

Mandibular growth comparisons of Class I and Class II division 1 skeletofacial patterns

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ABSTRACT

Objective: To determine class and sex differences in mandibular growth and modeling.

Materials and Methods: A mixed-longitudinal sample of 130 untreated French-Canadian adolescents, 77 (45 boys and 32 girls) with Class I (normal or abnormal) occlusion and 53 (26 boys and 27 girls) with Class II division 1 malocclusion, was used. Based on eight landmarks, eight traditional measurements were used to compare the anteroposterior position of the maxilla and mandible, relationship between the jaws, and mandibular size. Mandibular superimpositions were used to compare the horizontal and vertical changes of condylion, gonion, and menton.

Results: While there were no differences in maxillary position based on the SNA angle, Class IIs had more retrognathic mandibles than did Class Is. Total mandibular length was greater in Class Is than in Class IIs at 15 years of age. Superior and total growth and modeling changes at condylion and gonion, respectively, were greater for Class Is than Class IIs. Boys were more prognathic than girls; they had larger mandibles and exhibited greater size increases and growth changes than girls did.

Conclusions: There are both class and sex differences in mandibular growth and modeling. (*Angle Orthod.* 2014;84:755–761.)

KEY WORDS: Craniofacial; Growth; Class II malocclusion; Normal occlusion; Mandibular growth

INTRODUCTION

Class II malocclusion, classified based on the distal relationship of the mandibular molar relative to the maxillary molar,¹ affects a substantial numbers of individuals. The National Health and Nutrition Examination Survey estimated, based on overjet, that approximately 14.7% of the US population has Class II malocclusion, with prevalence decreasing from 22.6% between 8 and 11 years of age, to 15.6% between 12 and 17 years of age and then to 13.4% between 18 and 50 years of age.² The National Center for Health Statistics reported that 20.4% of 6- to 11-

year-olds have bilateral Class II molar relationships,³ compared with 14.5% of 12- to 17-year-olds.⁴

Most studies that classified malocclusion based on dental relationships have reported no differences between Class Is and IIs in maxillary AP position and mandibular retrusion among Class IIs.^{5–7} When individuals whose AP skeletal relationships worsened over time (ie, whose AP discrepancies increase) were compared with those whose relationships improved, the differences were again due to mandibular, and not maxillary, growth.⁸

Based on studies evaluating mandibular size and growth changes, it remains unclear exactly why Class IIs tend to be retrusive. Shorter total and mandibular corpus lengths have been reported among Class IIs compared with Class Is,^{9–12} although no differences have also been found.^{7,12–14} Some studies have shown greater growth in total mandibular length among Class Is than Class IIs,^{7,9,12} while others have not.^{10,11} Greater increases in mandibular corpus length among Class Is than Class IIs have been demonstrated by some^{7,9} but not all of the studies.^{13,14} Ramus heights have been reported to be shorter^{10,15} and no different^{9,12,14} among Class IIs than Class Is. Growth increases in ramus height have also been shown to be both different¹² and not different.^{9,14,15}

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Accepted: December 2013. Submitted: October 2013.

Published Online: February 13, 2014

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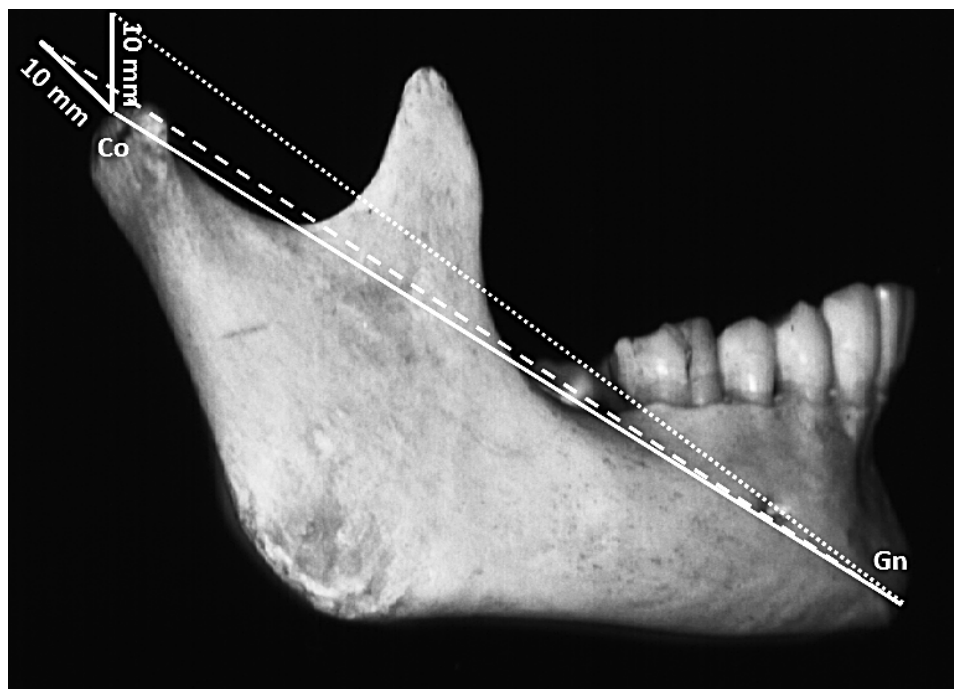


Figure 1. Same amounts (10 mm) of condylar growth (continuous lines) produce differences in total mandibular length (CoGn), depending on the growth direction. Initial CoGn (100 mm) (continuous line) increased to approximately 106 mm with vertical condylar growth (dotted line) and to approximately 110 mm with posterior condylar growth (dashed line).

To determine the growth differences between Class Is and Class IIs, individual landmarks must be examined. Evaluating landmarks, rather than distances and angles, makes it possible to quantify the changes that take place independent of the growth changes occurring at other sites. For example, increases of ramus height depend on the growth at condylion and resorption at gonion. Similarly, growth direction influences linear dimensions; 10 mm of vertical condylar growth affects overall mandibular length less than 10 mm of posteriorly directed growth (Figure 1). Class differences in the growth of individual landmarks, which make it possible to delineate growth direction, have not been previously evaluated.

To reconcile the existing inconsistencies and provide new comparisons based on the growth of individual landmarks, the present project was designed to evaluate longitudinal changes that occur during adolescence. The specific aims were to determine whether there are differences in mandibular growth between Class Is and Class IIs and to evaluate sex differences in mandibular growth. The null hypothesis was that there are no differences between groups.

MATERIALS AND METHODS

The data were derived from a mixed-longitudinal sample collected by the Human Growth Research Center, University of Montreal.¹⁶ Using a random-number generator, the sample was randomly chosen

from 107 schools from three school districts representing the socioeconomic background of the larger population. The sample was restricted to adolescents with four French-Canadian grandparents. The sample included 71 boys and 59 girls, evaluated at 10 (T1) and 15 (T2) years of age. Approximately 7.1% and 13.9% of the observations had missing data at T1 and T2, respectively. The sample included adolescents classified as having Class I (normal or abnormal) occlusion or Class II division 1 malocclusion based on their molar and canine relationships (Table 1).

All cephalograms were traced and digitized by the same technician. Radiographic enlargement was 11.08%. Eight landmarks (Figure 2) were used to compute eight traditional measurements. Technical reliability of the landmarks ranged between 90% and 99%, with the horizontal aspect of the condylion having the largest error (Table 2). Four measures of jaw position (SNA, SNB, ANB, and MPA angle), three

Table 1. Cross-Tabulation Showing the Sample Sizes Based on Class and Sex

	Classification		
	Dental		Total
	Class I	Class II	
Female	32	27	59
Male	45	26	71
Total	77	53	130

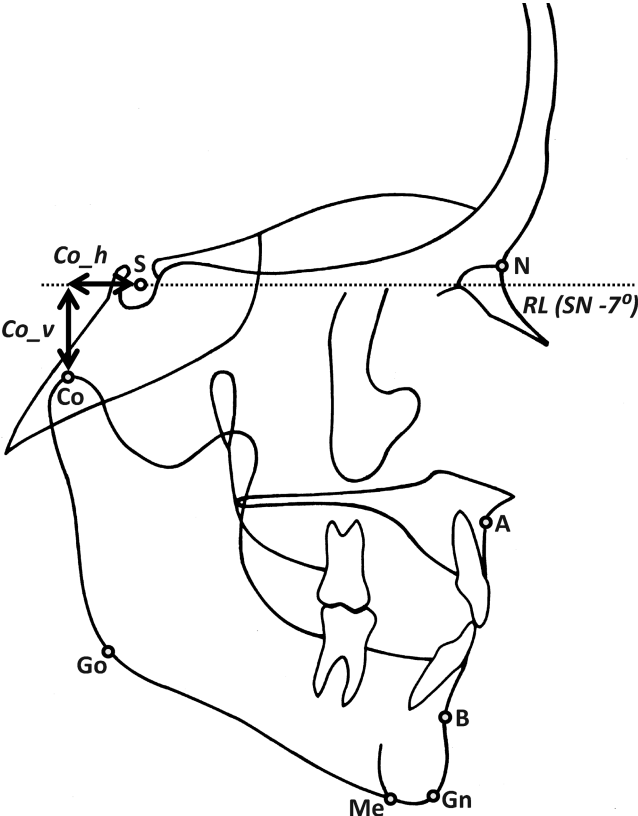


Figure 2. Cephalometric landmarks digitized: (S) sella, (N) nasion, (Co) condylion, (Go) gonion, (Me) menton, (A) A-point, and (B) B-point. Horizontal and vertical measurements were obtained by registering on sella (S) and orienting on SN - 7°.

measures of mandibular size (CoGn, CoGo, GoGn), and the gonial angle were computed.

To describe growth and modeling of the mandibular landmarks, each subject's radiographs were superimposed on natural mandibular reference structures.¹⁷ Reliability of the mandibular superimpositions was 93%.¹⁸ Rectangular coordinates (X, Y) were used to describe the horizontal and vertical positions of each landmark. The mandibles were superimposed and the tracings were registered on the T1 sella and oriented using a horizontal reference line (RL), defined by the T1 sella-nasion minus 7° (Figure 2). For example, the horizontal change of condylion (Co_h) was measured parallel to the RL, and its vertical (Co_v) change was measured perpendicular to the RL. The hypotenuse $\sqrt{(\text{horizontal change}^2 + \text{vertical change}^2)}$ was calculated to define the total change for each landmark. Negative values indicated changes in the inferior and posterior directions; positive values indicated changes in the superior and anterior directions. Relative growth differences between the sexes and between the classes were computed as percentages. For example, the relative difference between Class IIs and Class Is

Table 2. Technical Reliability of the Landmarks

Landmark	Reliability	
	Horizontal	Vertical
Nasion	.989	.983
A-point	.969	.973
Condyle	.899	.920
Gonion	.980	.989
Menton	.985	.982
Gnathion	.988	.984
Pogonion	.988	.995
B-point	.986	.977

was calculated as $\{[(\text{Change}_{\text{Class Is}} - \text{Change}_{\text{Class IIs}}) / \text{Change}_{\text{Class IIs}}] \times 100\}$.

Statistical Analysis

The measurements were transferred to SPSS software (version 19.0, SPSS, Chicago, Ill) for evaluation. Based on the skewness and kurtosis statistics, the variables were judged to be normally distributed. Paired *t*-tests were used to evaluate changes over time (ie, differences between 10 and 15 years of age). Two-way analysis of variance was used to compare the groups. A probability level of .05 was used to determine statistical significance.

RESULTS

Between 10 and 15 years of age, Class Is and Class IIs showed statistically significant (*P* < .05) decreases in the ANB angle, due primarily to increases in the SNB angle; they also demonstrated significant decreases in the mandibular plane (MPA) and gonial (CoGoMe) angles and increases in all three measures of mandibular size (Table 3). Both Class Is and IIs exhibited posterosuperior growth changes at condylion, posterosuperior modeling at gonion, and anteroinferior modeling at menton (Table 4).

While boys showed small decreases in ANB angle and MPA, girls showed no significant changes (Table 5). Both sexes demonstrated significant decreases in the gonial angle as well as increases in ramus height, corpus length, and total mandibular length. Boys and girls showed statistically significant condylar growth and mandibular modeling between 10 and 15 years of age (Table 6).

Class Differences

The ANB angle was significantly (*P* < .001) smaller in Class Is than in Class IIs at 10 and 15 years of age, due to differences in the SNB angle (Table 3). Total mandibular length (CoGn) was also significantly larger at 15 years in Class I than in Class II subjects, but there were no differences at 10 years of age. Neither the measures of jaw position nor size showed

Table 3. Descriptive Statistics and Statistical Comparisons for Cephalometric Measures in Class I and Class II Subjects at Age 10 Years and 15 Years and Changes Between 10 and 15 Years^a

Variable	10 Years of Age					15 Years of Age					10–15 Years of Age				
	Class I		Class II		Probability	Class I		Class II		Probability	Class I		Class II		Probability
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
SNA	80.38	3.66	80.40	2.79	.974	81.00	3.61	80.51	3.44	.481	0.32	1.43	0.17	1.69	.612
SNB	77.50	3.05	75.48	2.62	<.001	78.54	2.93	76.09	3.16	<.001	0.90	1.41	0.54	1.65	.227
ANB	2.87	1.75	4.91	1.74	<.001	2.36	1.99	4.43	1.81	<.001	–.58	1.58	–0.37	1.36	.473
MPA	36.11	4.48	36.64	4.13	.493	34.88	4.77	35.54	5.29	.501	–1.08	2.24	–1.34	2.54	.563
CoGoMe	127.38	4.18	126.81	4.52	.462	124.58	3.88	124.12	5.42	.602	–2.70	2.25	–2.66	2.38	.927
CoGn	95.71	4.36	94.69	3.99	.175	108.22	5.96	105.80	5.69	.026	11.94	3.41	10.88	2.54	.077
CoGo	45.36	2.96	44.81	2.46	.273	52.97	3.96	51.88	4.01	.138	7.36	2.43	6.93	2.08	.334
GoGn	61.79	3.42	61.44	3.06	.557	69.70	4.12	68.42	4.57	.109	7.50	2.07	6.78	1.75	.057

^a Bold font indicates significant change over time.

significant group differences in the changes that occurred between 10 and 15 years of age. Class Is showed significantly more superior and total condylar growth ($\approx 16\%$) than Class IIs (Table 4). They also showed significantly greater superior (24%) and total (14%) modeling at gonion.

Sex Differences

At 10 and 15 years of age, boys had larger mandibles than girls (Table 5), with differences increasing significantly over time. The only other statistically significant sex differences pertained to the SNA and SNB angles at 15 years of age, which were larger in boys than in girls, due to greater male increases between 10 and 15 years. Compared with girls, boys also had significantly greater (30%) superior and total condylar growth, greater (30%) posterosuperior modeling at gonion, and greater anterior (30%), vertical (24%), and total (23%) modeling at menton (Table 6).

DISCUSSION

As expected, the ANB angle was smaller (by approximately 2°) in Class Is than in Class IIs at both

10 and 15 years of age. While most studies have reported smaller ANB angles among untreated Class I than Class II subjects,^{7,12,13,15} Bishara reported no differences, which could have been due to the sample's age or the vertical growth patterns of the Class I sample.¹¹ Approximately 75% of subjects with Class II dental malocclusion also have Class II skeletal relationships,^{19,20} indicating that the Class II dental malocclusion is primarily due to the skeletal discrepancies.

Group differences in the ANB angle were mainly due to mandibular retrusion. Subjects with Class I and II malocclusion had SNA angles that were comparable; Class IIs had SNB angles that were approximately 2° smaller than Class Is at 10 years and almost 2.5° smaller at 15 years. Mandibular retrusion of Class IIs has been previously shown to be the primary determinant of the ANB discrepancies when the classification is based on dental criteria.^{6,9,12} The mandible might be expected to be the primary determinant because it is the least mature structure in the craniofacial complex and, therefore, under the greatest environmental and epigenetic influence.²¹

Importantly, the mandibular plane angles of both Class I and Class II subjects were similar, as were the decreases in the mandibular plane angles over time. Ngan and coworkers⁷ also found no differences in the MPA between Class Is and IIs. Previous reports of greater vertical growth among Class IIs did not compare their samples to Class I controls.^{6,22} The lack of vertical discrepancies is important because mandible rotation has been closely associated with chin projection.^{17,23–25} If the Class II problem is primarily mandibular and retrusion is not due to vertical discrepancies, then there must either be mandibular growth deficiencies or differences in cranial base morphology. Larger cranial base lengths and angles have been reported for Class IIs than Class Is.^{26–28}

Class II subjects have less condylar growth during adolescence than Class Is. Total and vertical condylar

Table 4. Horizontal, Vertical, and Total Changes Between Dental Class I and Class II Subjects Based on Mandibular Superimposition, Oriented Relative to SN -7°

Variable	Class I		Class II		Difference	Probability
	Mean	SD	Mean	SD		
Co_h	–1.89	1.45	–1.70	1.29	0.19	.474
Co_v	13.84	3.57	11.94	3.01	1.90	.004
Co_total	14.05	3.56	12.14	2.99	1.91	.003
Go_h	–3.78	1.45	–3.77	1.61	0.01	.975
Go_v	6.61	2.44	5.33	2.55	1.28	.009
Go_total	7.79	2.32	6.86	2.13	0.93	.034
Me_h	1.01	.85	0.99	.95	0.02	.912
Me_v	–0.53	.42	–0.57	.56	–0.04	.665
Me_total	1.24	.81	1.29	.93	–0.05	.795

^a Bold font indicates significant change over time.

Table 5. Descriptive Statistics and Statistical Comparisons of Males and Females at Ages 10 Years and 15 Years and Changes Between 10 and 15 Years

Variable	10 Years of Age					15 Years of Age					10–15 Years of Age				
	Male		Female		Probability	Male		Female		Probability	Male		Female		Probability
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
SNA	80.73	3.54	79.97	3.01	.195	81.35	3.65	79.95	3.21	.045	.49	1.51	−0.10	1.53	.049
SNB	77.09	3.19	76.19	2.80	.096	78.17	3.40	76.49	2.72	.007	1.11	1.45	0.18	1.45	.001
ANB	3.64	1.98	3.77	2.06	.709	3.09	2.25	3.46	2.05	.395	−0.64	1.49	−0.27	1.47	.212
MPA	35.87	4.36	36.87	4.27	.193	34.48	4.99	36.22	4.81	.072	−1.45	2.22	−0.77	2.52	.143
CoGoMe	127.08	4.04	127.22	4.66	.847	124.21	4.25	124.80	4.85	.502	−2.87	2.28	−2.40	2.29	.304
CoGn	97.18	3.93	93.02	3.38	<.001	109.94	5.24	102.80	3.88	<.001	12.67	3.26	9.64	1.61	<.001
CoGo	45.99	2.82	44.11	2.34	<.001	53.93	3.83	50.30	2.72	<.001	7.81	2.39	6.18	1.71	<.001
GoGn	62.91	2.88	60.11	3.07	<.001	70.90	3.84	66.18	3.27	<.001	8.00	1.87	5.94	1.37	<.001

^a Bold font indicates significant difference between sexes or significant change over time.

growths were approximately 16% less in the Class II sample (Figure 3A). Class differences in the growth of ramus height were much smaller (6.2%) than the differences in condylar growth. The difference can be explained by resorption at gonion. For every 1 mm that the condyles grew superiorly, resorption relocated gonion almost 0.5 mm.^{29,30} The Class differences in the growth direction of gonion over time (ie, slightly more posterior and less superior for Class IIs) reduces differences in ramus height (Figure 3B). Similar or slightly lesser amounts of vertical resorption at gonion have been previously shown to occur for every millimeter of superior condylar growth.^{29,30} The greater the inferior displacement, the greater the growth at condylion and resorption at gonion.³⁰ The fact that ramus height underestimates the growth that occurs at condylion explains why this and other studies have found no differences in ramus height between adolescents with Class I and Class II malocclusions.^{11,14} The present study is the first to show significantly more condylar growth, based on mandibular superimpositions, among untreated Class Is than Class IIs.

The total mandibular length of Class IIs was significantly shorter at 15 years of age but not at 10 years. Stahl and coworkers¹² also showed greater

total length among older, but not younger, Class Is. Bishara et al.¹⁰ suggested that Class Is have larger mandibles in the mixed but not the permanent dentition, but their Class I mixed dentition subjects were significantly more hyperdivergent than their Class II subjects.

The SNA and SNB angles increased significantly in boys between 10 and 15 years of age and did not change in girls, resulting in angles that were 1.7%–2.2% larger among 15-year-old boys. Previous studies have not shown sex differences in the anteroposterior position of the jaws among either Class IIs or Class Is.^{10,31–33} Boys also showed significant decreases in the MPA, whereas girls did not. Nevertheless, there were no sex differences in the MPA at 10 and 15 years nor in the changes of the mandibular plane that occurred, as previously reported.^{10,31,32} This suggests that boys undergo more horizontal and less vertical growth than girls do.²¹

Male mandibles were consistently larger and grew more than female mandibles. Previous studies have reported sex differences at some ages but not others.^{10,13,31} Riolo et al.³¹ reported significant sex differences for total mandibular length and ramus height but not for corpus length, while others have found sex differences in corpus length.^{13,33,34} With respect to ramus height, both statistically significant^{33,35} and no differences³⁴ have been reported. Sex differences increased between 10 and 15 years because boys have a more intense adolescent growth than girls.^{36,37}

The sexual dimorphism identified between 10 and 15 years of age may be confounded by sex differences in the timing of adolescence. Peak adolescent velocity is usually attained at 13.6 ± 1.3 years of age for boys and at 11.8 ± 1.2 years of age for girls.³⁷ As such, girls enter their adolescence phase of growth approximately 2 years before boys (ie, at approximately 10 years). As such, the 10-year-old estimates of dimorphism should not, on average, be affected by these maturational differences. If there were no sex differences in yearly growth rates during adolescence, these maturational

Table 6. Horizontal, Vertical, and Total Changes of Male and Female Subjects Based on Mandibular Superimposition, Oriented Relative to SN −7°

Variable	Male		Female		Difference	Probability
	Mean	SD	Mean	SD		
Co_h	−1.82	1.45	−1.79	1.30	0.03	.897
Co_v	14.35	3.45	11.01	2.35	3.34	<.001
Co_total	14.55	3.39	11.21	2.43	3.34	<.001
Go_h	−4.15	1.49	−3.19	1.36	0.96	.001
Go_v	6.56	2.66	5.31	2.21	1.25	.011
Go_total	7.99	2.40	6.48	1.74	1.51	.001
Me_h	1.19	0.97	0.71	0.65	0.48	.002
Me_v	−0.61	0.55	−0.45	0.32	0.16	.064
Me_total	1.47	0.93	0.93	0.60	0.54	<.001

^a Bold font indicates significant change over time.

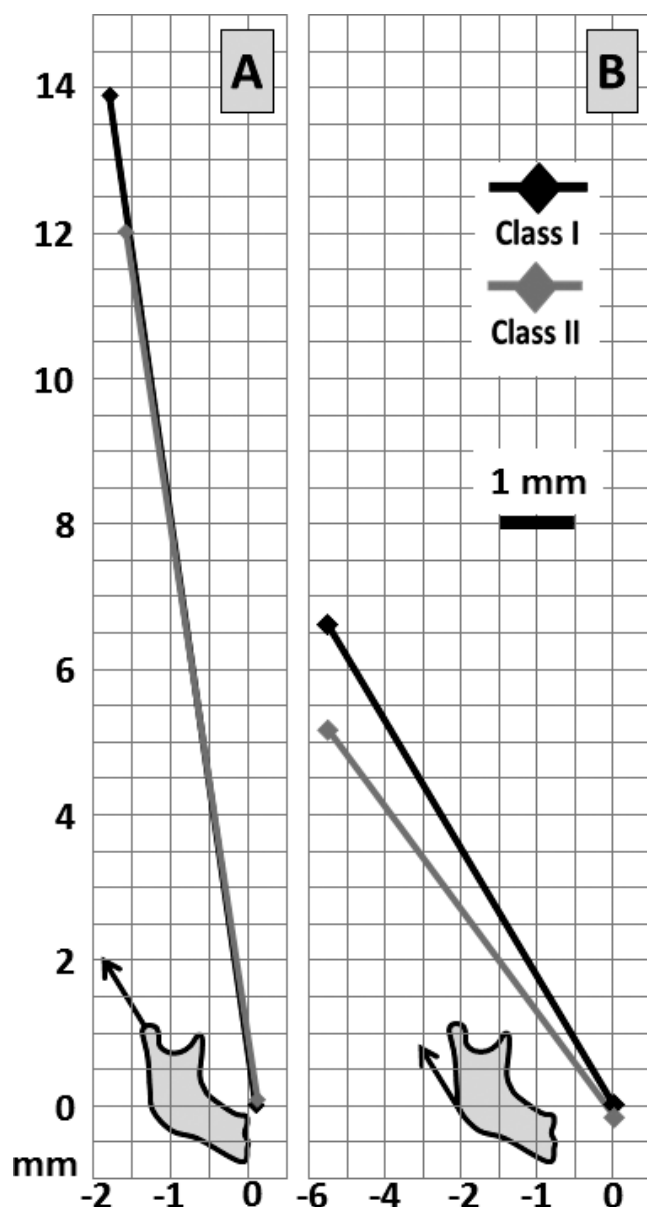


Figure 3. Chart representing the horizontal and vertical growth and modeling changes between 10 and 15 years of age based on mandibular superimposition. At 10 years of age, the initial position of the landmarks was at zero (X and Y). (A) Condylion changes. (B) Gonion changes.

differences might be expected to underestimate sex differences at 15 years of age, as well as the changes that occur between 10 and 15 years. However, boys have greater peak velocities than girls,^{36,37} making it difficult to determine exactly how sex differences in the timing of adolescence might be expected to affect the results of the present study.

CONCLUSIONS

Based on a sample of 130 untreated French-Canadian adolescents at 10 and 15 years of age:

- Class IIs have larger ANB angles due to retrusive mandibles rather than protrusive maxillas.
- Class IIs exhibit less vertical condylion growth and less gonial modeling than Class Is; condylar growth deficiencies among Class IIs resulted in shorter overall mandibular lengths at 15 years of age.
- Boys are relatively more protrusive than girls; their mandibles are larger and grow more than female mandibles.

ACKNOWLEDGMENT

This research was supported by MRC grant No. MA-8917.

REFERENCES

1. Angle EH. *Malocclusion of the Teeth*. 7th ed. Philadelphia, Pa: S.S. White Dental Mfg Co; 1907.
2. Proffit WR. Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. *Int J Adult Orthod Orthognath Surg*. 1998;13:97–106.
3. Kelly JE, Sanchez M, Van Kirk LE. An assessment of the occlusion of the teeth of children: 6–11 years. *Vital and Health Statistics*, series 11, number 130. Washington, DC: US Public Health Service; 1977.
4. Kelly JE, Harvey CR. An assessment of the occlusion of the teeth of youths: 12–17 years. *Vital and Health Statistics*, series 11, number 162. Washington, DC: US Public Health Service; 1977.
5. Hitchcock HP. A cephalometric description of Class II, Division 1 malocclusion. *Am J Orthod*. 1973;63:414–423.
6. McNamara JA. Components of Class II malocclusion in children 8–10 years of age. *Angle Orthod*. 1981;51:177–202.
7. Ngan PW, Byczek E, Sheick J. Longitudinal evaluation of growth changes in Class II Division 1 subjects. *Semin Orthod*. 1997;3:222–231.
8. Buschang PH, Martins J. Childhood and adolescent changes of skeletal relationships. *Angle Orthod*. 1998;68: 199–206.
9. Baccetti T, Franchi L, McNamara JA Jr, Tollaro I. Early dentofacial features of Class II malocclusion: a longitudinal study from the deciduous through the mixed dentition. *Am J Orthod Dentofacial Orthop*. 1997;111:502–509.
10. Bishara SE, Jakobsen JR, Vorhies B, Bayati P. Changes in dentofacial structures in untreated Class II division 1 and normal subjects: a longitudinal study. *Angle Orthod*. 1997; 67:55–66.
11. Bishara SE. Mandibular changes in persons with untreated and treated Class II division 1 malocclusion. *Am J Orthod Dentofacial Orthop*. 1998;113:661–673.
12. Stahl F, Baccetti T, Franchi L, McNamara JA Jr. Longitudinal growth changes in untreated subjects with Class II Division 1 malocclusion. *Am J Orthod Dentofacial Orthop*. 2008;134:125–137.
13. Riesmeijer AM, Prah Andersen B, Mascarenhas AK, Joo BH, Vig KW. A comparison of craniofacial Class I and Class II growth patterns. *Am J Orthod Dentofacial Orthop*. 2004;125:463–471.
14. Vásquez MJ, Baccetti T, Franchi L, McNamara JA Jr. Dentofacial features of Class II malocclusion associated with maxillary skeletal protrusion: a longitudinal study at the circumpubertal growth period. *Am J Orthod Dentofacial Orthop*. 2009;135:568.e1–7.

15. Baccetti T, Stahl F, McNamara JA Jr. Dentofacial growth changes in subjects with untreated Class II malocclusion from late puberty through young adulthood. *Am J Orthod Dentofacial Orthop.* 2009;135:148–154.
16. Demirjian A, Brault DM, Jenicek M. Etude comparative de la croissance de l'enfant canadien d'origine française à Montréal. *Can J Public Health.* 1971;62:11–19.
17. Björk A, Skieller V. Normal and abnormal growth of the mandible: a synthesis of longitudinal cephalometric implant studies over a period of 25 years. *Eur J Orthod.* 1983;5:1–46.
18. Buschang PH, LaPalme L, Tanguay R, Demirjian A. The technical reliability of superimposition on cranial base and mandibular structures. *Eur J Orthod.* 1986;8:152–156.
19. Beresford JS. Tooth size and class distinction. *Dent Pract.* 1969;20:113–120.
20. Milacic M, Markovic M. A comparative occlusal and cephalometric study of dental and skeletal anteroposterior relationships. *Br J Orthod.* 1983;10:53–54.
21. Buschang PH, Baume RM, Nass GG. A craniofacial growth maturity gradient for males and females between 4 and 16 years of age. *Am J Phys Anthropol.* 1983;61:373–381.
22. Hunter J. *The Natural History of the Human Teeth, Explaining Their Structure, Use, Formation, Growth, and Disease.* London, UK: J. Johnson; 1771.
23. Björk A. Prediction of mandibular growth rotation. *Am J Orthod.* 1969;55:585–599.
24. Björk A, Skieller V. Facial development and tooth eruption: an implant study at the age of puberty. *Am J Orthod.* 1972; 62:339–383.
25. Buschang PH, Santos-Pinto A. Condylar growth and glenoid fossa displacement during childhood and adolescence. *Am J Orthod Dentofac Orthop.* 1998;113:437–442.
26. Houston WJ. A cephalometric analysis of Angle class II, division II malocclusion in the mixed dentition. *Dent Pract Dent Rec.* 1967;17:372–376.
27. Hopkin GB, Houston WJ, James GA. The cranial base as an aetiological factor in malocclusion. *Angle Orthod.* 1968;38: 250–255.
28. Horowitz SL, Converse JM, Gerstman LJ. Craniofacial relationships in mandibular prognathism. *Arch Oral Biol.* 1969;14:121–131.
29. Baumrind S, Ben-Bassat Y, Korn EL, Bravo LA, Curry S. Mandibular remodeling measured on cephalograms: osseous changes relative to superimposition on metallic implants. *Am J Orthod Dentofac Orthop.* 1992;102:134–142.
30. Buschang PH, Gandini Júnior LG. Mandibular skeletal growth and modelling between 10 and 15 years of age. *Eur J Orthod.* 2002;24:69–79.
31. Riolo ML, Moyers RE, McNamara JA, Hunter WS. *An Atlas of Craniofacial Growth: Cephalometric Standards From University School Growth Study.* Ann Arbor, Mich: The University of Michigan, Center For Human Growth and Development; 1974.
32. Bhatia SN, Leighton BC. *A Manual of Facial Growth: A Computer Analysis of Longitudinal Cephalometric Growth Data.* New York, NY: Oxford University Press; 1993.
33. Coben SE. The integration of facial skeletal variants. *Am J Orthod.* 1955;41:407–434.
34. Cannon J. Craniofacial height and depth increments in normal children. *Angle Orthod.* 1970;40:202–218.
35. Maj G, Luzzi C, Lucchese PO. Cephalometric appraisal of Class II and Class III malocclusions. *Angle Orthod.* 1960;30: 26–32.
36. Nanda RS. The rates of growth of several facial components measured from serial cephalometric roentgenograms. *Am J Orthod.* 1955;41:658–673.
37. 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 Anthropol.* 1988;77:347–354.