4	−3.8	−0.5	6
	SNA	SD	Minimum	Maximum	*n*	SNA	SD	Minimum	Maximum	*n*	SNA	SD	Minimum	Maximum	*n*
1	80.4	3.6	73.1	88.7	37	81.0	3.1	75.0	85.0	16	77.0	3.0	72.3	81.7	6
2	80.6	4.0	72.8	88.4	41	81.5	2.9	76.3	84.9	15	76.1	3.3	71.3	80.7	7
3	80.7	3.5	72.3	88.3	40	81.8	3.2	76.6	85.7	16	76.1	2.9	73.0	80.0	4
4	81.5	3.6	73.5	90.2	34	82.1	3.2	75.7	85.9	14	76.9	3.0	74.3	80.9	4
5	81.5	3.2	73.9	87.8	36	82.6	3.6	74.8	87.5	13	78.5	3.3	74.5	84.9	9
6	81.6	3.5	73.7	87.0	35	82.0	3.0	76.5	86.5	14	77.5	4.3	73.3	84.9	6
	SNB	SD	Minimum	Maximum	*n*	SNB	SD	Minimum	Maximum	*n*	SNB	SD	Minimum	Maximum	*n*
1	76.6	3.1	70.4	82.6	37	75.2	2.6	70.8	78.8	16	76.0	2.3	73.3	79.1	6
2	77.2	3.4	70.5	84.8	41	75.6	2.4	71.3	79.3	15	76.5	2.6	72.6	80.5	7
3	77.8	3.1	70.2	84.1	40	76.2	2.6	72.0	80.0	16	76.9	2.5	73.8	70.2	4
4	78.7	3.2	71.5	85.8	34	76.8	2.7	71.7	79.5	14	78.6	2.4	76.0	80.8	4
5	79.0	3.0	72.4	84.3	36	77.3	3.0	71.4	81.9	13	79.9	3.2	75.9	86.3	9
6	79.3	3.3	72.0	83.7	35	76.0	3.2	70.4	81.2	14	79.2	4.6	76.0	87.8	6
	SNGoGn	SD	Minimum	Maximum	*n*	SNGoGn	SD	Minimum	Maximum	*n*	SNGoGn	SD	Minimum	Maximum	*n*
1	33.8	5.0	25.5	47.1	37	34.8	4.3	28.3	39.6	16	31.7	4.0	26.1	38.6	6
2	33.1	4.9	23.2	44.2	41	34.3	4.4	28.5	39.5	15	31.0	2.0	28.3	34.4	7
3	31.8	4.5	21.4	41.2	40	33.5	4.5	27.7	40.3	16	30.3	2.6	27.6	33.4	4
4	30.7	4.4	21.4	40.4	34	33.1	4.5	27.6	40.0	14	28.5	2.1	25.4	30.1	4
5	30.5	5.3	19.9	44.8	36	31.5	4.4	27.0	41.1	13	28.3	3.2	25.0	33.9	9
6	29.8	5.2	17.2	39.7	35	32.3	4.8	26.0	41.2	14	26.8	2.6	24.5	30.3	6

SD – Standard deviation; *n* – Number of radiographs; CVS – Cervical vertebral stage

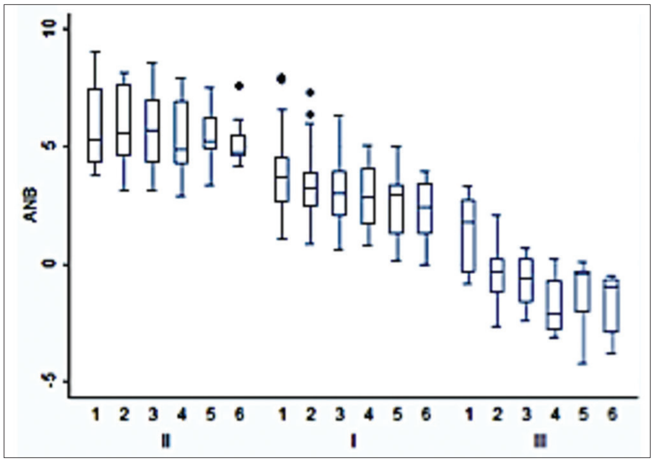

Figure 1: ANB angle description according to cervical maturation by skeletal class

increased. The largest decrease in the SN-GoGn measurement was seen in Class III patients, with an average reduction of 4.9°, in relation to a reduction of 4° for Class I, and 2.5° for Class II.

DISCUSSION

The present study was conducted to describe maxillomandibular relationships of clinical relevance throughout the development in a longitudinal sample of North American Caucasian individuals, obtained from different growth centers. The individuals were classified by maturational status and grouped by sagittal class. To account for the different radiographic magnification factors, only angular measurements were carried out, which allowed for the identification of relevant aspects of maxillomandibular development.

It is known that significant craniofacial differences may be observed between Caucasian individuals from different growth centers.[10] Several studies have grouped individuals according to chronological age and correlated them with skeletal changes.[24-29] However, if a heterogeneous sample of individuals is grouped considering sagittal and maturational characteristics, the inclusion of individuals from different growth centers may strengthen the external validity of the results. That was the approach adopted in the present study. The results are therefore grouped according to skeletal maturity and not to chronological age, making the subgroups of individuals comparable. The determination of skeletal maturity provides a better basis of comparison than chronological age for grouping individuals.[30]

Sexual dimorphism is clearly expressed in facial development,[22,31,32] mainly as differences in linear cephalometric measurements among genders.[27,33] The present study found no differences between sexes during growth using angular measurements. It is likely that the grouping methodology using skeletal maturation rather than age, together with the absence of linear measurements, may have influenced these findings.

The results of this study indicate that ANB angle decreases during growth, which is consistent with the results of other studies.[10-16,30,34] In the present study, the reduction in the ANB angle during development took place in all groups but differed according to skeletal class, with decreases averaging 1.5° in Class I, 0.85° in Class II, and 3.1° in Class III. This may imply a differential expression of maxillomandibular development dependent on the skeletal class. The smallest average variation occurred in Class II patients while the opposite was seen in Class III. Class III individuals experienced a greater decrease in the ANB angle than Class I, expressing their sagittal condition at a later point of development, as previously reported.[33] This may partially explain the progressive nature of the severity of Class III malocclusions. It also may account for the improvement in the sagittal relationship occasionally observed in patients with large ANB angle values at early ages that evolve to normal sagittal relationships as shown in Table 3. In fact, the Class I group included individuals with ANB values above 7° in CVS 1, which decreased to the Class I range in CVS 6.

Another factor that may affect the ANB angle reduction with age is mandibular counterclockwise rotation,[16] which is consistent with the decrease in the angle SN-GoGn observed in this sample. Thus, both the dominance of mandibular growth over the maxilla during development and a counterclockwise mandibular rotational tendency contribute to a reduction in facial convexity that is generally expected during facial development. The magnitude of these phenomena and their clinical relevance, aside from the skeletal classification, may relate to interindividual variability.

The SN-GoGn angle is an angular measurement included in the study to quantify the inclination of the mandibular base relative to the cranial base. Its average value is 32°.[6] Subranamian and Naidu[30] found a decrease from 36° to 31° between 6 and 16 years of age. This correlates with the findings in the present study, where there is an average decrease between CVS 1 (average 8-year-old) and CVS 6 (average age 17), from approximately 34°–30° in Class I individuals. Class II and III individuals also displayed a reduction throughout growth, with a 2.5° and 4.9°

reduction, respectively, showing a differential tendency among groups, consistent with the one observed with the ANB angle.

In the analyzed sample, both SNA and SNB angles increase as the individuals grow, with a higher increase in the SNB angle. The same has been described by others.[10,27] The SNA angle measurements in Class I and II individuals are very similar, and the differences between the skeletal classes originate in the mandibular position; therefore, Class II individuals had more retrognathic mandibles than did Class I as Jacob and Buschang[35] have reported. Others, however, have reported a greater difference between Class II and Class I[24] with the SNA angle 2–3° higher in Class II than in Class I individuals. On the other hand, in the present study, Class III individuals displayed a smaller SNA angle during development and similar SNB values between Class I and Class III individuals, while it was lower in Class II individuals. Reyes *et al.*,[36] analyzing an extensive cross-sectional sample of untreated Class III individuals, have found no differences between Class III and Class I individuals for the sagittal position of the maxilla in any of the age ranges, and larger SNB values in the Class III sample. Class II and III malocclusions are etiologically diverse and may result from altered mandibular or maxillary positions, or a combination of both. Our Class II and III groups included 17 and 9 untreated individuals, respectively, with sagittal malocclusions of a moderate severity, which were followed longitudinally. It is, thus, a small sample that reflects the growth tendency of individuals with sagittal malocclusions due to mandibular and maxillary deficiency in Class II and III individuals, respectively. This group may differ from others in their severity and reflects the diversity of expression that characterizes sagittal malocclusions.

CONCLUSIONS

ANB and SN-GoGn angles decrease during growth whereas SNA and SNB increase.

The magnitude of the decrease in ANB and SN-GoGn angles during growth varies depending on individual sagittal characteristics. They decrease more in Class III individuals and less in Class II individuals.

It is expected that regardless of the sagittal classification of an individual, the value of the measure of ANB and SN-GoGn angles tends to decrease during development.

Class II individuals presented a reduced SNB angle while Class III individuals displayed a reduced SNA angle.

Acknowledgments

We would like to acknowledge the AAOF craniofacial growth legacy collection for allowing the use of the collection. We would also like to thank Dr. Valeria Ramírez Lobos for her expert help with the statistical analysis of the data.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Proffit WR, Fields HW Jr., Moray LJ. Prevalence of malocclusion and orthodontic treatment need in the United States: Estimates from the NHANES III survey. Int J Adult Orthodon Orthognath Surg 1998;13:97-106.
2. Olsen JA, Inglehart MR. Malocclusions and perceptions of attractiveness, intelligence, and personality, and behavioral intentions. Am J Orthod Dentofacial Orthop 2011;140:669-79.
3. Kiyak HA. Does orthodontic treatment affect patients' quality of life? J Dent Educ 2008;72:886-94.
4. Enlow DH, Hans MG. Essentials of Facial Growth. Philadenphia: WB Saunders Co.; 1996.
5. Riedel RA. Esthetics and its relation to orthodontic therapy. Angle Orthod 1950;20:168-78.
6. Steiner CC. Cephalometrics for you and me. Am J Orthod 1953;39:729-55.
7. Oktay H, Freeman R, Broadbent B, Gazilerli Ü, Downs W, Riedel R, *et al*. A comparison of ANB, WITS, AF-BF, and APDI measurements. Am J Orthod Dentofacial Orthop 1991;99:122-8.
8. Han UK, Kim YH. Determination of Class II and Class III skeletal patterns: Receiver operating characteristic (ROC) analysis on various cephalometric measurements. Am J Orthod Dentofacial Orthop 1998;113:538-45.
9. Anderson G, Fields HW, Beck M, Chacon G, Vig KW. Development of cephalometric norms using a unified facial and dental approach. Angle Orthod 2006;76:612-8.
10. van Diepenbeek AF, Buschang PH, Prahl-Andersen B. Age-dependant cephalometric standards as determined by multilevel modeling. Am J Orthod Dentofacial Orthop 2009;135:79-87.
11. Ochoa BK, Nanda RS. Comparison of maxillary and mandibular growth. Am J Orthod Dentofacial Orthop 2004;125:148-59.
12. Foley TF, Stirling DL, Hall-Scott J, Broadbent B, Riedel R, Jenkins D, *et al*. The reliability of three sagittal reference planes in the assessment of Class II treatment. Am J Orthod Dentofacial Orthop 1997;112:320-9.
13. Hurmerinta K, Rahkamo A, Haavikko K. Comparison between cephalometric classification methods for sagittal jaw relationships. Eur J Oral Sci 1997;105:221-7.
14. Palleck S, Foley TF, Hall-Scott J. The reliability of 3 sagittal reference planes in the assessment of Class I and Class III treatment. Am J Orthod Dentofacial Orthop 2001;119:426-35.
15. 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.
16. Bishara SE, Fahl JA, Peterson LC. Longitudinal changes in the ANB angle and Wits appraisal: Clinical implications. Am J Orthod 1983;84:133-9.
17. Gordon Behrents R. Growth in the Aging Craniofacial Skeleton (Craniofacial Growth Series-Monograph 17). 1st ed. Ann Arbor, Michigan: Center for Human Growth and Development, the University of Michigan; 1985.

18. Björk A, Skieller V. Facial development and tooth eruption. An implant study at the age of puberty. Am J Orthod 1972;62:339-83.
19. Nanda RS, Ghosh J, Holdaway R, Wylie W, Taylor C, Riolo M, *et al*. Longitudinal growth changes in the sagittal relationship of maxilla and mandible. Am J Orthod Dentofacial Orthop 1995;107:79-90.
20. Silveira AM, Fishman LS, Subtelny JD, Kassebaum DK. Facial growth during adolescence in early, average and late maturers. Angle Orthod 1992;62:185-90.
21. Steiner CC. Cephalometrics in clinical practice. Angle Orthod 1959;29:8-29.
22. Fishman LS. Radiographic evaluation of skeletal maturation. A clinically oriented method based on hand-wrist films. Angle Orthod 1982;52:88-112.
23. Baccetti T, Franchi L, McNamara JA. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod 2005;11:119-29.
24. Riesmeijer AM, Prahl-Andersen B, Mascarenhas AK, Joo BH, Vig KW. A comparison of craniofacial Class I and Class II growth patterns. Am J Orthod Dentofacial Orthop 2004;125:463-71.
25. Bae EJ, Kwon HJ, Kwon OW. Changes in longitudinal craniofacial growth in subjects with normal occlusions using the Ricketts analysis. Korean J Orthod 2014;44:77-87.
26. Chung CH, Wong WW. Craniofacial growth in untreated skeletal Class II subjects: A longitudinal study. Am J Orthod Dentofacial Orthop 2002;122:619-26.
27. Chung CH, Mongiovi VD. Craniofacial growth in untreated skeletal Class I subjects with low, average, and high MP-SN angles: A longitudinal study. Am J Orthod Dentofacial Orthop 2003;124:670-8.
28. Wolfe SM, Araujo E, Behrents RG, Buschang PH. Craniofacial growth of Class III subjects six to sixteen years of age. Angle Orthod 2011;81:211-6.
29. Chen F, Wu L, Terada K, Saito I. Longitudinal intermaxillary relationships in Class III malocclusions with low and high mandibular plane angles. Angle Orthod 2007;77:397-403.
30. Subramaniam P, Naidu P. Mandibular dimensional changes and skeletal maturity. Contemp Clin Dent 2010;1:218-22.
31. Siriwat PP, Jarabak JR. Malocclusion and facial morphology is there a relationship? An epidemiologic study. Angle Orthod 1985;55:127-38.
32. Ursi WJ, Trotman CA, McNamara JA Jr., Behrents RG. Sexual dimorphism in normal craniofacial growth. Angle Orthod 1993;63:47-56.
33. Baccetti T, Reyes BC, McNamara JA Jr. Gender differences in Class III malocclusion. Angle Orthod 2005;75:510-20.
34. Hamamci N, Kiralp S, Selek M, Arslan S, Pratice P. Longitudinal study of untreated skeletal Class I subjects growth and development with McNamara cephalometric analysis. Biotechnol Biotechnol Equip 2006;3:175-83.
35. Jacob HB, Buschang PH. Mandibular growth comparisons of Class I and Class II division 1 skeletofacial patterns. Angle Orthod 2014;84:755-61.
36. Reyes BC, Baccetti T, McNamara JA Jr. An estimate of craniofacial growth in Class III malocclusion. Angle Orthod 2006;76:577-84.