ORIGINAL ARTICLE

Longitudinal growth changes in untreated subjects with Class II Division 1 malocclusion

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Introduction: The purpose of this longitudinal study was to compare the craniofacial growth changes in untreated subjects with Class II Division 1 malocclusion with those in subjects with normal (Class I) occlusion from the prepubertal through the postpubertal stages of development, as defined by a biological indicator of individual skeletal maturity (cervical vertebral maturation method). **Methods:** The Class II Division 1 sample consisted of 17 subjects (11 boys, 6 girls). The Class I sample also consisted of 17 subjects (13 boys, 4 girls). The lateral cephalograms of the subjects in both groups were analyzed at 6 consecutive stages of development, from CS1 through CS6. The statistical comparisons of the growth changes in the study groups were performed with Mann-Whitney U tests. **Results:** Craniofacial growth in subjects with untreated Class II malocclusion is essentially similar to that in untreated subjects with normal occlusion at all developmental intervals, with the exception of significantly smaller increases in mandibular length ($P < 0.001$) at the growth spurt (interval CS3-CS4) and during the overall observation period (intervals CS1-CS6). **Conclusions:** Class II dentoskeletal disharmony does not tend to self-correct with growth in association with worsening of the deficiency in total mandibular length and mandibular ramus height. (Am J Orthod Dentofacial Orthop 2008; 134:125-37)

Angle, in his classification of malocclusions, assumed that the position of the first permanent molars is constant relative to the jaws, and, furthermore, that the manner of occlusal locking of these teeth is linked to the relative sagittal position of the maxilla and the mandible.[1,2] Since then, the theory that various malocclusions are associated with distinctive craniofacial patterns has been studied extensively, with special emphasis on the craniofacial characteristics in growing subjects with Class II malocclusions.[3-20] The abundance of literature on Class II craniofacial features is a consequence of the fact that many patients with this malocclusion are treated routinely with orthodontics.[21] The issue of growth in Class II subjects has become more relevant because of the increasing interest in optimizing treatment timing and planning in dentofacial orthopedics.

Two study designs were used to compare craniofacial growth changes between Class II subjects and subjects with normal occlusion. Cross-sectional studies investigated the data of large craniofacial databases to infer conclusions for longitudinal changes in subjects with Class I and Class II malocclusions.[4,5,20] Following the same subjects over time, of course, is a more appropriate approach.[6-11,14,16]

In a literature review of longitudinal studies, we found the following cephalometric characteristics in subjects with Class II malocclusion vs Class I controls. (1) No differences in the configuration of the cranial base before the age of 7 years were found.[9,14] In studies where longitudinal changes were followed over a longer time (up to age 16 years), however, greater cranial base flexure[5,6] and shorter lower cranial height were observed in the Class II subjects.[5] (2) No significant differences were reported for the skeletal[5,14] and dentoalveolar positions[14] of the maxilla in the Class II study samples, except for Baccetti et al,[9] who described significant increases in maxillary protrusion during the transition from the deciduous to the early mixed dentitions. (3) Significantly shorter mandibles were present in subjects with Class II malocclusion at both infantile and adolescent ages.[7,9,11,14] In contrast, Bishara et al[10] and Bishara[12] found no differences in mandibular growth in Class II subjects from the deciduous dentition through the permanent dentition. (4) A

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retruded position of the mandible was described in growing patients with Class II malocclusion.[5,7,9,14] (5) The differences in craniofacial measures were found to be established early in life, and the growth trends in Class II and Class I subjects appeared to be essentially similar thereafter.[8-10,12]

The review of the literature, therefore, showed no consensus, especially with regard to the growth changes of the mandible in untreated subjects with Class II malocclusion when compared with subjects with normal occlusion. However, the results in most of these studies were based on longitudinal growth changes related to the subjects' chronologic ages or the dentition stages. The analysis of modifications in growth benefits greatly from considering the individual skeletal maturity of the subjects.[22] Neither chronologic age nor dentition stage is a reliable indicator of skeletal maturation.[23-27]

The aim of this study was to compare longitudinal craniofacial growth changes in untreated subjects with Class II malocclusion with those in subjects with normal occlusion from the prepubertal through the postpubertal stages of development, as defined by a biologic indicator of individual skeletal maturity (cervical vertebral maturation method).[28]

MATERIAL AND METHODS

The files of the University of Michigan Growth Study (UMGS, n = 706) and the Denver Growth Study (DGS, n = 155) were searched for longitudinal records of orthodontically untreated subjects with either Class II or Class I malocclusion. Lateral cephalograms of good quality at 6 consecutive developmental intervals (T1 through T6) corresponding to the 6 stages in cervical vertebral maturation (CS1-CS6) had to be available for all subjects.[28] The first 2 stages (CS1 and CS2) occur before the pubertal growth peak. The peak in skeletal growth is between CS3 and CS4. Deceleration in craniofacial growth occurs during the postpubertal intervals, from CS4 through CS6. Longitudinal records for all subjects, therefore, covered the entire circumpubertal period from the prepubertal through the postpubertal stages of skeletal development. All subjects were white and had no craniofacial abnormalities or tooth anomalies in number or eruption (supernumeraries, congenitally missing teeth, impacted canines).

Subjects with Class II Division 1 malocclusion were diagnosed according to the following signs at T1: full-cusp or half-cusp Class II molar relationship, excessive overjet (>4 mm) and ANB angle greater than 3°. After the eruption of the permanent dentition, all subjects with a half-cusp Class II molar relationship developed a full-cusp Class II molar relationship. Sub-

Table I. Descriptive statistics for age (y) at the 6 consecutive cervical vertebral maturation stages

	Class II subjects (n = 17)		Class I subjects (n = 17)	
	Mean	*SD*	*Mean*	*SD*
CS1	10.2	1.3	10.1	1.2
CS2	11.1	1.4	11.1	1.2
CS3	12.1	1.3	12.2	1.2
CS4	13.2	1.4	13.3	1.3
CS5	14.3	1.4	14.5	1.5
CS6	15.4	1.5	15.7	1.6

jects with Class I occlusion were selected according to the Class I molar relationship at T1, with normal overjet (2-4 mm) and ANB angle between 0° and 3°. All subjects in both groups had normal vertical relationships at T1 (Frankfort horizontal to mandibular plane, 23.6° ± 5.1° and 23.4° ± 4.0° in the Class II and Class I samples, respectively).

The Class II Division 1 sample consisted of 17 subjects (11 boys, 6 girls). The Class I sample also included 17 subjects (13 boys, 4 girls). Their mean ages at the 6 stages of cervical vertebral maturation are reported in Table I.

Cephalograms were traced by 1 investigator (F.S.) and verified for landmark location, anatomical contours, and tracing superimpositions by another (J.A.Mc.). Any disagreements were resolved by retracing the landmark or structure to the satisfaction of both observers. A customized digitization regimen and analysis from Dentofacial Planner (Dentofacial Software, Toronto, Ontario, Canada) was used for all cephalograms examined in this study. The cephalometric analysis required the digitization of 77 landmarks and 4 fiducial markers. The customized cephalometric analysis—containing measurements from the analyses of Steiner,[29] Jacobson,[30] Ricketts,[31] and McNamara[32]—generated 33 variables (11 angular, 22 linear) for each tracing.

All sets of cephalograms were traced at the same time. A preliminary tracing was made for each film in the series, with particular attention paid to tracing the outlines of the maxilla and the mandible, including the mandibular condyle. Then each set of consecutive films was checked thoroughly, beginning with the second and third films in the series. Fiducial markers were placed in the maxilla and the mandible on the third tracing and then transferred to the second tracings in each subject's cephalometric series, based on superimposition of internal maxillary or mandibular structures. The locations of the fiducial markers then were trans-

ferred to the first and then the fourth through the sixth films similarly.

The maxillae were superimposed along the palatal plane by registering on the bony internal details superior to the incisors, and the superior and inferior surfaces of the hard palate. Fiducial markers were placed in the anterior and posterior parts of the maxilla along the palatal plane. This superimposition describes the movement of the maxillary dentition.

The mandibles were superimposed posteriorly on the outline of the mandibular canal. Anteriorly, they were superimposed on the anterior contour of the chin and the bony structures of the symphysis.[31,32] A fiducial marker was placed in the center of the symphysis and another in the body of the mandible near the gonial angle. This superimposition facilitated measuring the movement of the mandibular dentition.

The magnifications of the 2 data sets were different, with the lateral cephalograms from the UMGS at 12.9% and those from the DGS at 4%. Therefore, the lateral cephalograms from the 2 studies were corrected to an 8% enlargement factor.

A total of 42 lateral cephalograms randomly chosen from all observations were retraced and redigitized to calculate the method error with Dahlberg's formula.[33] The error for linear measurements ranged from 0.2 (overjet) to 0.8 mm (pogonion to nasion perpendicular); the error for the angular measurements varied from 0.4° (ANB angle) to 1.6° (interincisal angle).

The stages in cervical vertebral maturation on the lateral cephalograms for each subject were assessed by 1 investigator (T.B.) and verified by another (L.F.).[28] Any disagreements were resolved to the satisfaction of both observers.

Statistical analysis

Descriptive statistics of craniofacial measurements in both Class II and Class I samples at T1 through T6 were calculated, as well as the between-stage changes. The Kolmogorov-Smirnov test showed lack of normal distribution for several measurements. Therefore, nonparametric statistics with Mann-Whitney U tests were used. The following comparisons were made: (1) starting forms between Class II and Class I samples at T1, (2) final forms between Class II and Class I samples at T6, (3) between-stage changes (T2-T1, T3-T2, T4-T3, T5-T4, T6-T5) in Class II vs Class I samples, and (4) overall changes (T6-T1) between the Class II and Class I samples.

RESULTS

Descriptive statistics for the cephalometric measurements in the Class II and Class I subjects at T1 and T6 are given in Tables II and III. Results of the statistical comparison between the Class II and Class I subjects of the changes in all cephalometric variables at the growth intervals, as well as the statistical comparisons of the overall changes are shown in Tables IV through IX.

In the comparison of the T1 forms between the Class II and Class I samples (Table II), the measurement of cranial base flexure was significantly greater in subjects with Class II malocclusion at the beginning of the observation period. There were no statistically significant differences between the 2 groups with regard to maxillary skeletal and dentoalveolar measures. No significant differences were found for mandibular dimensions. The mandible was significantly retruded in the Class II subjects when related to the anterior cranial base. This difference was also reflected by the significantly greater intermaxillary sagittal discrepancy (Wits appraisal, maxillomandibular differential, and ANB angle) in the Class II sample. No significant differences were found for vertical skeletal relationships. As expected on the basis of the inclusion criteria, overjet was significantly greater and the molar relationship was significantly smaller in the Class II subjects. The mandibular incisors were significantly retruded in the Class II sample when compared with the Class I sample.

In the comparison of T6 forms between the Class II and Class I samples (Table III), no significant difference was found between the flexure of the cranial base in the Class II and Class I samples at the end of the observation period. All differences that were statistically significant at T1 were so at T6 with 2 significant differences: total mandibular length (Co-Gn) was significantly shorter at the end of the observation period in the Class II sample than in the Class I sample; the maxillary incisors were more protruded in the Class II sample at T6.

In the comparison of between-stage changes (T2-T1, T3-T2, T4-T3, T5-T4, T6-T5) in the Class II vs Class I samples (Tables IV-VIII), no significant differences were found for the changes between T1 and T2. In the transition from T2 to T3, a significant difference in the maxillomandibular differential was found in the Class II group. A significantly smaller decrease in the gonial angle (ArGoMe) was observed in the Class II subjects than in the Class I subjects (+1.2°). Between T3 and T4, corresponding to the pubertal growth spurt, a significantly smaller increase in total mandibular length (Co-Gn) became apparent in the Class II group (−2.0 mm).[28] A significant buccal inclination of the mandibular incisors to the mandibular plane was also found in the Class II group (+1.4°). No significant

Table II. Descriptive statistics and statistical comparisons for cephalometric measurements in Class II and Class I subjects at T1 (CS1)

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	SD	Mean	SD		
Cranial base						
NSBa (°)	133.3	3.6	129.9	4.1	+3.4	*
Maxillary skeletal						
Co-Pt A (mm)	84.8	5.3	85.4	4.4	−0.6	NS
SNA (°)	79.5	2.8	80.3	2.2	−0.8	NS
Pt A to nasion perp (mm)	−0.9	2.9	−1.2	2.2	+0.3	NS
Mandibular skeletal						
Co-Gn (mm)	106.3	6.5	109.0	6.5	−2.7	NS
Co-Go (mm)	52.5	5.0	53.4	3.9	−0.9	NS
SNB (°)	74.7	2.2	78.1	2.8	−3.4	†
Pg to nasion perp (mm)	−9.2	5.1	−6.0	4.8	−3.2	NS
Maxillary/mandibular						
Wits (mm)	3.3	2.2	−0.9	2.7	+4.2	‡
Max/mand diff (mm)	21.1	3.5	24.5	4.2	−3.4	*
ANB (°)	4.9	1.8	2.2	2.1	+2.7	†
Vertical skeletal						
FH to palatal plane (°)	2.5	3.7	2.0	2.5	+0.5	NS
FH to mandibular plane (°)	23.6	5.1	23.4	4.0	+0.2	NS
ArGoMe (°)	122.0	7.6	123.6	5.4	−1.6	NS
CoGoMe (°)	122.4	6.1	124.2	4.5	−1.8	NS
N to ANS (mm)	49.8	3.2	49.2	3.1	+0.6	NS
ANS to Me (mm)	62.2	5.1	62.7	4.6	−0.5	NS
Interdental						
Overbite (mm)	4.2	1.8	3.3	1.8	+0.9	NS
Overjet (mm)	6.4	1.8	3.9	1.1	+2.5	‡
Interincisal angle (°)	130.4	10.8	129.1	8.6	+1.3	NS
Molar relationship (mm)	−1.9	1.2	0.8	1.0	−2.7	‡
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	4.6	1.7	5.4	2.3	−0.8	NS
U1 to FH (°)	110.2	6.8	111.4	8.6	−1.2	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	1.2	1.7	3.3	1.7	−2.1	†
L1 to mandibular plane (°)	95.8	6.4	93.9	6.9	+1.9	NS

NS, Not significant; **P* <0.05; †*P* <0.01; ‡*P* <0.001.

differences were found for the changes between T4 and T5 and between T5 and T6 in the 2 groups.

In the comparison of overall changes (T6-T1) between the Class II and Class I samples (Table IX), the total changes (CS1-CS6) showed a significantly smaller increase in total mandibular length (Co-Gn, −2.9 mm) and height of the mandibular ramus (Co-Go, −1.5 mm) in the Class II subjects. The growth deficiency in mandibular length was associated with a significantly smaller increase in the maxillomandibular differential (−1.7 mm) in the Class II group.

DISCUSSION

Class II malocclusion is a commonly observed clinical problem, occurring in about a quarter to a third of the United States population.[34-37] According to data from a federally funded study of the population (Third National Health and Nutrition Examination Survey, or NHANES III[38,39]), about 15% have overjets greater than 4 mm. Because Class II malocclusion is recognized easily by health professionals and by patients and their families, especially in instances of excessive overjet, the correction of Class II problems might be nearly half of the treatment protocols in a typical orthodontic practice.[21]

Despite the substantial prevalence of Class II Division 1 malocclusion as an orthodontic problem, few studies have analyzed the growth trends of subjects with distal molar relationship and excessive overjet. This information is vital in terms of growth expectations of patients observed at an early developmental

Table III. Descriptive statistics and statistical comparisons for cephalometric measurements in Class II and Class I subjects at T6 (CS6)

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	*SD*	*Mean*	*SD*		
Cranial base						
NSBa (°)	133.4	4.1	131.3	3.5	+2.1	NS
Maxillary skeletal						
Co-Pt A (mm)	93.3	5.7	94.6	4.4	−1.3	NS
SNA (°)	79.9	3.4	80.7	2.6	−0.8	NS
Pt A to nasion perp (mm)	−0.5	3.2	−0.5	3.2	0.0	NS
Mandibular skeletal						
Co-Gn (mm)	119.7	7.9	126.3	6.5	−6.6	†
Co-Go (mm)	61.6	6.4	64.7	3.8	−3.1	NS
SNB (°)	75.9	3.0	79.8	3.0	−3.9	†
Pg to nasion perp (mm)	−6.2	7.0	−0.9	7.0	−5.3	*
Maxillary/mandibular						
Wits (mm)	4.1	2.4	−0.9	3.1	+5.0	‡
Max/mand diff (mm)	26.8	4.9	32.1	5.6	−5.3	†
ANB (°)	4.0	1.7	0.9	2.6	+3.1	‡
Vertical skeletal						
FH to palatal plane (°)	1.3	4.6	1.3	2.9	0.0	NS
FH to mandibular plane (°)	22.0	5.5	20.1	4.2	+1.9	NS
ArGoMe (°)	119.3	7.8	120.4	6.5	−1.1	NS
CoGoMe (°)	120.9	6.1	122.5	5.1	−1.6	NS
N to ANS (mm)	56.5	3.6	55.6	3.3	+0.9	NS
ANS to Me (mm)	67.7	6.4	69.2	6.0	−1.5	NS
Interdental						
Overbite (mm)	4.5	1.9	3.3	1.6	+1.2	NS
Overjet (mm)	5.9	1.8	3.7	1.4	+2.2	‡
Interincisal angle (°)	133.3	12.3	134.3	8.5	−1.0	NS
Molar relationship (mm)	−1.1	1.3	1.6	1.6	−2.7	‡
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	5.2	2.3	7.0	1.9	−1.8	*
U1 to FH (°)	109.6	9.0	113.5	5.5	−3.9	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	1.3	2.5	3.2	1.7	−1.9	*
L1 to mandibular plane (°)	95.1	8.0	92.2	6.0	2.9	NS

NS, Not significant; *P <0.05; †*P* <0.01; ‡*P* <0.001.

phase for treatment planning and timing, and for the evaluation of treatment outcomes in growing patients. Only 3 major longitudinal studies have described the growth changes in the dentofacial region of orthodontically untreated Class II subjects compared with untreated samples with normal occlusion.[7,10,11] Bishara et al[10] observed the growth trends in Class II malocclusion from the deciduous through the permanent dentitions with an average starting age of 5 years and an average final age of 12.2 years. They did not report significant differences between the Class II and Class I samples (except for upper lip protrusion). Several characteristics of that investigation should be considered when evaluating their outcomes.[10] As they stated, the most severe cases were excluded from the group with Class II malocclusion. Furthermore, the analysis

of growth trends ended at an average age of 12.2 years when active growth is not completed.

On the other hand, both Kerr and Hirst[7] and Ngan et al[11] found significant differences in growth changes between Class II and Class I subjects. In particular, Kerr and Hirst[7] found a deficiency in mandibular growth (measured by means of Ar-Pg) in Class II subjects from 5 through 15 years of age, with the greatest difference between 10 and 15 years (about 2 mm). Ngan et al[11] described a much greater deficiency in mandibular growth in Class II vs Class I subjects: 9.6 mm from 7 through 14 years of age. None of these 3 longitudinal studies used a biologic indicator of individual skeletal maturity to determine the developmental status of their Class II and Class I subjects.

Our aim in this study was to analyze the longitudi-

Table IV. Changes between T1 and T2 (CS1 and CS2) in Class II and Class I subjects and statistical comparisons

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	SD	Mean	SD		
Cranial base						
NSBa (°)	0.0	1.5	0.4	1.4	−0.4	NS
Maxillary skeletal						
Co-Pt A (mm)	1.7	1.0	2.1	1.3	−0.3	NS
SNA (°)	0.3	0.9	0.4	1.1	−0.1	NS
Pt A to nasion perp (mm)	0.2	0.6	0.3	0.8	−0.1	NS
Mandibular skeletal						
Co-Gn (mm)	2.7	1.2	3.0	1.3	−0.3	NS
Co-Go (mm)	1.2	0.8	1.7	1.4	−0.5	NS
SNB (°)	0.3	1.0	0.2	0.9	+0.1	NS
Pg to nasion perp (mm)	0.6	1.3	0.5	1.1	+0.1	NS
Maxillary/mandibular						
Wits (mm)	0.2	1.3	0.3	1.4	−0.1	NS
Max/mand diff (mm)	0.9	1.0	0.4	1.0	+0.5	NS
ANB (°)	−0.1	0.7	0.2	0.7	−0.3	NS
Vertical skeletal						
FH to palatal plane (°)	−0.4	0.81	−0.4	1.1	0.0	NS
FH to mandibular plane (°)	−0.1	0.8	−0.5	0.7	+0.4	NS
ArGoMe (°)	−0.8	1.2	0.0	1.6	−0.8	NS
CoGoMe (°)	−0.4	1.0	−0.1	1.3	−0.3	NS
N to ANS (mm)	1.8	1.0	1.7	0.8	+0.1	NS
ANS to Me (mm)	0.9	1.0	0.8	0.9	+0.1	NS
Interdental						
Overbite (mm)	0.6	0.9	0.5	1.1	+0.1	NS
Overjet (mm)	−0.2	1.0	0.2	0.8	−0.4	NS
Interincisal angle (°)	1.4	3.2	2.0	3.3	−0.6	NS
Molar relationship (mm)	0.1	0.5	0.2	0.5	−0.1	NS
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	0.0	0.4	0.1	1.1	−0.1	NS
U1 to FH (°)	−1.1	2.4	0.6	6.6	−1.7	NS
U1 horizontal (mm)	0.3	0.5	0.4	1.1	−0.1	NS
U1 vertical (mm)	0.3	0.8	0.1	1.2	+0.2	NS
U6 horizontal (mm)	0.6	0.8	0.2	0.6	+0.4	NS
U6 vertical (mm)	0.8	0.6	0.4	0.8	+0.3	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	0.0	0.6	−0.2	0.7	+0.2	NS
L1 to mandibular plane (°)	−0.3	1.7	−0.2	2.8	−0.1	NS
L1 horizontal (mm)	0.1	0.5	0.2	0.6	−0.1	NS
L1 vertical (mm)	0.8	0.6	0.6	0.7	0.2	NS
L6 horizontal (mm)	0.3	0.5	0.4	0.5	−0.1	NS
L6 vertical (mm)	0.2	0.6	0.6	0.7	−0.4	NS

NS, Not significant.

nal craniofacial growth changes in untreated subjects with Class II malocclusion with those in subjects with normal occlusion from the prepubertal through the postpubertal stages with the cervical vertebral maturation method.[28] This method is reliable for detecting a subject's skeletal maturity and for identifying the pubertal growth spurt in the mandible. The 6 stages of cervical vertebral maturation cover the entire circumpubertal period, and these stages indicate the times of accelerated, maximum, and decelerated mandibular

growth. The peak in mandibular growth occurs between CS3 and CS4 in both sexes.[28]

At the beginning of the observation period (CS1), the Class II subjects were characterized by an obtuse cranial base angle, a retruded mandible, an excessive value for the Wits appraisal, and retroclined mandibular incisors, in addition to the occlusal features of Class II Division 1 malocclusion (excessive overjet and distal molar relationship). These results are consistent with those of previous studies, and they show that dentoskel-

Table V. Changes between T2 and T3 (CS2 and CS3) in Class II and Class I subjects and statistical comparisons

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	SD	Mean	SD		
Cranial base						
NSBa (°)	0.0	1.3	0.0	1.2	0.0	NS
Maxillary skeletal						
Co-Pt A (mm)	1.6	0.9	1.0	1.0	+0.6	NS
SNA (°)	−0.1	0.9	−0.2	1.1	+0.1	NS
Pt A to nasion perp (mm)	−0.1	0.6	−0.2	1.0	+0.1	NS
Mandibular skeletal						
Co-Gn (mm)	2.5	1.1	2.6	0.9	−0.1	NS
Co-Go (mm)	1.4	1.2	1.4	0.9	0.0	NS
SNB (°)	0.1	0.7	0.2	0.7	−0.1	NS
Pg to nasion perp (mm)	0.3	1.0	0.6	0.9	−0.3	NS
Maxillary/mandibular						
Wits (mm)	0.1	0.7	−0.2	1.0	+0.3	NS
Max/mand diff (mm)	1.0	0.8	1.6	0.9	−0.6	*
ANB (°)	−0.2	0.4	−0.3	0.8	+0.1	NS
Vertical skeletal						
FH to palatal plane (°)	−0.2	1.0	0.1	0.8	−0.3	NS
FH to mandibular plane (°)	−0.2	0.9	−0.4	1.0	+0.2	NS
ArGoMe (°)	−0.1	1.1	−1.3	1.3	+1.2	*
CoGoMe (°)	0.1	1.0	−0.4	0.9	+0.5	NS
N to ANS (mm)	1.4	0.9	1.1	0.7	+0.3	NS
ANS to Me (mm)	0.9	0.9	1.4	0.8	−0.5	NS
Interdental						
Overbite (mm)	0.2	0.6	0.0	0.9	+0.2	NS
Overjet (mm)	0.2	0.5	−0.1	0.5	+0.3	NS
Interincisal angle (°)	0.1	2.5	0.0	4.2	+0.1	NS
Molar relationship (mm)	0.3	0.6	0.3	0.8	0.0	NS
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	0.3	0.7	0.4	0.7	−0.1	NS
U1 to FH (°)	0.4	2.2	−0.5	2.4	+0.9	NS
U1 horizontal (mm)	0.5	0.7	0.6	0.6	−0.1	NS
U1 vertical (mm)	0.4	0.6	0.8	0.7	−0.4	NS
U6 horizontal (mm)	0.5	0.7	0.9	0.8	−0.4	NS
U6 vertical (mm)	0.5	0.7	1.0	0.7	−0.5	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	0.0	0.6	0.2	0.6	−0.2	NS
L1 to mandibular plane (°)	−0.3	2.0	0.9	2.8	−1.2	NS
L1 horizontal (mm)	0.0	0.6	0.2	0.6	−0.2	NS
L1 vertical (mm)	0.6	0.7	0.6	0.4	0.0	NS
L6 horizontal (mm)	0.8	0.7	0.6	0.6	+0.2	NS
L6 vertical (mm)	0.9	0.7	0.9	0.5	0.0	NS

NS, Not significant; *$P <0.05$.

etal characteristics of Class II malocclusion are established early in development.[5,7,9,14] There were no significant differences in the linear measurements of mandibular length (Co-Gn) and mandibular ramus height (Co-Go) between the 2 study groups at the beginning of the observation period, in contrast to the findings by Baccetti et al,[9] Bishara et al,[10] and Varrela[14] in young Class II subjects. However, average mandibular length in our Class II sample was 2.5 mm shorter than the Class I sample at CS1.

The finding of a more obtuse cranial base angle in the Class II subjects deserves specific attention. The characteristics of cranial base angulation can influence the overall craniofacial pattern in subjects with different malocclusions.[40-42] Closure of the cranial base angle has been associated with a tendency to Class III dentoskeletal disharmony, whereas Class II malocclusion is more prevalent with obtuse cranial base angulation.[7,41,42] In this case, the configuration of the cranial base induces a more distal position of the mandibular attachment to the cranium, thus facilitating a distal skeletal relationship of the mandible to the maxilla.

Table VI. Changes between T3 and T4 (CS3 and CS4) in Class II and Class I subjects and statistical comparisons

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	SD	Mean	SD		
Cranial base						
NSBa (°)	−0.2	1.2	0.3	1.1	−0.5	NS
Maxillary skeletal						
Co-Pt A (mm)	2.9	1.9	3.6	1.9	−0.7	NS
SNA (°)	0.5	0.8	0.3	1.2	+0.2	NS
Pt A to nasion perp (mm)	0.2	0.8	0.3	1.1	−0.1	NS
Mandibular skeletal						
Co-Gn (mm)	3.7	0.9	5.7	1.2	−2.0	‡
Co-Go (mm)	3.3	2.8	4.1	1.9	−0.8	NS
SNB (°)	0.6	0.9	0.6	0.5	0.0	NS
Pg to nasion perp (mm)	1.0	1.6	1.8	1.4	−0.8	NS
Maxillary/mandibular						
Wits (mm)	0.2	0.9	−0.1	1.2	+0.3	NS
Max/mand diff (mm)	1.7	1.2	2.4	1.2	−0.6	NS
ANB (°)	−0.1	0.7	−0.4	0.9	+0.3	NS
Vertical skeletal						
FH to palatal plane (°)	−0.4	1.4	−0.2	1.2	−0.2	NS
FH to mandibular plane (°)	−0.6	1.4	−0.8	1.2	+0.2	NS
ArGoMe (°)	−0.4	1.2	−0.2	1.7	−0.2	NS
CoGoMe (°)	−0.3	1.0	−0.3	1.1	0.0	NS
N to ANS (mm)	1.7	0.9	1.8	1.0	−0.1	NS
ANS to Me (mm)	1.6	0.9	2.2	1.6	−0.6	NS
Interdental						
Overbite (mm)	−0.2	0.8	−0.2	0.6	0.0	NS
Overjet (mm)	0.0	0.6	−0.2	0.3	+0.2	NS
Interincisal angle (°)	0.8	3.2	1.5	2.7	−0.7	NS
Molar relationship (mm)	0.1	0.5	0.3	0.6	−0.2	NS
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	0.2	0.7	0.4	0.8	−0.2	NS
U1 to FH (°)	−0.5	2.2	0.4	1.9	−0.9	NS
U1 horizontal (mm)	0.6	0.7	0.6	0.8	0.0	NS
U1 vertical (mm)	0.4	0.9	0.4	0.6	0.0	NS
U6 horizontal (mm)	1.0	0.8	0.8	0.8	+0.2	NS
U6 vertical (mm)	1.1	0.5	1.4	1.0	−0.3	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	0.0	0.6	0.0	0.6	0.0	NS
L1 to mandibular plane (°)	0.3	1.9	−1.1	1.8	+1.4	*
L1 horizontal (mm)	0.1	0.4	0.1	0.7	0.0	NS
L1 vertical (mm)	1.0	0.6	1.3	0.9	−0.3	NS
L6 horizontal (mm)	0.5	0.7	0.5	0.7	0.0	NS
L6 vertical (mm)	1.0	0.8	1.4	0.9	−0.4	NS

NS, Not significant; **P* <0.05; *‡P* <0.001.

At the end of the observation period (CS6), when craniofacial active growth was virtually completed, in the Class II sample, the mandible still was retruded significantly, the value for the Wits appraisal was still high (as well as the ANB angle), and overjet and distal molar relationship were still excessive. The Class II characteristics at CS1 were maintained at the end of the circumpubertal period (CS6), thus indicating no tendency to self-correction of the dentoskeletal disharmony in subjects with Class II malocclusion.

No significant differences between the 2 study groups were found with regard to vertical growth pattern—an important observation. This result disagrees with previous studies reporting increased vertical skeletal relationships in patients with Class II malocclusion.[11,20] An additional significant difference at CS6 between the Class II and Class I subjects was the deficiency in total mandibular length (Co-Gn) in the Class II group. Therefore, growth characteristics in the Class II sample when compared with the Class I sample led to an increase in the amount of mandibular deficiency from the initial prepubertal observation (−2.7

Table VII. Changes between T4 and T5 (CS4 and CS5) in Class II and Class I subjects and statistical comparison

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Cranial base						
NSBa (°)	0.1	1.1	0.2	0.6	−0.1	NS
Maxillary skeletal						
Co-Pt A (mm)	1.6	1.2	1.3	0.8	+0.3	NS
SNA (°)	0.2	0.8	−0.1	0.9	+0.3	NS
Pt A to nasion perp (mm)	0.3	0.6	−0.1	1.0	+0.4	NS
Mandibular skeletal						
Co-Gn (mm)	3.1	1.8	3.5	1.0	−0.4	NS
Co-Go (mm)	1.7	1.7	2.3	1.0	−0.6	NS
SNB (°)	0.4	0.9	0.3	0.4	+0.1	NS
Pg to nasion perp (mm)	1.0	1.5	1.0	1.2	0.0	NS
Maxillary/mandibular						
Wits (mm)	0.5	0.7	0.0	0.8	+0.5	NS
Max/mand diff (mm)	1.4	1.2	2.1	1.1	−0.6	NS
ANB (°)	−0.1	0.6	−0.4	0.7	+0.3	NS
Vertical skeletal						
FH to palatal plane (°)	−0.4	0.9	−0.3	0.8	−0.1	NS
FH to mandibular plane (°)	−0.4	1.7	−0.4	0.7	0.0	NS
ArGoMe (°)	−0.5	1.9	−1.2	1.8	+0.7	NS
CoGoMe (°)	−0.1	1.4	−0.4	1.5	+0.3	NS
N to ANS (mm)	1.3	1.0	1.4	1.0	−0.1	NS
ANS to Me (mm)	1.4	1.1	1.5	1.1	−0.1	NS
Interdental						
Overbite (mm)	−0.1	0.6	−0.2	0.5	+0.1	NS
Overjet (mm)	0.0	0.7	−0.1	0.3	+0.1	NS
Interincisal angle (°)	0.4	2.6	1.0	2.1	−0.6	NS
Molar relationship (mm)	0.0	0.6	0.1	0.7	−0.1	NS
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	0.0	0.7	0.2	0.5	−0.2	NS
U1 to FH (°)	0.2	2.7	0.3	1.8	−0.1	NS
U1 horizontal (mm)	0.1	0.7	0.3	0.6	−0.2	NS
U1 vertical (mm)	0.1	0.5	0.3	0.5	−0.2	NS
U6 horizontal (mm)	0.6	0.8	1.0	0.7	−0.4	NS
U6 vertical (mm)	0.9	0.6	0.9	0.6	0.0	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	−0.2	0.5	0.0	0.5	−0.2	NS
L1 to mandibular Plane (°)	−0.2	2.4	−0.8	2.0	+0.6	NS
L1 horizontal (mm)	−0.1	0.6	−0.1	0.4	0.0	NS
L1 vertical (mm)	1.0	0.7	1.1	0.8	−0.1	NS
L6 horizontal (mm)	0.5	0.6	0.4	0.8	+0.1	NS
L6 vertical (mm)	0.6	0.7	1.0	0.8	−0.4	NS

NS, Not significant.

mm, not a statistically significant difference) to the final postpubertal observation (−6.6 mm, a statistically significant difference).

The analysis of the longitudinal growth changes in the untreated Class II sample confirmed the observation that the features of Class II dentoskeletal disharmony established at the prepubertal stage of development are maintained throughout the circumpubertal period. Most dentofacial measures did not show a significant change, either between the subsequent stages in cervical vertebral maturation or during the overall observation period

in the Class II group when compared with the Class I group. The most significant exception to this trend was the change in total mandibular length (Co-Gn), with a significantly smaller increase in correspondence with the growth spurt interval (CS3-CS4) in the Class II sample vs the normal controls (about a 2-mm difference). The analysis of the changes from CS1 through CS6 showed also a significant deficiency in mandibular growth of 2.9 mm in the Class II subjects associated with significant deficiencies in the growth of the mandibular ramus (Co-Go, −1.5 mm) and the maxilloman-

Table VIII. Changes between T5 and T6 (CS5 and CS6) in Class II and Class I subjects and statistical comparisons

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	*SD*	*Mean*	*SD*		
Cranial base						
NSBa (°)	0.1	1.3	0.0	0.7	+0.1	NS
Maxillary skeletal						
Co-Pt A (mm)	1.0	1.1	0.9	1.0	+0.1	NS
SNA (°)	−0.4	0.9	−0.1	0.7	−0.3	NS
Pt A to nasion perp (mm)	−0.3	0.8	−0.2	0.6	−0.1	NS
Mandibular skeletal						
Co-Gn (mm)	1.9	1.1	2.2	1.2	−0.3	NS
Co-Go (mm)	1.6	1.0	1.5	0.8	+0.1	NS
SNB (°)	−0.1	0.8	0.2	0.8	−0.3	NS
Pg to nasion perp (mm)	0.3	1.2	0.5	1.2	−0.2	NS
Maxillary/mandibular						
Wits (mm)	−0.1	0.6	−0.2	0.6	+0.1	NS
Max/mand diff (mm)	1.0	0.9	1.3	1.0	−0.3	NS
ANB (°)	−0.4	0.6	−0.4	0.4	0.0	NS
Vertical skeletal						
FH to palatal plane (°)	0.3	1.2	0.0	0.8	+0.3	NS
FH to mandibular plane (°)	−0.4	0.9	−0.6	1.5	+0.2	NS
ArGoMe (°)	−0.9	1.8	0.3	−1.3	−1.2	NS
CoGoMe (°)	−0.8	1.2	−0.5	2.1	−0.3	NS
N to ANS (mm)	0.5	1.0	0.6	0.8	−0.1	NS
ANS to Me (mm)	1.1	0.7	1.0	1.0	+0.1	NS
Interdental						
Overbite (mm)	−0.3	0.4	−0.1	0.5	−0.2	NS
Overjet (mm)	−0.3	0.6	−0.1	0.3	−0.2	NS
Interincisal angle (°)	0.0	2.5	0.9	2.6	−0.9	NS
Molar relationship (mm)	0.2	0.5	0.0	0.7	+0.2	NS
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	0.0	0.6	0.2	0.5	−0.2	NS
U1 to FH (°)	0.4	1.7	0.5	1.6	−0.1	NS
U1 horizontal (mm)	−0.1	0.7	0.4	0.7	−0.5	NS
U1 vertical (mm)	0.1	0.7	0.3	0.7	−0.2	NS
U6 horizontal (mm)	0.2	0.7	1.0	1.5	−0.8	NS
U6 vertical (mm)	0.3	0.5	0.3	0.8	0.0	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	0.2	0.6	−0.1	0.4	+0.3	NS
L1 to mandibular plane (°)	−0.1	2.4	−0.7	2.5	+0.6	NS
L1 horizontal (mm)	−0.2	1.5	−0.1	0.4	−0.1	NS
L1 vertical (mm)	0.4	0.7	0.8	0.7	−0.4	NS
L6 horizontal (mm)	0.2	0.7	0.4	0.7	−0.2	NS
L6 vertical (mm)	0.6	0.6	0.9	0.9	−0.3	NS

NS, Not significant.

dibular differential (−1.7 mm). The size of our samples, although rather limited, warranted an acceptable power of the study. The assessment of the power of the study was based on the average standard deviation of 1.7 mm for the change in total mandibular length in the Class II subjects when compared with those with normal occlusion at the circumpubertal period, as derived from previous studies reported in a systematic review.[43] In a sample size of 17 subjects in each group, between-group differences for Co-Gn of 1.8 mm or greater can be considered statistically significant (*P*

<0.05) with a power of 0.85 (which equals 0.80 due to the use of nonparametric statistics).

These results agree with those of Kerr and Hirst,[7] who found an average deficiency in mandibular growth in Class II subjects when compared with Class I subjects of about 2.5 mm from 5 though 15 years of age. Ngan et al[11] reported also a significantly smaller increase in total mandibular length in Class II subjects from 7 through 14 years; however, the difference in mandibular growth between the Class II and Class I subjects in their study was much larger (9.6 mm) than

Table IX. Changes between T1 and T6 (CS1 and CS6) in Class II and Class I subjects and statistical comparisons

Cephalometric measure	Class II n = 17		Class I n = 17		Difference	Significance
	Mean	SD	Mean	SD		
Cranial base						
NSBa (°)	0.0	3.0	1.0	2.2	−1.0	NS
Maxillary skeletal						
Co-Pt A (mm)	9.1	2.8	9.0	2.4	+0.1	NS
SNA (°)	0.5	1.0	0.4	1.8	+0.1	NS
Pt A to nasion perp (mm)	0.5	0.9	0.5	1.9	0.0	NS
Mandibular skeletal						
Co-Gn (mm)	14.3	2.2	17.2	2.3	−2.9	†
Co-Go (mm)	9.6	3.5	11.1	2.4	−1.5	*
SNB (°)	1.4	1.5	1.6	1.3	−0.2	NS
Pg to nasion perp (mm)	3.5	2.7	4.8	3.2	−1.3	NS
Maxillary/mandibular						
Wits (mm)	0.9	1.2	0.2	1.4	+0.7	NS
Max/Mand diff (mm)	6.0	2.0	7.7	1.7	−1.7	*
ANB (°)	−0.9	1.1	−1.2	1.1	+0.3	NS
Vertical skeletal						
FH to palatal plane (°)	−1.1	2.3	−0.6	2.1	−0.5	NS
FH to mandibular plane (°)	−1.8	2.5	−2.8	1.8	+1.0	NS
ArGoMe (°)	−2.5	3.3	−3.0	3.2	+0.5	NS
CoGoMe (°)	−1.4	2.5	−1.6	2.5	+0.2	NS
N to ANS (mm)	6.8	1.5	6.6	1.7	+0.2	NS
ANS to Me (mm)	5.9	2.2	6.8	2.4	−0.9	NS
Interdental						
Overbite (mm)	0.2	1.4	0.0	1.7	+0.2	NS
Overjet (mm)	−0.4	1.6	−0.2	1.0	−0.2	NS
Interincisal angle (°)	3.0	7.2	5.1	5.8	−2.1	NS
Molar relationship (mm)	0.9	1.2	0.9	1.1	0.0	NS
Maxillary dentoalveolar						
U1 to Pt A vertical (mm)	0.5	1.1	1.4	1.4	−0.9	NS
U1 to FH (°)	−0.6	5.3	1.6	6.7	−2.2	NS
U1 horizontal (mm)	1.5	1.1	2.4	1.5	−0.9	NS
U1 vertical (mm)	1.4	1.0	2.1	1.3	−0.7	NS
U6 horizontal (mm)	2.9	0.8	3.7	1.3	−0.8	NS
U6 vertical (mm)	3.7	0.8	4.1	1.3	−0.4	NS
Mandibular dentoalveolar						
L1 to Pt A-pogonion (mm)	0.0	1.5	−0.1	0.9	+0.1	NS
L1 to mandibular plane (°)	−0.7	4.9	−1.9	4.8	+1.2	NS
L1 horizontal (mm)	0.1	2.1	0.5	1.1	−0.4	NS
L1 vertical (mm)	3.9	1.4	4.4	1.3	−0.5	NS
L6 horizontal (mm)	2.6	1.5	2.7	1.3	−0.1	NS
L6 vertical (mm)	3.5	1.5	4.6	1.5	−1.1	NS

NS, Not significant; *P <0.05; †P <0.01.

reported in both our study and that pf Kerr and Hirst.[7] In contrast, Bishara et al[10] and Bishara[12] found no significant difference in mandibular growth between Class II and Class I subjects from the deciduous through the permanent dentitions.

Several comments need to be made to elucidate the different findings. All previous studies used either Ar-Gn or Ar-Pg instead of Co-Gn as the measurement for total mandibular length. As was pointed out in the literature, Ar is not recommended as a landmark for the description of anatomic mandibular length because it is

not an anatomic landmark.[44,45] Moreover, no previous investigation used a biologic indicator of skeletal maturity to evaluate growth changes in longitudinal samples. Consequently, no information is available about the possible inclusion of the pubertal growth spurt or a postpubertal interval in the overall observation period. Finally, the Class II sample analyzed by Bishara et al[10] comprised subjects with "mild" Class II malocclusions, because, as stated by the authors, the most severe cases were excluded from the longitudinal study because they started orthodontic treatment. The group with Class II
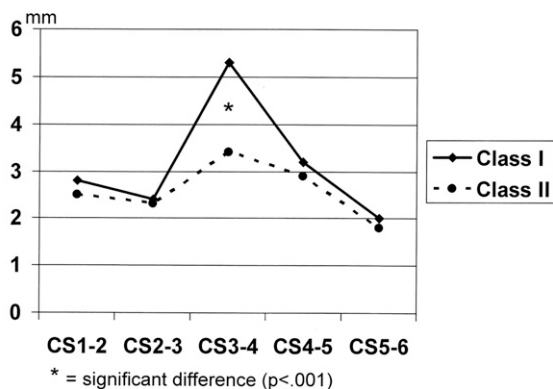
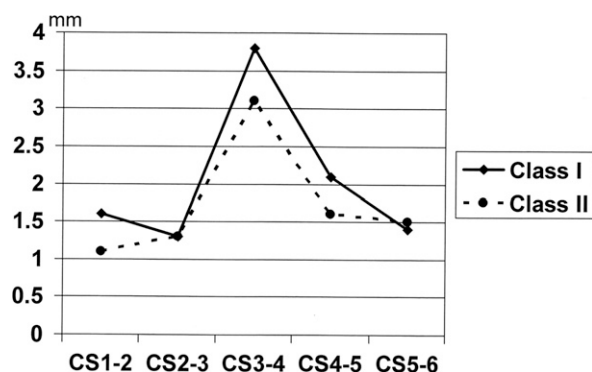**Fig 1.** Longitudinal changes in total mandibular length (Co-Gn).

Fig 2. Longitudinal changes in mandibular ramus height (Co-Go).

malocclusion investigated by Kerr and Hirst[7] also included subjects with Class II Division 2 malocclusion.

This study provides evidence of a significant increase in mandibular growth with the pubertal growth spurt[28] (from CS3 to CS4) in both Class II and Class I subjects (Figs 1 and 2). The absolute amount of mandibular lengthening at the pubertal peak, however, is significantly smaller in Class II subjects than in those with normal occlusion (Fig 1). The significant growth deficiency in mandibular length in Class II malocclusion (2 mm at the growth spurt, and 2.9 mm during the overall circumpubertal period) suggests that treatment strategies should be aimed to enhance mandibular growth as a component of Class II correction during the pubertal phases. The clinical relevance of this finding is emphasized when we consider that therapeutic modalities such as functional jaw orthopedics have the greatest effectiveness when they include the pubertal growth spurt in the active treatment period.[46-48] The significant difference in mandibular growth between

the Class II and Class I subjects strongly suggests that those with untreated Class II malocclusions are needed as controls in clinical studies on the mandibular effects of Class II treatment during the circumpubertal period, thus confirming previous statements in randomized clinical trials[49,50] and systematic reviews.[43]

CONCLUSIONS

Patterns of craniofacial growth in subjects with untreated Class II malocclusion essentially are similar to those of untreated subjects with normal occlusion, with the exception of significantly smaller increases in mandibular length. The deficiency in mandibular growth in Class II subjects is significant at the growth spurt (CS3-CS4), and it is maintained at the postpubertal observation (CS6). These findings show that Class II dentoskeletal disharmony does not have a tendency to self-correct with growth, in association with worsening of the deficiency in mandibular dimensions. The use of untreated Class II controls in studies on the effectiveness of dentofacial orthopedics on mandibular growth during the circumpubertal period is recommended.

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