Childhood and pubertal growth changes of the human symphysis

P. H. Buschang, MA, PhD; K. Julien, BS, DDS; R. Sachdeva, BDS, MDS; and A. Demirjian, MS, DDS

For the clinical orthodontist, the symphysis is one of the most important regions of the craniofacial complex. It serves as a primary reference for esthetic considerations in the lower third of the face. Furthermore, vertical and sagittal positions of the mandibular incisors and mental protuberance are important determinants in planning occlusal and skeletal relations for orthodontic treatment and orthognathic surgical procedures. An understanding of the structure and function of basal and alveolar bone, which ultimately requires description and explanation of ontogenetic variation in symphyseal morphology, is therefore essential in order to develop a differential diagnosis.

Despite its clinical significance, there exists little quantitative information pertaining to symphyseal growth. Few investigations are longitudinal; none of the human studies are comprehensive. Existing reports provide qualitative descriptions of growth changes,[1,2] theoretical discussions of its development,[3-5] and evaluations of isolated symphyseal events.[2,6-9] Quantitative guidelines are necessary to assess the growth pattern of the symphysis; estimates of variability are necessary to establish probabilities of observed growth changes for individual patients.

The present investigation was undertaken to more fully evaluate childhood and pubertal growth changes of 15 symphyseal landmarks. The purpose is to provide reference data on untreated subjects for use in planning and evaluating treatment.

Abstract

Longitudinal growth changes of the human symphysis were evaluated for 75 children (37 males and 38 females) between 6 and 15 years old. Childhood growth was described by mean yearly rates of change between 6 and 10 years for females and between 7 and 11 years for males; pubertal changes pertain to growth between 10 and 14 for females and between 11 and 15 for males. Cephalometric tracings of the mandible were superimposed using stable reference structures. Vertical growth changes, particularly for landmarks located in the upper 20% of the symphysis, were most pronounced. Annual rates of vertical growth ranged between 0.9 mm/yr for the lingual incisor contact point to -0.2 mm/yr for gnathion. Males showed significantly greater rates of vertical growth than females, especially for the upper half of the symphysis. Vertical growth rates were also greater during puberty than during childhood. The horizontal growth changes indicated lingual movement of most symphyseal landmarks. Annual rates of growth were greatest for landmarks located in the upper half of the symphysis. B-point showed the greatest lingual drift. During puberty, the mandibular incisors in females moved lingually as the upper anterior half of the symphysis remodeled; in males, the incisors maintained their horizontal position as the labial sulcus developed.

This manuscript was submitted July 1991. It was revised and accepted for publication November 1991.

Key Words

Symphysis • Longitudinal growth • Cephalometrics

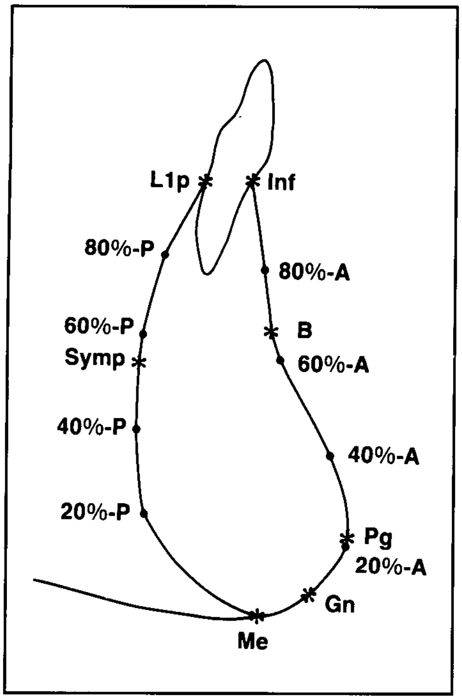

Figure 1

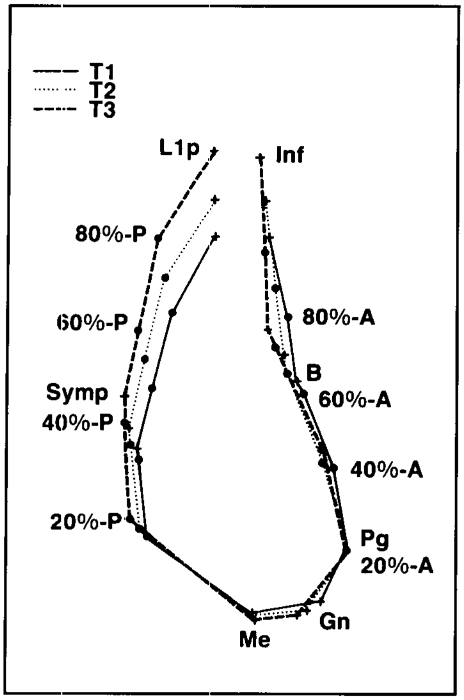

Figure 2A

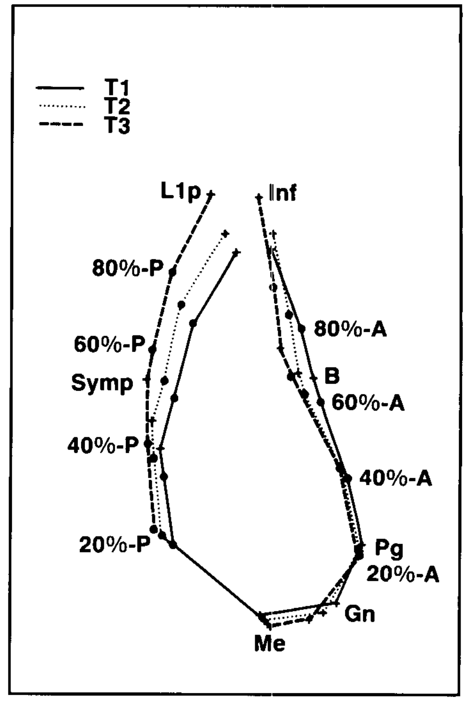

Figure 2B

Figure 1
Traditional and relative landmarks describing symphyseal morphology

Figure 2A-B
Childhood and pubertal change in symphyseal morphology of males (A) and females (B).

Materials and methods

The data were derived from lateral cephalograms collected by the Human Growth Research Center at the University of Montreal.[10] Subjects were selected from a larger sample based on the availability of longitudinal records. To describe childhood and pubertal growth, three measurement occasions were chosen for each of 75 individuals (38 males and 37 females). Ages 10 and 11 most closely approximate the whole-year ages of minimum preadolescent mandibular growth velocity for females and males, respectively.[11,12] The initial and final occasions were chosen 4 years before and after the estimated ages of minimum prepubertal growth velocity. The majority of children were seen ± 15 days of their birthday.

The three tracings were superimposed using stable mandibular reference structures, including the tip of the chin, the inner cortical structure at the inferior border of the symphysis, the trabecular structures associated with the mandibular canal, and the lower contour of the molar germ. The validity of the superimposition methodology is based on metallic implant[1] and histological studies.[2] Reference lines, drawn parallel and perpendicular to the mandibular plane of the first tracing, were transferred to subsequent tracings and used for orientation. Replicate analyses show that the reliability of the mandibular superimposition ranges between 97% and 99%.[13]

Seven traditional and eight relative landmarks were identified and digitized (Figure 1). Traditional landmarks, including infradentale, B-point, pogonion, gnathion, menton, lingual symphyseal point, and lingual incisor contact point, were selected as described by Riolo et al.[14] The relative landmarks chosen divided the symphysis vertically into five equal parts, separated by planes parallel to the mandibular plane. The labial and lingual cortical surfaces intersecting the four planes were identified and digitized.

The horizontal and vertical movements of each landmark were evaluated relative to the stable structure reference lines. Positive changes reflected superior and labial movements; negative changes indicated inferior and lingual movements. For landmarks showing both positive and negative growth movements, mean values close to zero were expected. The data were not adjusted for magnification (adjustment factor=0.889). Changes between the three occasions were computed as yearly rates (mm/yr). Measures with distributions departing significantly from normal were described by their medians and interquartile ranges.

Results

Vertical growth changes: (Table 1; Figure 2)

Vertical growth changes range between -0.19 mm/yr and 0.94 mm/yr. Growth rates are greatest for infradentale and the lingual incisor contact point, representing the most superior aspect of the alveolar crest. Vertical growth velocities for B-point and the lingual symphyseal point are intermediate and also superiorly directed. Pogonion, gnathion, and menton show approximately 1 mm of inferior movement over the 8-year period. The relative land-

Table 1
Vertical Changes (mm/yr) in Position for Traditional and Relative Cephalometric Landmarks

Landmarks	Sex	Childhood Mean (S.D.)	Puberty Mean (S.D.)	Total Mean (S.D.)
Traditional				
Infradentale	F	0.33 (0.56)	0.66 (0.31)	0.49 (0.30)
	M	0.85 (0.46,1.06)[2]	0.85 (0.33)	0.78 (0.28)
B-Point	F	0.07 (0.23)[1]	0.47 (0.47)	0.26 (0.40)
	M	0.47 (0.68)	0.43 (0.29,0.79)[2]	0.47 (0.33)
Pogonion	F	-0.15 (0.21)	-0.09 (0.24)	-0.12 (0.13)
	M	-0.13 (0.26)	-0.03 (0.24)[1]	-0.08 (0.19)
Gnathion	F	-0.19 (0.13)	-0.15 (0.15)	-0.17 (0.10)
	M	-0.13 (0.15)	-0.13 (0.14)	-0.13 (0.10)
Menton	F	-0.07 (0.13)	-0.09 (0.16)	-0.09 (0.07)
	M	-0.07 (0.15)	-0.08 (0.17)	-0.07 (0.11)
Lingual Symphysis	F	0.22 (-0.16,0.95)[2]	0.48 (-0.12,1.14)[2]	0.30 (0.03,1.22)[2]
	M	0.37 (0.86)	0.39 (0.19,0.56)[2]	0.40 (0.01,0.75)[2]
Lingual Incisor	F	0.34 (0.52)	0.72 (0.28)	0.53 (0.27)
	M	0.70 (0.45)	0.94 (0.36)	0.82 (0.26)
Relative				
80%-Ant.	F	0.25 (0.46)	0.52 (0.29)	0.38 (0.26)
	M	0.53 (0.43)	0.67 (0.27)	0.60 (0.24)
60%-Ant.	F	0.15 (0.34)	0.36 (0.28)	0.25 (0.21)
	M	0.38 (0.36)	0.47 (0.25)	0.42 (0.20)
40%-Ant.	F	0.06 (0.47)[1]	0.12 (0.27)	0.05 (0.19)[1]
	M	0.05 (0.28)[1]	0.23 (0.26)[1]	0.14 (0.19)
20%-Ant.	F	-0.09 (0.18)	-0.02 (0.24)[1]	-0.05 (0.14)[1]
	M	-0.06 (0.25)[1]	-0.01 (0.24)[1]	-0.03 (0.16)[1]
20%-Post.	F	0.16 (0.18)	0.14 (0.22)	0.15 (0.13)
	M	0.17 (0.23)	0.15 (0.25)	0.16 (0.16)
40%-Post.	F	0.25 (0.28)	0.28 (0.22)	0.27 (0.18)
	M	0.30 (0.29)	0.39 (0.18,0.56)[2]	0.35 (0.18)
60%-Post.	F	0.33 (0.34)	0.44 (0.25)	0.38 (0.21)
	M	0.54 (0.34)	0.55 (0.23)	0.55 (0.19)
80%-Post.	F	0.38 (0.47)	0.57 (0.28)	0.47 (0.25)
	M	0.64 (0.43)	0.76 (0.24)	0.70 (0.22)

[1] Change not significant ($p < 0.05$)
[2] Median values, with interquartile range (25th, 75th)

Figure 3
Pubertal growth/remodeling changes and limits of variation (± 1 SD) for boys.

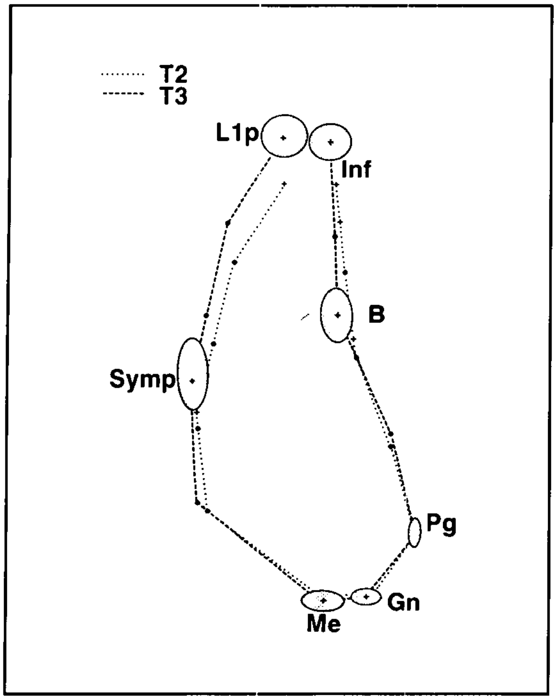

Figure 3

marks follow a similar pattern of vertical growth, with the upper half of the symphysis showing the greatest growth rates. Little or no growth changes occur at the anterior 20% level. It is worth reemphasizing that mean values approaching zero mm/yr indicate that variation of the actual changes between individuals, as defined by the SD, can be either a positive or negative (i.e., growth is not unidirectional).

Males display significantly greater rates of vertical change than females, especially during the childhood period. The upper half of the symphysis shows the most pronounced dimorphism. Differences in growth rates between childhood and adolescent growth are most evident for females. They show significantly greater vertical adolescent changes for the upper anterior 40% of the symphysis. Vertical growth of males also tends to be greater during the adolescent period, but the differences are statistically significant only for lingual incisor contact point and the anterior 40% level.

Horizontal Changes: (Table 2; Figure 2)

Horizontal changes are also statistically significant for the majority of landmarks. Pogonion, located at or near the anterior 20% level, shows no significant horizontal movement. Menton drifts labially in females during childhood. Importantly, infradentale and the lingual incisor contact point show lingual movements in females and no horizontal movement in males. B-point displays the greatest horizontal change for both boys and girls; it moves lingually over 2mm during the eight year period. The remaining landmarks also move lingually. Relative landmarks located in the anterior upper half of the symphysis show the greatest lingual changes of position (-0.19 mm/yr to -0.33 mm/yr).

Females have significantly greater rates of lingual movement than males for points in the upper anterior aspect of the symphysis. During the adolescent years, incisors in females drift lingually as the upper anterior half of the symphysis remodels. Females also display significantly more lingual movement of B-point. In males, the incisors maintain their horizontal position and the chin develops a sulcus. Horizontal growth differences between childhood and adolescence are limited. Girls show significantly greater rates of adolescent growth at infradentale and the anterior 80% level. Boys display more lingual movement at B-point and the anterior 60% level during childhood.

Discussion

The results demonstrate considerable variation between subjects in the actual direction of growth. Pubertal changes of B point, for example, tend to be in a superior/lingual direction (Figure 3). However, approximately 15% of the sample demonstrates inferior and/or labial growth changes. Part of the variability appears to be due to measurement error; landmarks located on vertical and horizontal planes tend to show greater vertical and horizontal error variance, respectively. There may also be difficulty in identifying the same structures over time because of the phenomenon of area relocation. More importantly, there appears to be a relationship between the position of the mandibular incisors and symphyseal remodelling. In turn, the position of the dentition is subject to a number of epigenetic factors not accounted for in the present study. These factors may be as diverse in nature as oral habits to the existing sagittal relationships of dentition, both of which can affect the subsequent eruption patterns of teeth and the remodeling response. Finally, individual differences in amount and direction of mandibular growth, rotation and skeletal remodeling might be expected to further account for the observed variability.

The vertical growth change of alveolar bone observed is associated with continuous or supra-eruption of the dentition. Following initial break-through of the tooth, a second phase of active eruption, which lasts until approximately 18 years of age, readjusts the occlusal plane in relation to facial growth.[15] The major stimuli for supra-eruption appears to be the removal of opposing forces, as a result of extraction, attrition, and/or differential maxillary/mandibular growth.[16,17]

Actual growth of the alveolus closely follows

Table 2
Horizontal Changes (mm/yr) in Position for Traditional and Relative Cephalometric Landmarks

Landmarks	Sex	Childhood Mean (S.D.)	Puberty Mean (S.D.)	Total Mean (S.D.)
Traditional				
Infradentale	F	0.01 (0.29)[1]	-0.29 (0.26)	-0.13 (0.20)
	M	-0.04 (0.34)[1]	-0.06 (0.32)[1]	-0.06 (0.20)[1]
B-Point	F	-0.25 (0.23)	-0.33 (0.22)	-0.29 (0.15)
	M	-0.37 (0.33)	-0.19 (0.25)	-0.28 (0.18)
Pogonion	F	-0.01 (0.12)[1]	-0.03 (0.12)[1]	-0.02 (0.06)[1]
	M	-0.03 (0.15)[1]	0.03 (0.08)[1]	-0.01 (0.06)[1]
Gnathion	F	-0.24 (0.20)	-0.28 (0.23)	-0.26 (0.16)
	M	-0.25 (0.22)	-0.18 (0.15)	-0.21 (0.12)
Menton	F	0.12 (0.30)	0.09 (0.36)[1]	0.10 (0.16)
	M	-0.06 (0.28)[1]	-0.08 (0.37)[1]	-0.04 (0.14)[1]
Lingual Symphysis	F	-0.12 (0.24)	-0.11 (0.30)	-0.11 (0.17)
	M	-0.16 (0.20)	-0.16 (0.22)	-0.16 (0.12)
Lingual Incisor	F	-0.21 (0.31)	-0.28 (0.31)	-0.24 (0.21)
	M	-0.07 (0.36)[1]	-0.06 (0.37)[1]	-0.07 (0.23)[1]
Relative				
80%-Ant.	F	-0.21 (0.23)	-0.33 (0.21)	-0.27 (0.16)
	M	-0.22 (0.27)	-0.20 (0.25)	-0.21 (0.16)
60%-Ant.	F	-0.26 (0.24)	-0.28 (0.23)	-0.27 (0.14)
	M	-0.33 (0.26)	-0.19 (0.22)	-0.27 (0.16)
40%-Ant.	F	-0.10 (0.22)	-0.07 (0.17)	-0.08 (0.11)
	M	-0.12 (0.19)	-0.05 (0.18)[1]	-0.09 (0.12)
20%-Ant.	F	-0.01 (0.11)[1]	-0.02 (0.11)[1]	-0.02 (0.07)[1]
	M	-0.02 (0.15)[1]	0.07 (0.10)[1]	0.00 (0.07)[1]
20%-Post.	F	-0.16 (0.20)	-0.14 (0.19)	-0.15 (0.15)
	M	-0.18 (0.22)	-0.19(-0.29,-0.07)[2]	-0.17 (0.16)
40%-Post.	F	-0.14 (0.23)	-0.14 (0.19)	-0.14 (0.15)
	M	-0.13 (0.20)	-0.16 (0.26)	-0.15 (0.13)
60%-Post.	F	-0.17 (0.27)	-0.12 (0.22)	-0.15 (0.15)
	M	-0.14 (0.28)	-0.13 (0.24)	-0.14 (0.13)
80%-Post.	F	-0.24 (0.30)	-0.17 (0.22)	-0.21 (0.16)
	M	-0.11 (0.28)	-0.13 (0.29)	-0.13 (0.15)

[1] Change not significant ($p < 0.05$)
[2] Median values, with interquartile range (25th, 75th)

patterns of condylar[18] and mandibular[11,12] growth. As the mandible is displaced downward and forward, supra-eruption of the incisors fills the space created, as indicated by significant correlations between vertical condylar growth and vertical alveolar growth.[19] Mandibular rotation also interacts with vertical growth;[20] anterior or counterclockwise rotation might be expected to limit vertical change in the anterior region.

Periosteal deposition and endosteal resorption of the lingual symphyseal surface have been previously qualified,[2] but not quantified. Hylander[21] associates such changes with masticatory stress. It appears that bone is deposited on the lingual surface and resorbed from the labial surface due to the mandible's curved beam structure. The resulting forces during incision probably cause a clockwise moment of a force in the mandibular incisor region, which might be counteracted by bony deposition on the lingual symphyseal surface.

Remodelling changes described for the inferior mandibular border have been related to rotational changes of the mandible.[1,18] Generally, anterior rotation is associated with deposition on the inferior aspect; posterior rotation is associated with resorption. These remodelling changes might be indirectly related to the nature of the stresses generated by the supra-hyoid musculature.

It is well established that the mental protuberance of humans is unique among primates.[3] In contrast to the periosteal deposition which characterizes the labial surface of other primates, the present results support the notion that the human chin develops by resorption of the alveolar bone.[2] They also partially support Bolk's shifting theory,[22] which suggests that differential growth slides the basal bone forward under the alveolar processes as the mandible is displaced during growth.

Importantly, sex differences in chin development occur during puberty. During puberty, females show significantly more posterior movement than males for both infradentale and B-point. Interestingly, Spady[18] showed greater horizontal growth of the mandibular condyle for pubertal females than males; more recently, rates of horizontal condylar growth have been related to the rates of lingual movements of both infradentale and the lingual incisor contact point.[19] In contrast, males show little or no lingual movement of infradentale. As B-point drifts posteriorly, the male chin develops as a concavity, making it appear "stronger" than the female chin. We interpret the observed sex differences as dentoalveolar compensations,[23] required to maintain the relationships of the anterior dentition during growth.

Conclusions

The clinical applicability of these results are threefold: First, the descriptive statistics can be used to help in diagnosis. Since teeth will supra-erupt in the absence of their antagonists, greater than expected vertical growth of the alveolar bone implies either increased condylar growth, abnormal incisor position, and/or posturing of the mandible. Vertical growers, especially those developing open bite, might be expected to show the fastest rates of supraeruption. This might also explain the development of deep curves of Spee in patients with retropositioned mandibles. Furthermore, the results may provide the clinician with appropriate reference standards to plan for either relative intrusion or pure intrusion in the correction of deep overbite. The ultimate applicability of these results in the clinical environment may be directed at developing a risk analysis approach by more fully accounting for the aforementioned source variation and formulating a treatment strategy.

Secondly, the rates of vertical growth associated with continuous eruption are large, up to 0.7 to 0.9mm/yr during puberty. Given this much change, treatment plans should incorporate incisal eruption, with adjustment or compensation for mandibular growth and rotation.

Finally, the dimorphic nature of growth for the upper half of the symphysis indicates that early loss of the primary canines in females might lead to reduced arch space as a result of lingual and vertical dental movement. Thus, space maintenance for the mandibular anterior dentition may be more important for pubertal females than males. Assuming that the maxillary incisors do not upright, an added disadvantage of the lingual eruption path might be the development of a deep bite in response to a break in the usual stops provided by the upper dentition. For males, maintenance of the presenting axial inclination of the mandibular incisors is indicated to maximize treatment stability.

Acknowledgments

The research was partially funded by MRC grant # MA-8097. The manuscript was typed by Martha Black.

Author Address

P.H. Buschang, PhD
Department of Orthodontics
Baylor College of Dentistry
3302 Gaston Ave.
Dallas, Texas 75246
(214) 828-8122

P.H. Buschang is Associate Professor in the Department of Orthodontics, Baylor College of Dentistry, 3302 Gaston Ave., Dallas Texas, 75246.

K. Julien is Resident Department of Orthodontics, Baylor College of Dentistry, 3302 Gaston Ave. Dallas, Texas.

R. Sachdeva is Associate Professor, Department of Orthodontics, Baylor College of Dentistry, 3302 Gaston Ave., Dallas, Texas.

A. Demirjian is Professor, Department of Stomatology, University of Montreal, Montreal, Quebec, H4V 3J7.

References

1. Björk A. The use of metallic implants in the study of facial growth in children: method and application. Am J Phys Anthrop 1968;29:243-254.
2. Enlow DH, Harris DB. A study of the postnatal growth of the human mandible. Am J Orthod 1964;75:25-50.
3. DuBrul EL, Sicher H. The Adaptive Chin. Charles C Thomas, Springfield, 1954.
4. Berger H. The chin problem from an orthodontist's point of view. Am J Orthod 1969;56:516-52.
5. Biggerstaff RH. The biology of the human chin. In: Orofacial Growth and Development, AA Dahlberg and TM Graber (eds), Mouton, The Hague, 1977.
6. Meredith HV. Change in the profile of the osseous chin during childhood. Am J Phys Anthrop 1957;15:247-252.
7. Garn SM, Lewis AB, Vicinus JH. The inheritance of the symphyseal size during growth. ANGLE ORTHOD 1963;33:222-231.
8. Horowitz SL, Thompson RH. Variations of the craniofacial skeleton in post-adolescent males and females. ANGLE ORTHOD 1964;34:97-102.
9. DeKock WH, Knott VB, Meredith HV. Change during childhood and youth in facial depth from integumental profile points to a line through bregma and sellion. Am J Orthod 1968;54:111-131.
10. Demirjian A, Brault Dubuc M, Jenicek M. Etude comparative de la croissance de l'enfant candien d'origine francais a Montreal, 1971.
11. Buschang PH, Tanguay R, Demirjian A, LaPalme L, Goldstein H. Pubertal growth of the cephalometric point gnathion: Multilevel models for boys and girls. Am J Phys Anthrop 1988;77:347-354.
12. Buschang PH, Tanguay R, Demirjian A, LaPalme L, Goldstein H. Modeling longitudinal mandibular growth: Percentiles for gnathion from 6 to 15 years of age in girls. Am J Orthod 1989;95:60-66.
13. Buschang PH, LaPalme L, Tangury R, Demirjian A. The technical reliability of superimposition on cranial base and mandibular structures. Eur J Orthod 1986;8:152-156.
14. Riolo ML, Mayers RE, McNamara JA, Hunter WS. An Atlas of Craniofacial Growth. Monograph 2, Center for Human Growth and Development, The University of Michigan, Ann Arbor, 1974.
15. Darling AI, Levers BGH. The pattern of eruption of some human teeth. Arch Oral Biol 1975;20:89-96.
16. Newman HN, Levers BGH. Tooth eruption and function in an early Anglo-Saxon population. Proc R Soc Med 1979;72:341-350.
17. Schneiderman ED A longitudinal cephalometric study of incisor supra-eruption in young and adult rhesus monkeys (Macaca Mulatta). Arch Oral Biol 1989;34:137-141.
18. Spady MP. Prediction and evaluation of mandibular growth rotation. Unpublished Master's Thesis, Baylor College of Dentistry, Dallas, Texas, 1990.
19. Buschang PH, Julien K, Spady M, Demirjian. A. Vertical and horizontal growth of alveolar growth. J Dent Res 1991;70:426.
20. Björk A, Skieller V. Facial development and tooth eruption. Am J Orthod 1972;62:339-383.
21. Hylander WL. Stress and strain in the mandibular symphysis of primates: a test of competing hypotheses. Am J Phys Anthrop 1984;64:1-46.
22. Bolk L. Die Entstehung des Menschen Kinnes, Ein Beitrag zur Entwicklungsgeschichete des Unterkiefers. Verhandelingen der Koninklijke Akademie van Westenschappen te Amsterdam, Tweede Sectie, 1924;25(5).
23. Solow B. The dento-alveolar compensatory mechanism: Background and clinical implications. Brit J Orthod 1980;7:145-161.