Semilongitudinal cephalometric study of craniofacial growth in untreated Class III malocclusion

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Introduction: Class III growth in white subjects is poorly characterized because of the low prevalence of the disharmony and the clinical tendency to treat this condition early. The purpose of this study was to investigate craniofacial growth changes by using longitudinal cephalometric records of white subjects with untreated Class III malocclusions to provide comparison data for studies of Class III treatment outcomes. **Methods:** Longitudinal records of 103 subjects were analyzed. Annual incremental growth changes in craniofacial variables from early childhood to late adolescence were examined for each sex. Inferential statistics were applied to changes in mandibular length, midfacial length, and lower anterior facial height of each sex (Wilcoxon tests) and between sexes (Mann-Whitney U tests). **Results:** In the girls, the adolescent spurt in mandibular growth occurred between the ages of 10 and 12 years. In the boys, the adolescent mandibular growth spurt was between 12 and 15 years. Statistically significant growth changes in the average increments of growth of these linear measurements occurred in both sexes between 12 and 15 years. Adolescent peaks in midfacial growth were at prepubertal ages in both sexes. During childhood (5-7 years), much craniofacial growth occurred. Moreover, there was considerable mandibular growth relative to the maxilla in Class III subjects after the adolescent growth spurt. **Conclusions:** White Class III subjects showed definite worsening of the relative mandibular prognathism and sagittal skeletal discrepancy between the jaws with growth. The growth pattern of 3 fundamental cephalometric measurements (lower anterior face height, midfacial length, and mandibular length) exhibited differences between Class III male and female subjects in both the timing and the size of average growth increments in the adolescent growth spurt. (Am J Orthod Dentofacial Orthop 2009;135:700.e1-700.e14)

Over the past century, the compromised esthetics and function of an anterior crossbite have motivated many people to seek correction of their malocclusion. Several orthodontic, orthopedic, and surgical treatment modalities have evolved to correct a Class III dentoskeletal disharmony.[1,2] Today, however, this type of disharmony remains difficult for orthodontists because of varied etiologies and limited understanding of Class III skeletal growth.

Cephalometric studies, expressed either cross-sectionally or longitudinally, allow investigators to acquire information regarding craniofacial growth. Most longitudinal cephalometric studies characterizing the growth pattern of Class III malocclusions have used subjects of Asian ancestry,[3-6] because of the relatively greater prevalence of this malocclusion in these populations (4%-19%).[7-9]

Lower frequencies of Class III malocclusion occur in other racial and ethnic groups, especially in white people of European or North American ancestry. The reported prevalence estimates range from 0.2% to 12%.[10,11] Most growth trend data on white people with untreated Class III malocclusions come from cross-sectional cephalometric studies. These studies show that Class III growth has significant differences from Class I growth.[2,12,13] Development of a Class III disharmony is multi-factorial and complex: it can result from combinations of skeletal and dental features, and from variations in magnitude, direction, and timing of facial growth. Such features include the relative prognathism of the jaws and teeth[14-19]; the size of the jaws[14,15,17-19];

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the size, shape, and angulation of the cranial base[20-25]; and the position of the glenoid fossa.[15,18,20,23,25] Several investigators noted significant sexual dimorphism in the morphologic variability of Class III features and the growth trends in their study samples.[13,15,18,26]

The few longitudinal studies conducted with untreated Class III white subjects also found significant differences in the growth of the jaws compared with Class I subjects.[12,27-31] The skeletal and dental components of Class III malocclusion are present in early childhood[17,19] and tend to worsen with growth.[12,27-31] These longitudinal studies, however, are limited in terms of the numbers of subjects and the periods of growth evaluated. A more complete characterization of the craniofacial growth in white people of European and North American ancestry with Class III malocclusions is needed to assist in treatment planning and evaluating expectations of physiological growth, treatment effects, and posttreatment relapse tendencies.

The purpose of this study, therefore, was to investigate craniofacial growth changes in white subjects with untreated Class III malocclusions with a series of longitudinal cephalometric records. The changes from early childhood to early adulthood were examined at various age intervals, with particular emphasis on analyzing any differences between the growth patterns of the sexes. This unique data set concerning untreated Class III subjects followed longitudinally could also be used for comparison in studies of Class III treatment outcomes.

MATERIAL AND METHODS

A unique collection of lateral cephalometric longitudinal series was assembled from private practices, university-affiliated orthodontic offices, and growth center studies in the United States, Canada, and Italy. The growth centers included the Bolton-Brush Growth Study, the University of Michigan Elementary and Secondary School Growth Study, the Denver Growth Study, and the Burlington Growth Centre. Other longitudinal record sets were obtained from the Department of Orthodontics at the University of Florence in Italy.

An initial sample of 155 longitudinal lateral cephalometric series was acquired. The series ranged between 2 and 9 films and covered a varying number of years between 4 and 20 years of age. Forty-five series were obtained from growth study collections; 110 series were acquired from private practices and university-affiliated orthodontic offices.

The following inclusionary criteria were applied to the total collection of longitudinal series to create the final Class III sample: (1) European or American ancestry (white); (2) no orthopedic or orthodontic treatment before the initial cephalometric record or between any subsequent cephalometric records; (3) Angle Class III malocclusion identified on initial cephalometric film and defined as an anterior crossbite, an edge-to-edge incisal relationship concomitant with 1 skeletal Class III criterion, an accentuated mesial step relationship of the deciduous second molars, or at least one half cusp Angle Class III relationship of the permanent first molars; (4) skeletal Class III relationship defined as having either or both a negative Wits appraisal greater than –2.0 mm and an ANB angle less than 0°; (5) no congenitally missing or extracted teeth; (6) no craniofacial syndromes; and (7) not less than 9 months and not more than 30 months between consecutive cephalometric films.

All lateral cephalograms were taken in centric occlusion. Pseudo-Class III anterior crossbites were excluded based on 2 factors: a functional shift noted by the treating orthodontist and an increase in the linear distance between the second vertebral body and the posterior border of the ascending ramus during intercuspation of the teeth.

A final sample of 103 subjects (ie, 103 longitudinal cephalometric series) with Class III malocclusions met the inclusion criteria (Table I). The sample included 55 females and 48 males. Further analysis of the sample was conducted in the sexes separately, because significant sexual dimorphism was demonstrated previously in Class III subjects.[13,15,18,26]

Magnification of the cephalometric images was adjusted according to the appropriate enlargement factor for each growth center or orthodontic office. A standardized 8% magnification factor was applied to all linear cephalometric measurements.

Lateral cephalograms were hand traced by using 0.003-in matte acetate and a 2H lead drafting pencil. All cephalograms in a series were traced by 1 investigator (A.E.Z.A.) in 1 sitting with all films available for comparison. Landmark identification, fixed fiducial points, and superimpositions were verified by a second investigator (J.A.M.). Superimpositions were made by using the 4-point superimposition method of Ricketts.[2,32-34] Fixed fiducial points were transferred from the first cephalometric tracing to the subsequent tracings in the subject's series. Any disparities between investigators were addressed by retracing the structure. All tracings were digitized with a customized digitization program in Dentofacial Planner (Dentofacial Software, Toronto, Ontario, Canada). A cephalometric analysis including measurements adopted from the analyses of Steiner,[35] Jacobson,[36] Ricketts,[33] and McNamara[34] was performed on each tracing. Soft-tissue measurements were excluded from this analysis because approximately half of the longitudinal series had

Table I. Sample before and after exclusionary criteria

Sample selection	*n*
Initial patient sample	155
Exclusions	
Prior treatment	2
Craniofacial syndrome	1
Poor quality cephalograms in series	6
Disqualifying incisor or molar relationship	3
Patient not occluding in film	2
Age of patient at time of films unknown	8
Time between films < 9 mo and > 30 mo	27
Different magnification between consecutive films	2
Final sample	103

Table II. Definition of the age groups

Group	*Years*	*Range (T1-Tf)*	*Female*	*Male*	*Total*
1	4–5	≤ 4 y 9 mo - ≥ 4 y 3 mo	3	3	6
2	5–6	≤ 5 y 9 mo - ≥ 5 y 3 mo	4	7	11
3	6–7	≤ 6 y 9 mo - ≥ 6 y 3 mo	10	12	22
4	7–8	≤ 7 y 9 mo - ≥ 7 y 3 mo	13	13	26
5	8–9	≤ 8 y 9 mo - ≥ 8 y 3 mo	12	12	24
6	9–10	≤ 9 y 9 mo - ≥ 9 y 3 mo	12	14	26
7	10–11	≤ 10 y 9 mo - ≥ 10 y 3 mo	16	10	26
8	11–12	≤ 11 y 9 mo - ≥ 11 y 3 mo	16	10	26
9	12–13	≤ 12 y 9 mo - ≥ 12 y 3 mo	25	10	35
10	13–14	≤ 13 y 9 mo - ≥ 13 y 3 mo	27	12	39
11	14–15	≤ 14 y 9 mo - ≥ 14 y 3 mo	23	14	37
12	15–16	≤ 15 y 9 mo - ≥ 15 y 3 mo	18	11	29
13	16–17	≤ 16 y 9 mo - ≥ 16 y 3 mo	4	11	15
14	17–18	≤ 17 y 9 mo - ≥ 17 y 3 mo	2	8	10
15	18–19	≤ 18 y 9 mo - ≥ 18 y 3 mo	1	2	3
16	19–20	≤ 19 y 9 mo - ≥ 19 y 3 mo	0	2	2

T1, first observation time; *Tf,* final observation time.

at least 1 cephalogram with a missing or poor-quality soft-tissue image.

The age range of the final sample was 3 years 11 months to 20 years 3 months. Because of the wide age range and the variations in observation times inherent in the longitudinal series of the sample, the monthly increment of change between each subject's serial cephalometric measurements was calculated. Based on this age range, 16 age increments were defined by using multiples of monthly increases in cephalometric variables to annualize the intervals (Table II). The stages in cervical vertebral maturation (CVM) of all subjects were recorded at all subsequent observations.[37] This allowed for assessment of the timing of cephalometric records with respect to the pubertal growth spurt.

Statistical analysis

Descriptive statistics for annualized age intervals were calculated for each sex in every group. For the inferential statistics, the increments in 3 fundamental skeletal variables were considered: lower anterior face height (ANS to Me), midfacial length (Co-Pt A), and mandibular length (Co-Gn). Significant sex differences for each age group were determined by using Mann-Whitney U tests. The use of nonparametric statistics was recommended because of the lack of normal distribution of the data. Significant growth differences for the same 3 cephalometric measurements between consecutive-age, average-growth increments in the sex groups were tested with the Wilcoxon test. Statistical difference was tested at $P < 0.05$ and $P < 0.01$. All computations were made with SPSS software (version 12.0, SPSS, Chicago, Ill). Growth trends also were plotted for the average group increments of growth for lower anterior face height, midfacial length, and mandibular length.

The error of the method for the cephalometric measurements was evaluated by repeating the measurements of 100 randomly selected cephalograms. Error was on average 0.6° for angular measures and 0.9 mm for linear measures (and 0.2° and 0.3 mm for the annual increments in these measures, respectively), thus confirming the error reported in a previous study.[13]

RESULTS

Descriptive statistics for the annual increments of all cephalometric variables at the examined ages for the untreated Class III samples of both sexes are summarized in Tables III and IV. Significant differences in the average growth increments between age groups in the female or male sample also are included in these tables. The results of statistical tests to determine sex differences between the average growth increments for lower anterior face height, midfacial length, and mandibular length are shown in Table V.

The growth curves for the same 3 measurements are shown in Figures 1 and 2. The graphs comparing the male and female growth curves for midfacial and mandibular length growth increments are shown in Figures 3 and 4. Subjects in the 4 to 5, 5 to 6, 16 to 17, and 17 to 18 year age groups for girls, and subjects in the 4 to 5 year age group for boys, were excluded from the analysis because of insufficient sample sizes.

There were significant differences in the female sample between the age groups 6 to 7 and 7 to 8 years in the growth changes for mandibular length (significant decreases), and between the age groups 10 to 11 and 11 to 12 years for midfacial length (significant decreases; Table III).

Table III. Descriptive statistics for female age groups

	6-7 y n = 10		*7-8 y n = 13*		*8-9 y n = 12*		*9-10 y n = 12*	
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Cranial base								
SN-FH (°)	–0.41	0.30	–0.24	0.29	–0.28	0.36	–0.07	0.53
S-N (mm)	1.03	0.50	0.91	0.66	0.77	0.86	0.60	0.67
Cranial flexure (°)	0.07	0.94	0.05	1.07	0.16	1.21	0.15	0.99
Maxillary skeletal								
SNA (°)	–0.57	1.40	–0.31	1.03	–0.09	0.72	0.07	0.65
Pt A to Na perp (mm)	–0.82	1.04	–0.48	0.95	–0.34	0.75	–0.01	0.78
PP-FH (°)	0.19	2.02	–0.14	1.61	0.56	0.96	–0.13	1.38
Co-Pt A (mm)	1.31	1.64	0.94	1.05	0.94	0.61	1.05	0.92
Mandibular skeletal								
SNB (°)	0.00	0.76	0.08	0.81	0.32	0.60	0.68	0.65
Pog-Na perp (mm)	0.07	0.75	0.36	1.13	0.24	0.99	1.18	1.90
Facial angle (°)	0.12	0.52	0.28	0.64	0.17	0.56	0.69	1.02
Co-Gn (mm)	3.22*	1.62	2.35	0.77	2.45	0.70	2.89	1.57
Ramus height (mm)	1.04	1.15	0.82	0.82	1.74	1.07	1.39	1.02
Gonial angle (°)	–0.35	1.47	–1.39	1.27	–0.62	1.87	–0.67	1.63
Maxillary/mandibular								
FMA (°)	0.30	1.16	0.02	0.91	0.09	1.12	–0.49	1.55
ANB (°)	–0.55	0.96	–0.39	0.98	–0.39	0.64	–0.61	0.77
Wits (mm)	–1.24	3.06	–0.49	3.2	0.02	0.77	–0.67	1.50
Mx-md diff (mm)	1.96	1.42	1.42	1.02	1.48	0.67	1.87	1.05
Molar relation (mm)	0.02	1.01	0.18	0.74	–0.05	0.75	0.57	0.98
Vertical								
Nasion to ANS (mm)	2.05	1.58	1.43	0.95	1.52	0.81	1.03	0.61
ANS to Me (mm)	1.03	1.27	1.01	1.15	1.25	0.85	1.02	0.91
UFH/LAFH ratio	1.75	3.9	0.77	3.44	0.93	2.52	0.01	1.43
AFH (mm)	3.37	2.08	2.56	1.02	2.90	1.06	2.23	1.19
PFH (mm)	2.15	1.30	1.45	0.88	2.24	1.00	1.78	0.97
PFH/AFH ratio	0.16	0.94	–0.07	0.98	0.43	1.12	0.46	1.22
Vertical dentoalveolar								
U1-ANS (mm)	1.66	5.22	1.59	4.49	0.52	0.73	0.68	0.65
U6-PP (mm)	0.19	1.25	0.59	1.10	1.10	0.90	0.75	0.71
L1-Me (mm)	0.73	1.01	0.99	0.67	0.98	0.63	0.73	0.49
Sagittal dentoalveolar								
U1-Pt A (V) (mm)	1.16	1.61	1.41	1.32	0.59	0.54	0.78	0.60
U1-SN (°)	5.41	4.97	4.55	4.37	3.01	3.38	1.12	2.90
IMPA (°)	0.60	4.19	1.28	2.58	1.48	1.43	–0.53	2.72
FMIA (°)	–0.95	3.31	–1.31	2.23	–1.56	1.33	1.02	3.11
L1-A Pog (mm)	0.27	1.08	0.67	0.67	0.64	0.71	0.38	0.83
Interincisal angle (°)	–6.23	5.64	–5.82	4.57	–4.28	4.05	–0.02	3.89

	10-11 y n = 16		*11-12 y n = 16*		*12-13 y n = 25*		*13-14 y n = 27*	
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Cranial base								
SN-FH (°)	0.31	0.55	0.01	0.52	0.11	0.48	0.09	0.49
S-N (mm)	0.77	0.62	0.54	0.81	0.65	0.50	0.29	0.51
Cranial flexure (°)	0.46	0.72	–0.10	0.86	0.08	0.96	0.25	1.13
Maxillary skeletal								
SNA (°)	–0.05	0.73	0.15	0.84	–0.16	0.79	0.07	0.86
Pt A to Na perp (mm)	0.22	0.75	0.09	0.72	–0.11	0.58	0.13	0.64
PP-FH (°)	0.79	1.12	0.35	1.16	–0.24	0.86	–0.26	0.90
Co-Pt A (mm)	1.40*	1.00	1.01	1.22	0.87	0.67	0.73	0.82
Mandibular skeletal								
SNB (°)	0.25	0.52	0.42	0.61	0.27	0.61	0.44	0.68

Table III. Continued

Cephalometric measures	10-11 y n = 16 Mean	10-11 y n = 16 SD	11-12 y n = 16 Mean	11-12 y n = 16 SD	12-13 y n = 25 Mean	12-13 y n = 25 SD	13-14 y n = 27 Mean	13-14 y n = 27 SD
Pog-Na perp (mm)	1.05	1.57	0.98	1.05	0.93	0.95	1.09	1.02
Facial angle (°)	0.59	0.82	0.50	0.56	0.51	0.52	0.61	0.57
Co-Gn (mm)	2.97	1.69	2.84	1.01	2.55	1.08	2.07	1.19
Ramus height (mm)	1.61	1.33	1.52	1.24	1.33	1.28	0.98	1.49
Gonial angle (°)	0.36	1.43	–0.45	1.19	–0.86	1.75	–0.28	1.26
Maxillary/mandibular								
FMA (°)	–0.35	0.99	–0.16	1.15	–0.40	0.60	–0.33	0.57
ANB (°)	–0.32	0.74	–0.28	0.81	–0.44	0.66	–0.38	0.55
Wits (mm)	–0.37	1.23	–0.30	1.05	–0.50	0.94	–0.45	1.10
Mx-md diff (mm)	1.61	1.05	1.83	1.50	1.65	1.01	1.38	0.89
Molar relation (mm)	0.91	1.14	0.99	0.86	0.46	1.03	0.19	0.73
Vertical								
Nasion to ANS (mm)	1.50	0.84	1.32	0.93	0.97	0.83	0.55	0.77
ANS to Me (mm)	0.95	0.91	1.54	1.33	1.15	0.76	0.88	0.84
UFH/LAFH ratio	1.25	1.54	0.33	2.59	–0.05	1.55	–0.51	1.55
AFH (mm)	2.67	1.55	3.04	1.73	2.30	1.22	1.64	1.34
PFH (mm)	1.92	0.97	2.31	1.14	1.74	0.88	1.27	0.92
PFH/AFH ratio	0.30	0.65	0.46	0.91	0.29	0.62	0.20	0.75
Vertical dentoalveolar								
U1-ANS (mm)	0.33	0.65	0.64	0.77	0.41	0.37	0.41	0.46
U6-PP (mm)	1.01	0.80	1.19	0.77	0.60	0.57	0.62	0.50
L1-Me (mm)	0.53	0.65	0.48	0.74	0.50	0.47	0.43	0.62
Sagittal dentoalveolar								
U1-Pt A (V) (mm)	0.20	0.54	0.09	0.52	0.34	0.45	0.35	0.43
U1-SN (°)	–0.27	2.15	0.21	1.54	0.83	1.63	0.92	1.47
IMPA (°)	–0.92	1.85	–0.82	1.97	–0.56	1.30	–0.32	1.85
FMIA (°)	1.26	2.13	0.97	2.07	0.95	1.42	0.64	1.76
L1-A Pog (mm)	–0.09	0.62	–0.05	0.65	0.20	0.49	0.22	0.52
Interincisal angle (°)	1.21	3.29	0.76	2.30	0.01	2.01	–0.35	2.23

Cephalometric measures	14-15 y n = 23 Mean	14-15 y n = 23 SD	15-16 y n = 18 Mean	15-16 y n = 18 SD
Cranial base				
SN-FH (°)	0.12	0.54	0.06	0.52
S-N (mm)	0.26	0.64	0.22	0.34
Cranial flexure (°)	–0.02	1.22	–0.01	0.92
Maxillary skeletal				
SNA (°)	0.18	0.84	0.19	0.78
Pt A to Na perp (mm)	0.28	0.48	0.26	0.40
PP-FH (°)	–0.58	1.04	–0.24	0.75
Co-Pt A (mm)	0.50	0.63	0.44	0.64
Mandibular skeletal				
SNB (°)	0.50	0.83	0.38	0.77
Pog-Na perp (mm)	1.25	1.00	0.93	0.94
Facial angle (°)	0.68	0.57	0.46	0.50
Co-Gn (mm)	1.66	0.93	1.45	1.05
Ramus height (mm)	0.84	1.15	1.22	1.45
Gonial angle (°)	–0.49	1.41	–0.89	1.55
Maxillary/mandibular				
FMA (°)	–0.67	0.91	–0.63	0.86
ANB (°)	–0.31	0.47	–0.17	0.47
Wits (mm)	–0.30	0.94	–0.35	0.77
Mx-md diff (mm)	1.18	0.83	0.96	0.84
Molar relation (mm)	0.29	0.64	0.19	0.65

Table III. Continued

	14-15 y n = 23		15-16 y n = 18	
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*
Vertical				
Nasion to ANS (mm)	0.18	0.73	0.06	0.60
ANS to Me (mm)	0.76	0.67	0.65	0.64
UFH/LAFH ratio	–0.76	1.54	–0.74	1.14
AFH (mm)	1.06	1.31	0.71	1.21
PFH (mm)	1.27	1.05	1.04	1.13
PFH/AFH ratio	0.53	1.03	0.51	1.25
Vertical dentoalveolar				
U1-ANS (mm)	0.31	0.48	0.25	0.41
U6-PP (mm)	0.48	0.50	0.31	0.71
L1-Me (mm)	0.35	0.73	0.15	0.51
Sagittal dentoalveolar				
U1-Pt A (V) (mm)	0.36	0.54	0.22	0.47
U1-SN (°)	1.02	1.50	0.25	2.22
IMPA (°)	–0.61	1.87	0.13	2.06
FMIA (°)	1.28	1.58	0.51	1.81
L1-A Pog (mm)	0.09	0.39	0.07	0.42
Interincisal angle (°)	0.17	2.25	0.22	2.64

*$P < 0.05$ (from following value).

The growth curves (Fig 1) showed growth peaks in mandibular length and lower anterior face height between 11 and 12 years of age and, in midfacial length, change between 10 and 11 years. The greatest average increment of growth for mandibular length, however, occurred before age 7.

In the male Class III subjects, a significant decrease in the mandibular length occurred between the age groups 14 to 15 and 15 to 16 years, as well as for all 3 examined variables between the age groups 5 to 6 and 6 to 7 years (Table IV). The growth curves showed peaks in all 3 linear cephalometric measurements between ages 10 and 14 years (Fig 2). The greatest average increment of change for midfacial and mandibular lengths occurred between 5 and 6 years of age. The largest increment of increase in lower anterior face height occurred between 12 and 13 years.

Growth spurts in lower anterior face height, midfacial length, and mandibular length began between 9 and 10 years of age for both sexes, but the male spurts lasted 2 years longer, extending to 14 years; growth peaks occur 1 to 2 years later in boys (Figs 3 and 4). A significant decrease in the growth of all 3 craniofacial components between the first and second age groups considered (6-7 years for boys; 7-8 years for girls with regard to the previous intervals) was evident.

The average growth increments were significantly different between the sexes in lower anterior face height at 12 to 13 and 13 to 14 years, and in midfacial length at 12 to 13 and 14 to 15 years (Table V). The average annual growth increments in mandibular length were significantly different ($P < 0.01$) between ages 13 and 15 years. All significant between-sex differences showed greater values for the male groups.

DISCUSSION

This investigation is to date the largest study on longitudinal cephalometric series of white subjects with untreated Class III malocclusions. The longitudinal records cover a wide age range and varying lengths of observation. The task of accumulating longitudinal records on this segment of the population was complicated by several factors: low prevalence of this malocclusion in white patients, the considerable tendency of the public and the dental profession to treat Class III malocclusion early in life, and the scarcity of longitudinal growth study records. These data are valuable in understanding further the etiologies contributing to this malocclusion, establishing control data from which to evaluate treatment effectiveness in clinical studies, and aiding the clinician in diagnostic treatment planning and communication with patients, parents, and other health care providers.

In our investigation, the craniofacial growth patterns of the subjects with Class III malocclusion were characterized separately from childhood to late adolescence. Several previous investigations on Class III malocclusion noted differences in the craniofacial structures between the sexes in their samples.[15,18,26]

Three fundamental cephalometric measurements (lower anterior face height, midfacial length, and

Table IV. Descriptive statistics for male age groups

	5-6 y n = 7		6-7 y n = 12		7-8 y n = 13	
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Cranial base						
SN-FH (°)	–0.70	0.29	–0.02	0.58	0.15	0.48
S-N (mm)	1.63	1.10	0.99	0.65	0.88	0.72
Cranial flexure (°)	1.24	1.97	0.33	1.56	0.77	1.56
Maxillary skeletal						
SNA (°)	0.36	1.79	–0.28	1.10	–0.50	1.25
Pt A to Na perp (mm)	–0.31	0.93	–0.27	0.79	–0.38	0.92
PP-FH (°)	–0.24	1.49	0.91	1.09	0.27	0.46
Co-Pt A (mm)	2.25*	1.82	1.30	0.97	1.10	0.78
Mandibular skeletal						
SNB (°)	1.15	1.54	–0.01	1.12	0.10	0.81
Pog-Na perp (mm)	0.70	1.03	0.51	1.43	0.59	1.15
Facial angle (°)	1.19	1.49	0.37	0.85	0.44	0.65
Co-Gn (mm)	4.09*	2.25	2.45	1.21	2.58	1.08
Ramus height (mm)	1.91	1.81	0.31	1.19	1.13	1.45
Gonial angle (°)	1.50	2.54	–0.95	2.13	–1.71	1.09
Maxillary/mandibular						
FMA (°)	0.11	0.96	0.04	0.90	–0.32	0.59
ANB (°)	–0.78	0.72	–0.27	0.89	–0.63	1.09
Wits (mm)	–0.20	1.17	–0.22	1.24	–0.34	1.06
Mx-md diff (mm)	1.83	1.34	1.25	1.57	1.63	1.31
Molar relation (mm)	0.88	0.82	–0.16	0.90	0.13	0.89
Vertical						
Nasion to ANS (mm)	1.79	0.83	1.84	0.97	1.66	0.81
ANS to Me (mm)	1.79*	1.62	0.54	0.93	0.64	0.79
UFH/LAFH ratio	0.53	2.11	2.19	2.94	1.87	1.92
AFH (mm)	4.01	2.17	2.63	1.36	2.51	1.26
PFH (mm)	2.74	1.73	1.23	0.86	1.61	1.45
PFH/AFH ratio	0.76	1.46	–0.33	0.78	0.06	0.91
Vertical dentoalveolar						
U1-ANS (mm)	0.36	1.21	0.32	0.92	0.43	0.65
U6-PP (mm)	0.36	1.17	0.26	1.23	0.65	0.83
L1-Me (mm)	1.35	1.56	1.20	1.15	0.69	0.94
Sagittal dentoalveolar						
U1 - Pt A (V) (mm)	0.17	0.57	0.84	1.17	1.44	0.95
U1-SN (°)	6.34	4.41	3.88	5.46	5.47	6.48
IMPA (°)	0.36	5.11	–0.14	4.45	1.12	2.59
FMIA (°)	0.63	3.97	0.07	4.23	–0.78	2.77
L1-A Pog (mm)	0.45	0.96	0.11	0.76	0.61	0.80
Interincisal angle (°)	–4.52	5.68	–3.74	6.51	–6.41	5.90

	8-9 y n = 12		9-10 y n = 14		10-11 y n = 10	
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Cranial base						
SN-FH (°)	–0.11	0.45	–0.12	0.69	0.09	0.36
S-N (mm)	0.86	0.84	1.18	1.13	1.03	0.86
Cranial flexure (°)	–0.48	1.56	0.54	1.27	0.26	0.77
Maxillary skeletal						
SNA (°)	–0.04	0.94	–0.44	0.92	–0.02	1.14
Pt A to Na perp (mm)	–0.16	0.64	–0.59	0.89	–0.08	1.26
PP-FH (°)	–0.44	0.64	–0.38	1.43	–0.41	0.63
Co-Pt A (mm)	0.95	0.61	1.05	0.81	1.24	0.59
Mandibular skeletal						
SNB (°)	0.76	0.88	0.10	0.91	0.30	1.22
Pog-Na perp (mm)	1.43	1.13	–0.05	1.40	0.72	1.75

Table IV. Continued

Cephalometric measures	8-9 y n = 12 Mean	8-9 y n = 12 SD	9-10 y n = 14 Mean	9-10 y n = 14 SD	10-11 y n = 10 Mean	10-11 y n = 10 SD
Facial angle (°)	0.86	0.66	0.03	0.78	0.48	0.94
Co-Gn (mm)	2.71	0.75	2.64	1.35	3.11	1.07
Ramus height (mm)	1.64	1.29	1.63	1.55	1.55	1.69
Gonial angle (°)	–0.63	2.13	–0.82	1.72	–0.75	0.91
Maxillary/mandibular						
FMA (°)	–0.46	0.89	–0.42	1.12	–0.15	1.24
ANB (°)	–0.77	0.75	–0.54	0.58	–0.33	0.95
Wits (mm)	–0.22	1.58	–0.36	0.76	–0.65	0.97
Mx-md diff (mm)	1.81	0.83	1.53	1.30	1.89	0.92
Molar relation (mm)	0.08	0.77	0.10	0.71	0.68	0.94
Vertical						
Nasion to ANS (mm)	1.22	0.64	1.28	1.00	1.25	0.93
ANS to Me (mm)	0.98	0.69	1.45	1.20	1.56	1.32
UFH/LAFH ratio	0.59	1.58	0.10	2.68	–0.60	1.93
AFH (mm)	2.65	1.05	2.82	1.75	3.05	1.98
PFH (mm)	2.28	1.24	2.61	1.38	1.96	1.66
PFH/AFH ratio	0.63	0.88	0.88	1.15	0.17	1.26
Vertical dentoalveolar						
U1-ANS (mm)	0.24	0.80	0.83	0.83	0.65	0.74
U6-PP (mm)	0.86	0.81	0.73	0.77	0.60	0.60
L1-Me (mm)	0.88	0.78	0.89	0.59	0.90	0.69
Sagittal dentoalveolar						
U1-Pt A (V) (mm)	1.44	0.82	0.73	0.78	0.36	0.56
U1-SN (°)	4.58	3.38	1.46	2.00	0.58	1.45
IMPA (°)	–1.10	2.40	0.97	2.42	0.19	1.37
FMIA (°)	1.57	2.18	–0.57	2.62	–0.02	2.26
L1-A Pog (mm)	0.44	0.66	0.48	0.74	0.57	0.52
Interincisal angle (°)	–2.88	4.14	–1.92	2.82	–0.69	2.70

Cephalometric measures	11-12 y n = 7 Mean	11-12 y n = 7 SD	12-13 yr n = 7 Mean	12-13 yr n = 7 SD	13-14 y n = 12 Mean	13-14 y n = 12 SD
Cranial base						
SN-FH (°)	–0.20	0.51	0.01	0.68	0.00	0.74
S-N (mm)	0.58	0.68	1.06	0.66	1.13	0.87
Cranial flexure (°)	0.27	1.44	0.74	1.43	–0.02	1.36
Maxillary skeletal						
SNA (°)	0.01	0.72	0.22	0.49	–0.15	1.18
Pt A to Na perp (mm)	–0.29	0.71	0.26	0.81	–0.12	1.02
PP-FH (°)	–0.03	0.93	–0.70	1.14	0.02	1.19
Co-Pt A (mm)	1.46	1.24	1.49	0.43	1.38	1.18
Mandibular skeletal						
SNB (°)	0.56	1.18	0.41	0.59	0.36	0.81
Pog-Na perp (mm)	0.71	1.87	1.17	1.66	1.00	1.48
Facial angle (°)	0.49	0.91	0.59	0.80	0.50	0.76
Co-Gn (mm)	3.31	1.90	3.59	2.22	3.69	1.45
Ramus height (mm)	2.03	1.59	1.43	2.83	2.24	2.67
Gonial angle (°)	1.11	1.32	–0.32	2.08	–1.08	2.11
Maxillary/mandibular						
FMA (°)	0.09	1.19	–0.18	0.93	–0.55	1.03
ANB (°)	–0.54	0.60	–0.22	0.86	–0.49	0.78
Wits (mm)	–1.03	0.83	–0.13	1.57	–0.22	1.72
Mx-md diff (mm)	1.92	1.28	2.07	2.13	2.28	1.48
Molar relation (mm)	0.91	1.21	0.63	0.80	0.53	0.84
Vertical						
Nasion to ANS (mm)	1.41	0.98	1.53	1.02	1.50	1.11

Table IV. Continued

Cephalometric measures	*11-12 y n = 7* Mean	*11-12 y n = 7* SD	*12-13 yr n = 7* Mean	*12-13 yr n = 7* SD	*13-14 y n = 12* Mean	*13-14 y n = 12* SD
ANS to Me (mm)	1.28	1.36	1.89	1.03	1.63	1.12
UFH/LAFH ratio	0.32	2.09	0.28	2.44	–0.15	2.35
AFH (mm)	2.76	2.12	3.83	1.72	3.50	2.09
PFH (mm)	2.16	1.35	3.01	1.37	2.89	1.91
PFH/AFH ratio	0.46	1.33	0.61	1.00	0.65	1.47
Vertical dentoalveolar						
U1-ANS (mm)	0.80	0.66	0.73	0.63	0.63	0.79
U6-PP (mm)	0.79	0.82	0.62	0.63	1.06	0.50
L1 -Me (mm)	0.26	0.78	1.02	0.54	1.10	0.87
Sagittal dentoalveolar						
U1-Pt A (V) (mm)	0.30	0.29	0.56	0.60	0.27	0.56
U1-SN (°)	–0.45	1.84	1.12	3.04	0.03	2.07
IMPA (°)	–1.13	1.45	0.60	1.66	0.36	1.55
FMIA (°)	1.00	2.39	–0.41	1.29	0.22	1.23
L1-A Pog (mm)	0.19	0.57	0.21	0.68	0.18	0.60
Interincisal angle (°)	1.61	1.97	–1.48	3.22	0.21	2.40

Cephalometric measures	*14-15 y n = 14* Mean	*14-15 y n = 14* SD	*15-16 y n = 11* Mean	*15-16 y n = 11* SD	*16-17 y n = 11* Mean	*16-17 y n = 11* SD	*17-18 y n = 8* Mean	*17-18 y n = 8* SD
Cranial base								
SN-FH (°)	–0.03	0.48	–0.05	0.50	0.21	0.41	0.10	0.47
S-N (mm)	1.04	0.69	0.54	0.55	0.44	0.61	0.26	0.49
Cranial flexure (°)	0.07	0.74	–0.02	1.13	0.16	0.70	0.55	0.77
Maxillary skeletal								
SNA (°)	–0.15	0.96	0.04	0.53	0.01	0.47	–0.04	0.37
Pt A to Na perp (mm)	–0.21	0.96	0.00	0.56	0.21	0.43	0.02	0.47
PP-FH (°)	0.12	1.56	0.14	0.87	–0.05	0.72	0.12	0.80
Co-Pt A (mm)	1.01	0.89	0.88	0.76	0.80	0.62	0.32	0.98
Mandibular skeletal								
SNB (°)	0.60	0.68	0.50	0.50	0.38	0.39	0.70	1.14
Pog-Na perp (mm)	1.43	1.51	1.03	1.31	1.20	0.89	1.47	1.97
Facial angle (°)	0.75	0.78	0.55	0.65	0.61	0.48	0.74	1.00
Co-Gn (mm)	3.33*	1.61	2.00	0.89	1.70	0.89	1.62	0.86
Ramus height (mm)	1.78	1.70	1.70	1.59	1.12	1.35	0.92	1.60
Gonial angle (°)	–0.59	1.94	–0.56	1.45	0.05	1.97	1.84	1.05
Maxillary/mandibular								
FMA (°)	–0.62	1.02	–0.53	1.07	–0.67	1.23	–0.13	0.74
ANB (°)	–0.74	0.68	–0.46	0.42	–0.36	0.33	–0.72	1.11
Wits (mm)	–0.81	1.70	–0.27	1.28	–0.87	0.74	–1.25	1.62
Mx-md diff (mm)	2.32	1.50	1.11	0.89	0.91	0.94	1.28	1.47
Molar relation (mm)	0.52	1.35	0.21	0.73	0.22	0.54	0.85	1.26
Vertical								
Nasion to ANS (mm)	1.01	0.93	0.56	0.79	0.29	0.75	0.39	0.40
ANS to Me (mm)	1.29	1.47	0.84	1.04	0.74	1.03	0.21	0.68
UFH/LAFH ratio	–0.33	2.81	–0.37	1.54	–0.44	2.16	0.43	0.98
AFH (mm)	2.66	1.72	1.80	1.49	1.17	0.96	0.84	0.44
PFH (mm)	2.34	1.30	1.84	1.03	1.30	1.31	0.56	0.93
PFH/AFH ratio	0.60	1.04	0.65	1.24	0.47	1.18	–0.05	0.66
Vertical dentoalveolar								
U1-ANS (mm)	0.30	0.75	0.19	0.58	0.44	0.46	0.15	0.53
U6-PP (mm)	0.59	1.03	0.50	0.86	0.39	0.55	0.16	0.61
L1-Me (mm)	1.16	0.62	0.98	0.57	0.39	0.47	0.38	0.41
Sagittal dentoalveolar								
U1-Pt A (V) (mm)	0.41	0.46	0.51	0.60	0.20	0.59	0.08	0.78

Table IV. Continued

	14-15 y n = 14		15-16 y n = 11		16-17 y n = 11		17-18 y n = 8	
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
U1-SN (°)	1.06	2.01	0.64	1.81	0.43	1.86	–0.17	0.98
IMPA (°)	0.10	2.18	–0.06	1.15	0.66	2.07	–1.04	1.93
FMIA (°)	0.50	2.31	0.58	1.46	0.03	1.72	1.15	2.29
L1-A Pog (mm)	0.48	0.54	0.41	0.49	0.24	0.47	0.22	0.57
Interincisal angle (°)	–0.53	2.32	–0.01	1.92	–0.62	1.86	1.24	2.80

*$P < 0.05$ (from following value).

Table V. Sex comparisons for average growth increments

Age group (y)	*Sex*	*n*	*LAFH*	t *test*	*Midfacial length*	t *test*	*Mandibular length*	t *test*
6-7	Female	10	1.03	NS	1.31	NS	3.22	NS
	Male	12	0.54		1.30		2.45	
7-8	Female	13	1.01	NS	0.94	NS	2.35	NS
	Male	13	0.64		1.10		2.58	
8-9	Female	12	1.25	NS	0.94	NS	2.45	NS
	Male	12	0.98		0.95		2.71	
9-10	Female	12	1.02	NS	1.05	NS	2.89	NS
	Male	14	1.45		1.05		2.64	
10-11	Female	16	0.95	NS	1.40	NS	2.97	NS
	Male	10	1.56		1.24		3.11	
11-12	Female	16	1.54	NS	1.01	NS	2.84	NS
	Male	10	1.28		1.46		3.31	
12-13	Female	25	1.15	*	0.87	*	2.55	NS
	Male	10	1.89		1.49		3.59	
13-14	Female	27	0.88	*	0.73	NS	2.07	†
	Male	12	1.63		1.38		3.69	
14-15	Female	23	0.76	NS	0.50	*	1.66	†
	Male	14	1.29		1.01		3.33	
15-16	Female	18	0.65	NS	0.44	NS	1.45	NS
	Male	11	0.84		0.88		2.00	

*$P < 0.05$; †$P < 0.01$; *LAFH,* lower anterior facial height; *NS,* not significant.

mandibular length) were used to construct average incremental growth curves. The age-related increments in these measurements were examined with inferential statistics to identify whether significant growth events became apparent as each sex aged. The growth changes observed in other cephalometric measurements will be characterized, for the most part, as trends instead of quantitative terms.

The anterior cranial base increased in length as all subjects aged. The annualized average increment of growth for the linear measurement sella-nasion was slightly less than 1 mm for the female sample and approximately 1 mm for the male sample. The size of this growth increment was similar to estimated annual growth increments for Class I subjects.[38-40] The angular measurements, cranial base flexure, and sella-nasion to Frankfort horizontal remained relatively constant as each sex aged.

The position of the maxilla relative to the cranial base, measured by the SNA angle, remained constant in both sexes at all ages, a similar finding for normal or Class I occlusion subjects.[39,40] The average incremental growth changes for the linear measurement of Point A to nasion perpendicular differed between the sexes. The position of Point A relative to nasion perpendicular was relatively constant in girls but became progressively more retrusive in boys, compared with subjects with normal occlusion.[2]

The midfacial length of all subjects increased as they aged. The average annual increments in midfacial length increase were approximately 1 mm for the females and 1.5 mm for the males. The maximum average increase in midfacial length during the adolescent growth spurt for both sexes approximated 1.5 mm. This amount is slightly less than the estimated annual increase in midfacial length of 2 mm for normal occlusion subjects,[34] yet it agrees with results of several smaller longitudinal studies of untreated Class III white subjects.[12,27-31]

The overall shapes of the midfacial-length growth curves plotted relative to age were similar between the sexes. Both had their greatest average increments of growth in early childhood and slight adolescent growth peaks; similar behavior in linear measurements of midfacial growth was inferred for groups with normal occlusion.[38] In both sexes with Class III malocclusion, the growth spurt in midfacial length occurred rather early (about 10 years of age in girls and 12 years of age in boys), during prepubertal ages as assessed by the CVM analysis. This finding agrees with previous indications that point to prepubertal stages of craniofacial development as the optimal time for orthopedic intervention on the maxillary structures.[37] A comparison of the midfacial growth curves from this longitudinal study with data from a cross-sectional study by Reyes et al[26] shows that the cross-sectional data estimated slightly greater midfacial growth changes across most ages, and

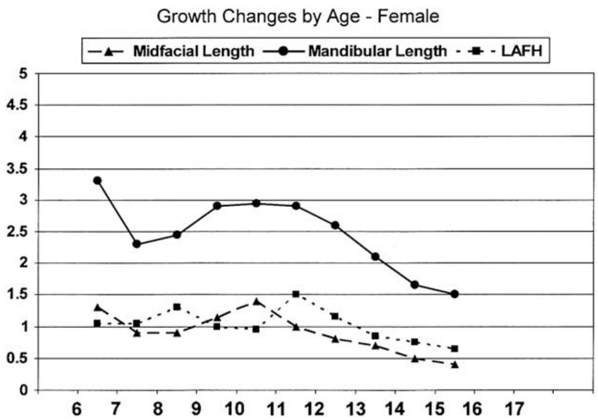

Fig 1. Growth changes (mm) with age (y) in female Class III subjects .

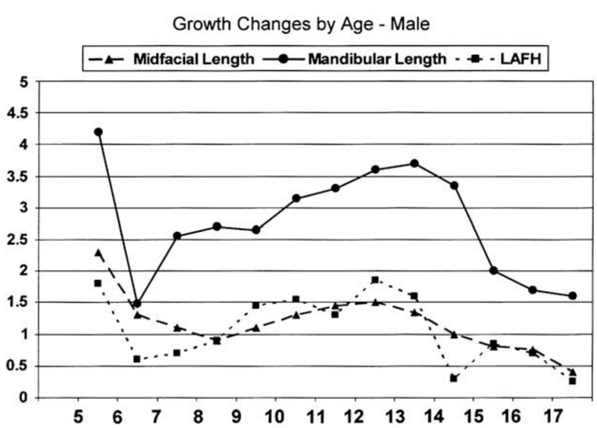

Fig 2. Growth changes (mm) with age (y) in male Class III subjects.

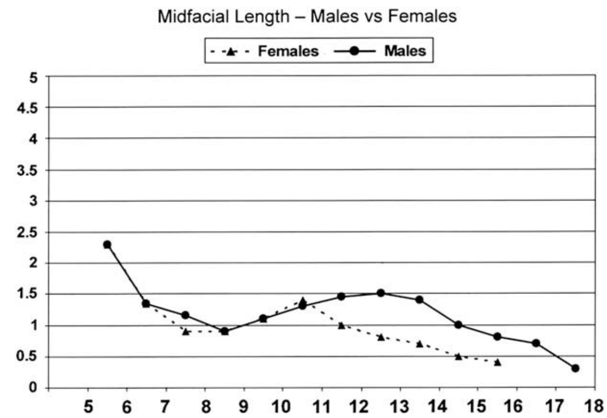

Fig 3. Differences between growth trends in midfacial length (mm) in male and female Class III subjects.

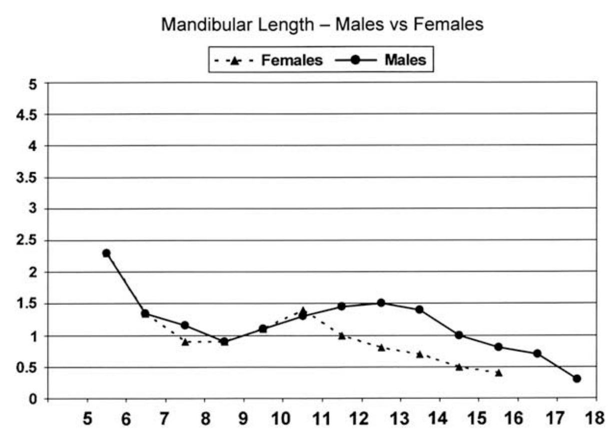

Fig 4. Differences between growth trends in mandibular length (mm) in male and female Class III subjects.

particularly in the 13 to 14 and 15 to 16 year age groups. The total amount of change for midfacial length in the age intervals examined, however, was similar when grouping the sexes together (Table VI). When the results of our large-scale longitudinal study are contrasted with those of the smaller longitudinal investigation by Baccetti et al[31] that analyzed 22 untreated Class III subjects between 8 and 16 years of age, similar findings also can be seen (Table VI).

The position of the mandible relative to the cranial base as measured by the distance of pogonion to nasion perpendicular, the facial angle, and the SNB angle increased in both sexes as the subjects matured from childhood to late adolescence. The advancement of the chin relative to the cranial base and the straightening of the skeletal profile have been well documented as part of normal craniofacial growth regardless of the Angle classification.[7,29,41,42]

The cephalometric measurement of pogonion to nasion perpendicular increased approximately 1 mm per year in the female sample and slightly over 1 mm per year in the male sample. The proposed increase in this measurement based on normal or Class I occlusion subjects is 0.5 mm per year.[2]

The average annual increment of growth in mandibular length was approximately 3 mm for the female sample and slightly greater than 3 mm for the male sample. This approximation over 10 age groups trivializes the pattern of growth, but it agrees with the estimated increments of growth from untreated white Class III groups reported in previous studies.[12,27-31] Total accumulated mandibular lengthening values in the Class III samples we examined between 8 and 16 years of age were approximately 18 mm for the girls and 21.5 mm for the boys; these closely agree with previous longitudinal[31] and cross-sectional[25] data on male and

Table VI. Average growth increments for midfacial length, mandibular length, and lower anterior facial height in studies conducted in untreated white subjects with Class III malocclusion (increments are relative to the age interval between 8 and 17 years)

Cephalometric measurement	*Present study Females (n = 55) Longitudinal*	*Present study Males (n = 48) Longitudinal*	*Baccetti et al[31] (n = 22) Longitudinal*	*Reyes et al[26] (n = 949) Cross-sectional*
Co-A (mm)	6.9	9.4	7.6	8.3
Co-Gn (mm)	18.1	21.3	19.3	20.3
ANS-Me (mm)	8.3	10.8	9.7	10.9

female subjects pooled (about 19.5 and 20.3 mm, respectively; Table VI). The greatest average annual increments of mandibular length during the adolescent growth spurt were 3.0 and 3.7 mm for the female and male samples, respectively. A relative comparison can be made to the estimated maximum 3-mm increase in mandibular length of subjects with normal occlusions.[34] The amount of annual increase in mandibular length in Class III boys is consistently over 3 mm from age 12 to 15 years, thus confirming previous observations by Reyes et al,[26] who described an extended duration of the mandibular growth spurt in boys with Class III malocclusions.

As seen in Figure 4, the shape of the incremental growth curves for mandibular length plotted against chronologic age was similar between the sexes. The shape of the plot showed intense mandibular growth in early childhood and a prominent adolescent growth peak. The curves agree with the described behavior of mandibular length incremental growth curves plotted from subjects with normal occlusion.[38]

A comparison between the male and female samples showed significant differences in the mandibular-length growth curves at ages 13 to 14 and 14 to 15 years. Similarly to the midfacial length incremental growth curves, the male sample achieved the adolescent growth spurt maximums approximately 2 years later than did the female sample. As described above, the duration of the peak in mandibular growth appears to last from 13 to 15 years of age in the boys, with annual increments larger than 3.4 mm each during this peak period. A significant difference ($P < 0.001$) in the average annualized growth increment of mandibular length (Co-Gn) between the male and female samples at the peak of the adolescent growth spurts is shown in Figure 4.

The amount of residual mandibular growth after the pubertal growth spurt should be emphasized in Class III subjects. During the postpubertal ages (as assessed by CVM analysis in this study), after age 13 years in girls and 15 years in boys, and until age 17 years in both groups, annual increments in mandibular length are between 2 and 1.5 mm, whereas increments in midfacial length have dropped well under 1 mm. The differential behavior in postpubertal growth of the 2 jaws might be challenging factors of continued mandibular growth and potential relapse after orthopedic treatment of Class III disharmonies before or at puberty. The findings of studies that incorporated postpubertal observations after therapy of Class III malocclusion in growing patients confirm the risk of a possible rebound of therapeutic outcomes after active treatment.[29,30]

The average incremental changes in ANB angle, Wits appraisal, and molar relationship all indicate worsening of the Class III relationship with increasing skeletal maturity as the mandible outgrows the maxilla. Differential growth of the jaws is an expression of normal craniofacial growth.[38,40,41] Other investigations of subjects with Class III malocclusions also noted decreases in the ANB angle and Wits appraisal with age.[14-19] The Wits appraisal is expected to decrease by 1 mm as subjects with normal occlusions advance from childhood to late adolescence.[36] A simple cumulative estimate of all negative average incremental changes from our Class III sample resulted in much greater decreases in the Wits appraisal (> -4 mm in females and > -5 mm in males) than expected for Class I subjects.

The mandibular plane angle decreased in both groups as the subjects aged. This phenomenon was well documented in several longitudinal studies of subjects with normal occlusion.[38-40] The average incremental growth curves for lower anterior face height, illustrated in Figures 1 and 2, show peak growth increments that correspond to the adolescent growth spurts seen in midfacial and mandibular lengths as analyzed by either age or CVM stage. The average annual increments of growth in lower anterior face height for the female and male samples were approximately 1 and 1.5 mm, respectively. Lower anterior face height is estimated to increase not more than 1 mm per year in subjects with normal occlusion.[34]

The growth pattern for lower anterior face height showed differences in the timing of the adolescent growth spurts between the sexes similar to those already described in the growth curves for midfacial and mandibular lengths. There were significant differences between the female and male average increments of growth in lower anterior face height between the ages of 12 to 14 years. The girls experienced their greatest average increment of growth between 11 and 12 years of age, and the boys had their peak 1 year later.

Dentoalveolar measures

The permanent maxillary incisor tended to increase in both proclination (U1-SN) and protrusion relative to the maxillary base (U1 to Pt A Vert) in both sexes as the subjects aged. The maxillary permanent incisor tended to procline at a relatively constant rate of 1° per year and advance 0.3 mm per year toward the Point A vertical line. The position of the maxillary incisor is relatively constant in subjects with normal occlusions.[2]

The mandibular permanent incisors became more upright with time relative to the lower border of the mandible and the Frankfort horizontal in both sexes. The mandibular incisor behaved differently between the sexes. The angular measurement IMPA in the female sample had greater negative changes than in the males.

The interincisal angle of the total sample tended to decrease slightly as the subjects progressed toward skeletal maturity. This relationship reflected the increasing proclination of the maxillary incisor and the slight retroclination of the mandibular incisor as the subjects aged. The interincisal angle is relatively constant in those with normal occlusions.[39] All dentoalveolar measurements support the concept of the "dentoalveolar compensatory mechanism," which states that the dentition moves to compensate for underlying skeletal imbalance.[42] Despite this compensation, overjet decreased progressively in both sexes with advancing age.

CONCLUSIONS

The purpose of this investigation was to characterize cephalometrically craniofacial growth changes in white subjects of European or North American ancestry with untreated Class III malocclusions by using semilongitudinal cephalometric records. The final sample size comprised 103 subjects and is the largest study of longitudinal cephalometric series derived from a white population.

Incremental growth changes from early childhood to late adolescence were examined for each sex. The growth data we gathered expand the knowledge of growth in Class III malocclusion with regard to previous smaller longitudinal samples. They also follow the established pattern of normal craniofacial growth more adequately than in cross-sectional studies.

The growth pattern of 3 fundamental cephalometric measurements (lower anterior face height, midfacial length, and mandibular length) exhibited differences between the male and female subjects in both the timing and the size of average growth increments in the adolescent growth spurt. The girls had their adolescent spurt in mandibular growth between 10 and 12 years. The boys had their adolescent mandibular growth spurt between 12 and 15 years. Statistically significant changes in the average increments of growth of these linear measurements occurred between all subjects from 12 to 15 years. Adolescent peaks in midfacial growth were at prepubertal ages in both sexes.

The approximated average increments of growth for the Class III girls from ages 6 to 16 years were 1 mm in lower anterior face height, 1 mm in midfacial length, and 3 mm in mandibular length. The approximated average increments of growth for the Class III boys in the same time interval were 0.5 mm greater than for the girls at every measurement from 6 to 16 years. Male subjects showed more than 3 mm of mandibular growth at 3 consecutive age intervals starting from 15 years.

The average increments of change in several mandibular skeletal and intermaxillary cephalometric measurements indicated definite worsening of the relative mandibular prognathism and sagittal skeletal discrepancy between the jaws with growth. During childhood (5-7 years), much craniofacial growth occurred. Moreover, much mandibular growth relative to the maxilla still occurred in Class III subjects after the adolescent growth spurt. The dentoalveolar measurements demonstrated dental incremental movements consistent to compensate for the worsening skeletal discrepancy that accompanied differential growth of the jaws.

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