Original Article

Mandibular Growth, Remodeling, and Maturation During Infancy and Early Childhood

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ABSTRACT

Objective: To describe the growth, maturation, and remodeling changes of the mandible during infancy and early childhood.

Materials and Methods: Seven Bolton-Brush Growth Study longitudinal cephalograms (N = 336) of each of 24 females and 24 males, taken between birth and 5 years of age, as well as early adulthood, were traced and digitized. Five measurements and nine landmarks were used to characterize mandibular growth, remodeling, and degree of adult maturity.

Results: Overall, mandibular length showed the greatest growth changes, followed by ramus height and corpus length. Corpus length was the most mature of the three linear measures; ramus height was less mature than overall mandibular length. The greatest growth rates occurred between 0.4–1 year; yearly velocities decelerated thereafter. The ramus remodeled superiorly only slightly more than it remodeled posteriorly. Male mandibles were significantly ($P \leq .05$) larger, displayed greater growth rates, and were significantly less mature than female mandibles. There were no significant differences in mandibular growth or maturation between Class I and Class II patients.

Conclusions: The mandible displays decelerating rates of growth and a maturity gradient during infancy and early childhood, with males showing more growth and being more mature than females. (*Angle Orthod* 2010;80:97–105.)

KEY WORDS: Mandible; Maturation; Growth; Remodeling; Infancy; Early childhood

INTRODUCTION

Although the craniofacial complex has been extensively studied,[1–4] growth and development during infancy and early childhood remain poorly understood. It is, however, well established that the greatest postnatal rates of somatic growth occur during the first 5 postnatal years.[5] US children, for example, undergo a marked deceleration of growth in recumbent length during the first 3 years (http://www.cdc.gov/growthcharts).[6] Based on the close associations between somatic and craniofacial growth and development,[7–9] greater rates of craniofacial growth might also be expected during the first few postnatal years. Craniometric and anthropometric studies support the notion of marked craniofacial growth changes during the first 5 years.[10,11,12] Ohtshuki et al[13] reported greater cranial base growth during the first 5 postnatal years, especially during the first 2–3 years, than during the remaining postnatal years.

While the studies are limited and the data fragmentary, mandibular growth also appears to be most rapid during infancy and early childhood. The ascending ramus dramatically changes its spatial relationship with the mandibular corpus during infancy, when the gonial angle decreases substantially.[14] Mandibular ramus height and corpus length demonstrate higher growth velocities between 3 and 5 years than anytime thereafter.[15] Based on a subsample of 32 subjects, Broadbent et al[16] showed greatest growth rates for ramus height between 1 and 2 years of age, with rates decreasing thereafter. The greatest increases in bicondylar width have also been reported to occur during the first 3 years of life.[17]

The purpose of this study was to describe mandibular growth, remodeling, and maturational changes that occur during infancy and early childhood. The matura-

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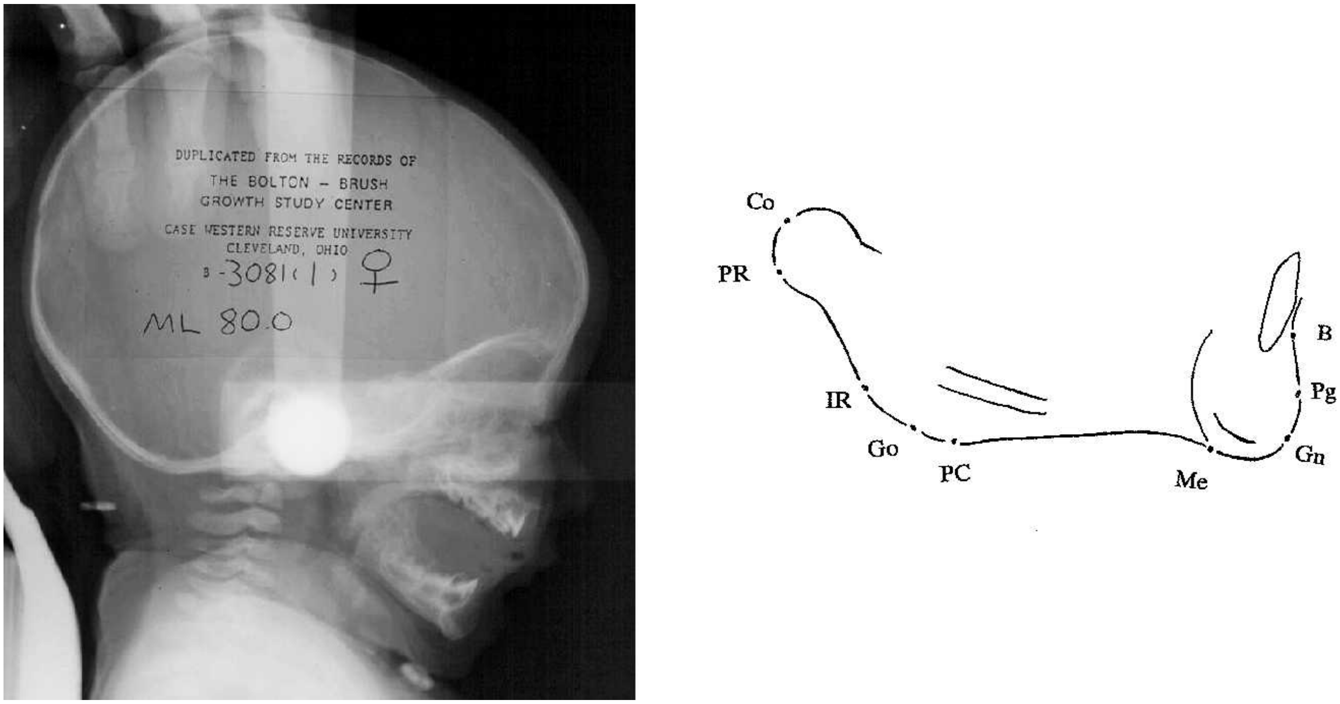

Figure 1. Cephalogram, cephalometric tracing, and landmarks digitized.

tion, growth at the condyle, and remodeling at specific sites of the mandible have not been previously quantified for children aged 0.4–5 years. The aims were to determine whether there are differences in growth and maturation associated with age, sex, or molar relationship.

MATERIALS AND METHODS

Serial lateral cephalometric records of 48 normal, untreated, healthy Caucasians (24 males and 24 females) were drawn from the longitudinal Bolton-Brush Growth Study, which includes approximately 5400 individuals of mostly European ancestry.[21] The sample included 24 subjects with Angle Class I and 24 subjects with Class II occlusions, as categorized by the Bolton Study. Subjects with growth anomalies, syndromes, or poor quality cephalograms were excluded.

The subjects were also chosen based on having good quality serial lateral cephalograms taken sometime during the first year of life (average age 0.4 $\pm$ 0.1 year), at approximately 1 year of age, and every year thereafter until approximately age 5. Each subject also had to have an adult cephalogram, taken at the minimum ages of 15 and 17 years for females and males, respectively; females were 16.9 $\pm$ 0.9 years old on average, and males, 18.6 $\pm$ 1.2 years on average.

Cephalometric Analysis

A total of 336 cephalograms were traced and digitized using the Dentofacial Planner (Dentofacial Software, v. 7.02, Toronto, Canada) software. All cephalograms were traced on 0.003-inch matte acetate and digitized by the primary author using a Numonics Model A30BL (Numonics Corporation, Montgomeryville, Pa) digitizer. The cephalograms were taken at the minimum midsagittal plane-to-film distance, producing average magnifications ranging from 7.4% to 8.4%.[16] Differences due to magnification were not corrected in the present study.

Two cranial base and nine mandibular landmarks were identified on each tracing (Figure 1; Table 1). Three linear and two angular measurements were calculated to provide overall representations of mandibular growth and shape changes, including

Ramus height (Co-Go)
Overall length (Co-Gn)
Corpus length (Go-Gn)
Condylion angle (Go-Co-Me)
Gonial angle (Co-Go-Me)

Anterior and posterior reference landmarks registered on sella and oriented on sella-nasion plane minus 7° (SN−7°) were marked on the adult tracing and transferred to the other tracings following each superimposition. The mandibles were superimposed on naturally stable structures using the techniques described by Björk and Skieller.[2] They were superimposed on 1) the anterior contour of the chin, 2) the inner contour of the cortical plate at the lower border of the symphysis, 3) any distinct trabecular structure in the symphysis, and 4) the contour of the mandibular

Table 1. Landmarks, Abbreviations, and Definitions of Landmarks

Landmark	Abbreviation	Definitions
Sella	S	Sella turcica, the center of the pituitary fossa of the sphenoid bone
Nasion	N	Junction of the frontonasal suture at the most posterior point on the curve at the bridge of the nose
Condylion	Co	Superior tangent on the mandibular condyle determined from a perpendicular from the ramal plane
Posterior ramus	PR	Point on the posterior contour of the condyle defined by the superior tangent of the ramal plane
Inferior ramus	IR	Intersection point of posterior contour of the mandibular ramus with its inferior tangent
Gonion	Go	Point on the contour of the mandible determined by bisecting angle formed by the mandibular and ramal planes
Posterior corpus	PC	Intersection point between the inferior contour of the mandible corpus and its posterior tangent
Menton	Me	Intersection point of posterior symphysis contour with the inferior contour of the corpus
Gnathion	Gn	Point between menton and pogonion, determined by bisecting the angle formed by the mandibular plane and its perpendicular tangent to pogonion
Pogonion	Pg	Most anterior point on the contour of the chin, determined by the perpendicular tangent to the mandibular plane.
Point B	B	The point most posterior to a line joining the anterior-superior point on the mandible at its labial contact with the mandibular central incisor and pogonion

canal. The tracing of the 5-year-old mandible was first superimposed on the adult tracing, the 4-year-old tracing was then superimposed on the 5-year-old tracing, and so on, with the 0.4-year tracing being the last to be superimposed. Rectangular coordinates were used to describe mandibular remodeling changes, defined as the changes in landmark position over time evaluated horizontally and perpendicularly to the adult SN-7° reference plane.

To determine the cephalometric errors associated with tracing and landmark identification, 28 randomly selected cephalograms were replicated. Systematic errors, ranging from 0.01 mm–0.09 mm and 0.02°–0.11°, were not statistically significant. Method errors ($\sqrt{\sum \text{deviatons}^2/2n}$) ranged between 0.06 mm and 0.27 mm and between 0.26° and 0.42°, with the gonial angle and menton horizontal showing the largest random measurement errors.

Statistics

Descriptive and inferential statistics were calculated using SPSS version 15.0 (Social Sciences, SPSS Inc, Chicago, Ill). Annual growth velocities were calculated by dividing the measurement differences between occasions by the corresponding age differences. Because the data were normally distributed, two-way analyses of variance were used to evaluate the effects of sex and occlusion. Relative growth changes of each of the measures were calculated as percentages of each subject's adult size.

RESULTS

A two-way analysis of variance showed that there was no significant ($P > .05$) interaction between sex and class of occlusion, and no significant class-of-occlusion effect. There were statistically significant ($P < .05$) sex differences in mandibular size, growth changes, and remodeling changes.

Mandibular size increased 18.2 mm to 34.7 mm between 0.4 and 5.0 years of age (Table 2). Overall mandibular length (Co-Gn) increased the most. Males displayed greater growth increases for ramus height (Co-Go) than for corpus length (Go-Gn), and females showed similar changes. While the condylar angle did not change significantly between 6 months and 5 years, the gonial angle decreased 2.8° and 2.0° in males and females, respectively.

Although yearly increments were significantly larger for males than for females, they showed similar patterns of change between 0.4 and 5.0 years (Table 3; Figure 2). Growth changes were greatest during the first 6 months, and they decreased progressively thereafter. Growth rates in mandibular size were approximately 1.8–2.2 times greater during the first postnatal year of life than during the second year and 1.3–1.9 times greater during the second than during the third year for females and males, respectively (Table 3). The gonial angle also showed the greatest changes during the first year (Figure 2).

Condylion, posterior ramus, inferior ramus, gonion, posterior corpus, and point B remodeled superiorly and posteriorly. Gnathion and pogonion remodeled inferiorly and posteriorly (Figure 3; Tables 4 and 5). Between 0.4 and 5.0 years of age, the condyle and posterior ramus remodeled 18.3 mm–22.5 mm posteriorly and 25.0 mm–29.4 mm superiorly. Landmarks in the gonial region remodeled 15.2 mm–19.7 mm posteriorly and only 6.3 mm–11.7 mm superiorly. The ramus landmarks showed the greatest yearly growth velocities between 0.4–1.0 year, with velocities decelerating thereafter. With the exception of the superior remodeling of B-point, the symphyseal landmarks showed only limited remodeling changes.

Table 2. Mandibular Size (mm) and Shape (°) During Infancy and Early Childhood

	Mandibular Size and Shape													
Age, years	0.4		1		2		3		4		5		16	
Landmark	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Males (n = 24)														
Co-Go	26.13	4.01	33.00	3.46	38.75	3.00	41.76	2.62	44.80	3.46	47.13	3.89	67.57	5.18
Co-Gn	60.59	4.53	71.48	5.14	80.42	4.14	85.94	4.28	91.50	4.48	95.30	4.68	126.54	5.83
Go-Gn	40.99	2.78	46.23	3.22	50.95	3.65	54.10	3.38	57.62	2.93	60.21	3.14	80.05	4.34
Go-Co-Me	29.01	4.52	27.65	3.17	27.53	2.97	27.63	2.64	27.89	2.48	28.85	2.73	32.09	2.93
Co-Go-Me	129.10	5.83	129.26	4.61	128.19	5.04	128.24	4.39	127.67	4.47	126.33	4.44	119.40	5.35
Females (n = 24)														
Co-Go	24.89	2.17	31.62	2.45	36.16	3.88	38.47	3.38	40.24	2.62	43.18	3.11	58.78	3.11
Co-Gn	58.01	4.03	69.06	4.28	76.56	4.71	80.97	4.24	85.14	3.51	90.00	4.43	114.16	4.65
Go-Gn	39.60	3.63	45.10	3.07	49.05	2.95	51.60	3.01	54.78	3.03	57.83	2.60	72.55	3.91
Go-Co-Me	29.65	4.45	28.46	2.65	28.15	3.31	28.06	2.44	28.65	2.10	29.28	2.41	31.27	2.79
Co-Go-Me	128.80	6.39	128.78	3.78	128.5	3.82	128.71	3.24	128.00	3.46	126.78	3.43	121.93	3.71

At approximately age 0.4 year, male mandibles were significantly ($P < .05$) less mature than female mandibles. For both sexes, ramus height was the least mature, followed by corpus length, and overall size, respectively. During the first 5 years, ramus height matured by approximately 31%, corpus length matured 25.2%–27.4%, and overall mandibular size matured 24.0%–25.2%. All three measures showed the greatest maturity changes during the youngest ages (Figure 4; Table 6).

DISCUSSION

Yearly rates of ramal growth and remodeling were greatest during the first postnatal year, and they decreased regularly thereafter. In the only other study quantifying longitudinal mandibular growth between 1 and 5 years of age, Broadbent et al[16] reported mean values indicating that ramus height (Ar-Go) increases 2.1 mm–2.2 mm between ages 1 and 2, and 1.8 mm–1.3 mm between 2 and 3 years for males and females, respectively. Yearly velocities for ramus height (Co-Go) in the present study decreased from 10.1 mm–11.5 mm per year between 0.4 and 1.0 year, to 4.6 mm–5.8 mm per year between 1 and 2 years, and then to 2.9 mm–3.0 mm per year between 2–3 years for males and females, respectively. This indicates that articulare underestimates actual growth rates. The rapid deceleration of growth that occurred during the first 2 postnatal years also occurs in general somatic growth; yearly growth velocities for recumbent length of boys decrease from approximately 25 cm per year during the first year, to approximately 12 cm per year during the second year (http://www.cdc.gov/growthcharts).[6] The rapid growth observed immediately after birth reflects a continuation of the even more rapid rates of growth that occur prenatally.[18]

Between 2 and 5 years of age, mandibular growth rates continued to decrease; growth rates were greater between ages 2 and 3 than between 3 and 4, which

Table 3. Growth Changes of Linear (mm/yr) and Angular (deg/yr) Mandibular Measures during infancy and early Childhood

	Yearly Growth Change												Total Change	
Age, years	0.4		1–2		2–3		3–4		4–5		5–16		0.4–5	
Landmark	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Males (n = 24)														
Co-Go	**11.45**[a]	7.71	**5.78**	3.29	**2.97**	3.10	**2.65**	2.22	**1.15**	2.18	**1.53**	0.31	**21.00**	4.77
Co-Gn	**17.70**	6.98	**8.95**	3.34	**4.88**	2.35	**4.97**	2.08	**2.63**	2.30	**2.35**	0.35	**34.71**	5.20
Go-Gn	**7.82**	3.45	**4.32**	1.86	**3.52**	2.00	**3.04**	1.15	**2.43**	1.39	**1.49**	0.23	**19.23**	3.11
Go-Co-Me	−2.60	6.81	−0.21	3.65	−0.20	3.00	0.01	1.58	**1.44**	1.73	**0.24**	0.23	−0.16	5.23
Co-Go-Me	−2.23	8.73	−0.98	4.19	0.20	3.84	−0.10	2.96	−1.17	3.01	**−0.52**	0.35	−2.77	7.01
Females (n = 24)														
Co-Go	**10.06**	5.65	**4.64**	3.05	**2.82**	2.72	**1.86**	2.55	**2.41**	2.10	**1.34**	0.33	**18.29**	4.27
Co-Gn	**14.97**	3.75	**7.79**	2.72	**5.00**	2.72	**4.31**	2.34	**4.01**	1.73	**2.07**	0.36	**31.99**	5.43
Go-Gn	**7.95**	3.75	**4.30**	1.87	**2.78**	1.17	**3.02**	1.09	**2.63**	1.00	**1.26**	0.24	**18.23**	2.96
Go-Co-Me	−1.44	5.84	0.05	3.25	0.02	2.56	0.58	1.42	0.51	1.36	**0.17**	0.25	−0.38	4.72
Co-Go-Me	−3.04	7.11	−0.59	3.27	0.03	3.18	−0.75	2.53	**−1.21**	2.31	**−0.42**	0.31	−2.02	6.93

[a] Bold indicates statistically significant growth changes.

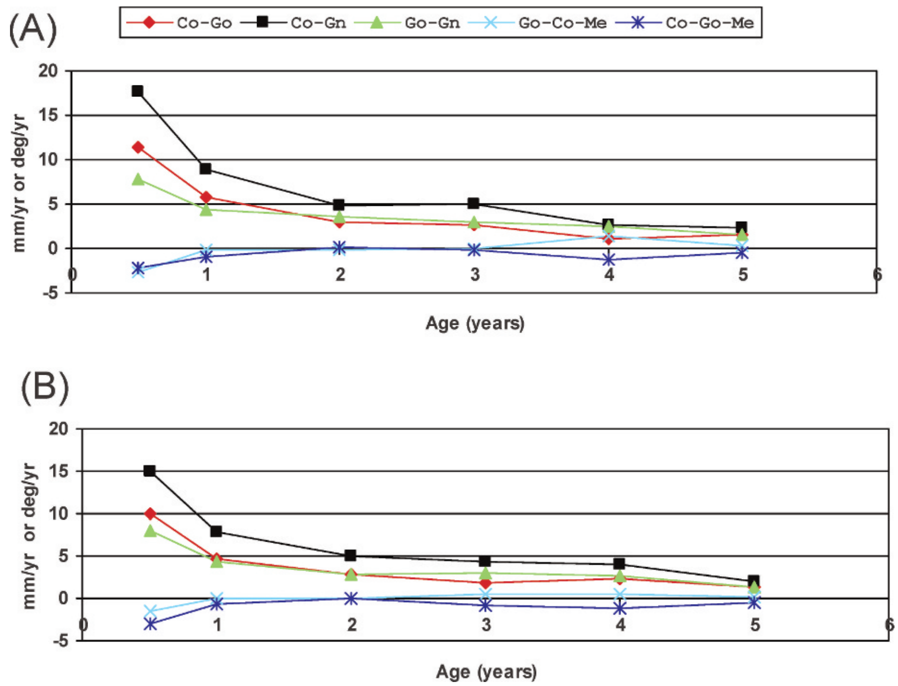

Figure 2. Mandibular growth velocities of (A) males and (B) females.

were in turn greater than the changes occurring between 4 and 5. Tracy and Savara,[15] who studied the mandibular growth of 50 girls between ages 3 and 16, reported that annual increments of overall mandibular length, ramus height, and corpus length also decreased between 3 and 5. Based on a mixed longitudinal sample of 51 subjects, Baume et al[19] reported similar trends for mid- and lower facial growth between 4 and 8 years. Again, the deceleration of craniofacial growth observed reflects a general somatic growth trend that occurs during the first 5 postnatal years.[5]

Condylion and posterior ramus remodeled superiorly only slightly more than they remodeled posteriorly, which is dramatically different than the pattern seen in older children and adolescents. In fact, the condyle grew only 1.1 times more superiorly than posteriorly. In contrast, Björk's implant studies of 100 children 5 to 22 years of age show substantially greater amounts of vertical than posterior condylar growth.[1,2,20] Baumrind et al[21] evaluated 31 patients who had metallic implants placed in their mandibles and reported that condylion grew nine times more superiorly than posteriorly between ages 8.5 and 15.5. Using the same SN−7°

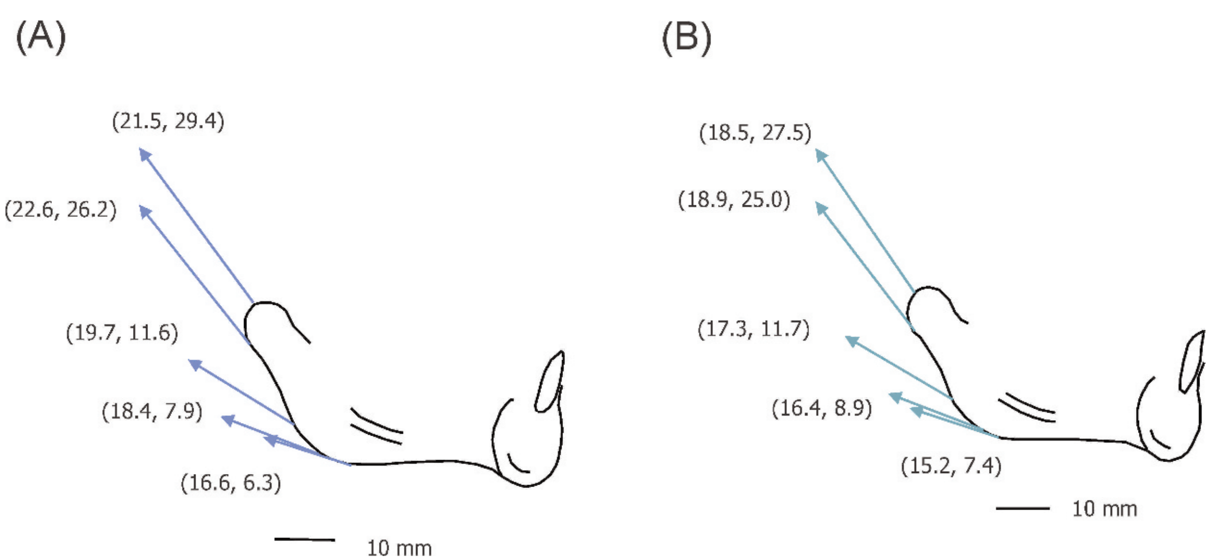

Figure 3. Mandibular remodeling between 0.4 and 5 years for (A) males and (B) females.

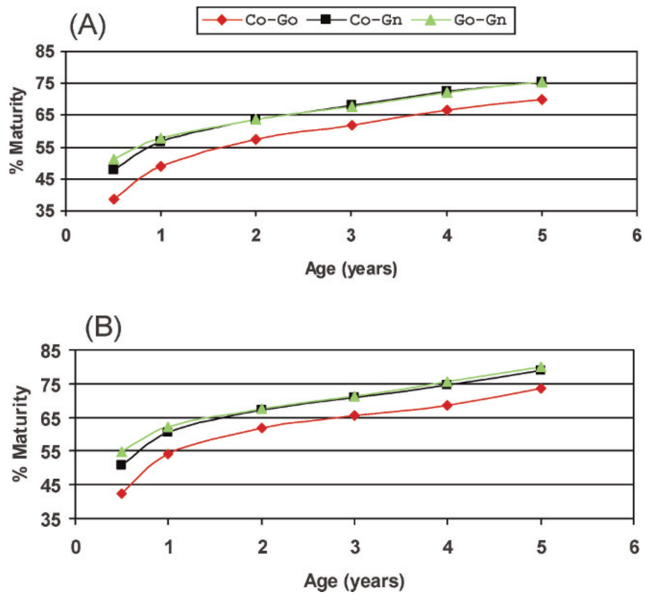

Figure 4. Relative mandibular maturity (percent adult size) of (A) males and (B) females.

orientation as in the present study, Buschang and Gandini[22] reported that condylion and posterior ramus grew approximately eight times more superiorly than posteriorly between 6 and 15 years. These differences imply a definitive change in condylar growth direction during later childhood and adolescence, which may be related to the transition from the primary to permanent dentitions.

In contrast to the condylar region, the gonial region showed approximately twice as much posterior than superior remodeling. More specifically, gonion remodeled approximately two times more posteriorly than superiorly. While this follows the pattern of resorption and deposition of bone along the inferior and posterior aspects of the gonial region reported during later childhood and adolescence,[1,2] the relative amounts of horizontal and vertical growth are again substantially different. Baumrind et al[21] reported that gonion remodeled 6.7 mm posteriorly and 6.0 mm superiorly between 8.5 and 15.5 years of age.

Buschang and Gandini[22] found that gonion remodeled superiorly approximately the same amount or slightly more than it remodeled posteriorly between 6 and 15. This again indicates a dramatic difference in the remodeling patterns of younger and older children that has not been previously reported. The remodeling changes observed for the ramus do not support the notion that the form and proportions of the human mandible are determined at a very early age and, once established, do not change.[23]

The gonial angle decreased 2.5° from 129° at age 0.4 year to 126.5° at 5.0 years. Broadbent et al[16] reported somewhat larger decreases in the gonial angle, from 134.5° at 1 year to 130.5° at 5 years. Their use of articulare rather than condylion could explain the differences reported. Decreases of the gonial angle observed in the present study are also less than the

Table 4. Horizontal Remodeling Changes (mm/yr) of Males and Females During Infancy and Early Childhood

	Yearly Horizontal Growth Change												Total Change	
Age, years	0.4–1		1–2		2–3		3–4		4–5		5–16		0.4–5	
Landmark	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Males (n = 24)														
Co	**−10.85**[a,b]	5.15	**−5.56**	2.53	**−4.50**	4.12	**−2.82**	2.43	**−1.34**	2.00	**−0.83**	0.37	**−21.46**	3.58
PR	**−11.30**	5.03	**−5.58**	2.77	**−3.80**	2.50	**−3.16**	2.17	**−1.64**	2.23	**−1.02**	0.35	**−22.58**	3.54
IR	**−8.47**	4.05	**−4.34**	2.46	**−4.10**	2.56	**−2.62**	1.56	**−2.50**	1.56	**−1.36**	0.24	**−19.66**	3.61
Go	**−6.85**	3.39	**−3.77**	2.04	**−3.70**	1.89	**−2.67**	1.11	**−2.57**	1.45	**−1.32**	0.22	**−18.35**	3.33
PC	**−7.08**	4.65	**−3.60**	1.95	**−3.30**	1.94	**−2.31**	1.51	**−2.33**	1.72	**−1.10**	0.30	**−16.63**	3.69
Me	0.34	2.65	0.06	2.37	−0.10	2.53	−0.27	1.25	0.02	1.34	0.03	0.14	0.13	2.20
Gn	−0.21	1.33	0.08	0.88	−0.42	1.09	−0.04	0.58	−0.18	0.55	**−0.06**	0.06	**−0.91**	0.83
Pg	−0.32	1.13	0.19	0.85	0.04	0.77	0.01	0.35	−0.23	0.72	0.01	0.05	−0.24	1.11
B pt	0.55	1.73	0.23	1.03	−0.30	1.07	−0.02	0.58	−0.08	0.81	**−0.13**	0.10	−0.08	1.61
Females (n = 24)														
Co	**−10.53**	6.3	**−5.02**	2.51	**−2.70**	2.01	**−2.30**	1.86	**−1.61**	2.07	**−0.78**	0.22	**−18.28**	5.43
PR	**−9.75**	4.33	**−5.04**	2.39	**−2.48**	1.95	**−2.65**	1.96	**−1.65**	2.23	**−1.02**	0.35	**−18.97**	5.06
IR	**−7.70**	4.88	**−3.82**	2.34	**−2.80**	2.40	**−2.90**	1.75	**−1.81**	1.09	**−1.15**	0.27	**−17.32**	3.80
Go	**−6.52**	4.28	**−3.78**	1.52	**−2.70**	1.35	**−2.72**	1.01	**−2.12**	1.20	**−1.13**	0.24	**−16.43**	3.33
PC	**−5.92**	5.06	**−3.72**	2.56	**−2.80**	2.86	**−2.30**	1.93	**−1.46**	1.96	**−0.96**	0.35	**−15.21**	4.06
Me	0.07	2.83	−0.01	1.47	0.39	1.89	−0.23	1.50	0.18	0.98	−0.02	0.22	−0.21	1.84
Gn h	0.24	1.43	−0.18	0.63	**−0.38**	0.86	−0.11	0.53	0.14	0.77	**−0.08**	0.11	−0.45	1.15
Pg h	0.06	0.97	0.00	0.45	−0.20	0.69	0.06	0.47	**0.31**	0.63	**−0.04**	0.09	−0.00	1.01
B pt	−0.09	−1.26	−0.03	0.85	0.37	1.32	0.25	0.68	0.22	0.69	**−0.18**	0.13	**0.88**	1.47

[a] Negative values indicate posterior changes.
[b] Bold indicates statistically significant growth changes.

Table 5. Vertical Remodeling Changes (mm/yr) of Males and Females During Infancy and Early Childhood

	Yearly Vertical Growth Change												Total Change	
Age, years	0.4–1		1–2		2–3		3–4		4–5		5–16		0.4–5	
Landmark	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Males (n = 24)														
Co	**−15.07**[a,b]	6.83	**−6.57**	2.87	**−4.10**	2.20	**−4.25**	1.98	**−2.58**	2.19	**−2.47**	0.37	**−29.35**	5.87
PR	**−12.69**	7.00	**−5.17**	3.01	**−3.60**	2.68	**−4.19**	2.23	**−3.08**	4.02	**−2.38**	0.38	**−26.17**	6.33
IR	**−5.16**	4.95	**−2.83**	3.49	**−1.70**	2.55	**−1.49**	2.53	**−1.45**	1.82	**−1.25**	0.31	**−11.57**	4.18
Go	**−3.09**	3.42	**−1.45**	2.18	**−1.30**	1.69	**−1.49**	1.57	**−0.83**	1.37	−0.81	0.18	**−7.90**	2.89
PC	**−2.91**	3.96	**−1.47**	1.84	**−0.80**	1.73	**−1.26**	1.54	**−0.62**	1.16	**−0.56**	0.16	**−6.28**	3.08
Me	0.72	2.25	0.16	1.32	0.44	1.04	0.20	0.76	0.31	1.00	**0.09**	0.07	**1.47**	1.03
Gn	**0.93**	1.17	0.20	0.71	0.30	0.86	0.15	0.48	0.01	0.75	**0.06**	0.07	**1.32**	1.12
Pg	**1.64**	1.86	−0.13	1.07	0.07	1.48	0.20	1.22	−0.02	1.32	−0.01	0.12	**1.13**	1.74
B pt	0.59	4.52	**−1.91**	2.69	**−1.40**	2.56	**−1.67**	2.07	−0.29	2.25	**−0.35**	0.24	**−4.63**	3.22
Females (n = 24)														
Co	**−11.62**	4.75	**−6.03**	3.23	**−4.80**	3.51	**−3.80**	2.25	**−3.98**	2.03	**−2.13**	0.50	**−27.54**	5.19
PR	**−9.61**	3.89	**−6.30**	4.08	**−3.00**	2.91	**−4.10**	2.56	**−3.37**	2.80	**−2.07**	0.45	**−25.03**	4.79
IR	**−3.75**	3.87	**−2.10**	3.24	**−2.70**	3.81	**−3.06**	3.70	−0.35	0.75	**−1.01**	0.43	**−11.70**	3.60
Go	**−2.57**	1.84	**−1.84**	2.43	**−1.80**	1.72	**−1.68**	1.41	**−1.12**	1.37	**−0.70**	0.24	**−8.86**	2.42
PC	**−1.94**	2.01	**−1.93**	2.00	**−1.90**	1.97	**−1.23**	1.31	**−0.81**	1.44	**−0.52**	0.28	**−7.38**	2.28
Me	−0.18	1.82	0.27	1.34	−0.10	1.01	0.02	0.78	0.32	0.79	**0.10**	0.11	0.57	1.48
Gn	0.29	1.80	0.27	1.09	0.03	0.80	−0.09	0.43	**0.32**	0.38	**0.06**	0.07	**0.80**	0.99
Pg	**0.97**	1.89	0.12	1.08	0.09	1.19	−0.20	0.79	−0.20	0.80	**0.08**	0.10	0.42	1.34
B pt	−0.28	3.84	**−1.55**	2.47	**−1.60**	2.18	**−1.48**	1.90	0.02	2.04	**−0.21**	0.18	**−5.5**	2.80

[a] Negative values indicate superior changes.
[b] Bold indicates statistically significant growth changes.

5°–10° decrease reported by Izard between birth and complete eruption of the primary dentition,[24] and the 15° decrease reported by Stunz[25] during the first 2 postnatal years. The differences might again be due to the different measurement used. Importantly, there was great individual variability within the sample in the changes that occurred in gonial angulation, suggesting that sample composition might also explain some of the differences observed.

With the exception of point B, the symphyseal landmarks showed only minimal remodeling changes. Gnathion remodeled somewhat inferiorly and posteriorly, pogonion remodeled slightly superiorly, whereas point B remodeled 4.6 mm–5.5 mm superiorly. Björk[1] reported that the anterior aspect of the chin was extremely stable in the anteroposterior direction. Thickening of the symphysis is due to apposition on the posterior surface.[1,2,22] During childhood and adolescence, the height of the symphysis increases primarily due to vertical dentoalveolar development and secondarily from apposition at the lower border.[21,26,27]

In terms of relative growth, corpus length was consistently the most mature, followed by overall length, and then by ramus height. Buschang et al[28] reported a similar pattern of maturity for children 4.5 years of age, with corpus length being 71% and 76% complete for males and females, respectively; ramus height was 67% complete in males and 71% complete in females.[28] Most important, the present study showed that ramus height had attained only 38%–42% of its adult size at age 0.4 year. Ramus height, being the least mature, might be expected to show a greater response to environmental and epigenetic stress than overall mandibular length and corpus length.[29]

Table 6. Mandibular Maturity, as a Percentage of Adult Size, During Infancy and Early Childhood

Age, years	0.4		1		2		3		4		5	
Landmark	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Males (n = 24)												
Co-Go	38.77	5.90	49.00	5.28	57.53	4.62	62.02	4.49	66.47	4.78	69.88	4.80
Co-Gn	47.90	3.17	56.52	3.80	63.63	3.43	67.98	3.35	72.36	2.99	75.34	2.84
Go-Gn	51.27	3.31	57.82	3.80	63.68	3.54	67.64	3.46	72.05	3.06	75.29	3.10
Females (n = 24)												
Co-Go	42.47	4.42	54.01	5.96	61.72	7.71	65.64	6.92	68.63	5.60	73.57	5.47
Co-Gn	50.87	3.75	60.58	4.45	67.12	4.40	70.99	3.94	74.66	3.64	78.87	3.22
Go-Gn	54.65	4.95	62.25	4.45	67.68	3.87	71.19	3.75	75.60	4.14	79.82	3.41

The mandibles of males were significantly larger, they showed greater growth increments, and they were significantly less mature than female mandibles. Females were 3.3%–3.9% more mature than males, with corpus length (Go-Gn) showing the greatest maturity differences. Sex differences in mandibular size favoring males have been previously reported for older children and adolescents.[30] Loth and Henneberg, who studied 62 juvenile mandibles from birth to 19 years, also found sex differences in the shape of the inferior border of the symphysis and the outline of the mandibular body during the first few years of life.[31]

Variability in yearly growth changes between subjects during the first 5 postnatal years was large. Given the relatively good reliabilities obtained for the cephalometric procedures, the variability observed must have been partially innate and partially due to patient positioning. The latter was probably an important factor because many of the subjects had their mouths open to varying extents when the radiographs were taken, which is why the study was restricted to the mandible. It is reasonable to assume that some of these young children may have been positioning their mandibles off to one side, which would introduce projection errors that would increase intersubject variability. However, these errors might be expected to be random and, as such, have little or no effect on the mean values reported. They might, however, be expected to affect the statistical power of the tests performed. The fact that the present study was able to identify statistically significant differences make power a nonissue with respect to sex and age effects. However, power could have played a role in our inability to identify significant differences between Angle Class Is and Class IIs.

The lack of significant differences in mandibular growth and maturation between Class Is and Class IIs younger than 5 years of age can be supported by 1) the lack of clear pattern of Angle class differences across the ages and 2) previous studies showing little or no difference due to class in younger subjects. It has previously been shown that actual growth differences between Class Is and IIs are small,[32] and might require many years to accumulate and become statistically significant. Kerr and Hirst[33] found that only the cranial base angle could be used to distinguish between Class Is and IIs when they were 5 years of age. Bishara et al[34] reported that Class Is and IIs in the primary dentition differed in terms of arch width but not in mandibular size.

CONCLUSIONS

- During infancy and early childhood, the greatest increases occur during the first 6 months of life and decrease progressively thereafter.
- Overall mandibular length showed the greatest growth changes, followed by ramus height and corpus length.
- The gonial angle decreased 2.8° and 2.0° in males and females, respectively.
- The condylar region remodeled superiorly only slightly more than it remodeled posteriorly; the gonial region showed approximately twice as much posterior than superior remodeling.
- Male mandibles were significantly ($P \leq .05$) larger, displayed greater growth rates, and were significantly less mature than female mandibles.
- Ramus height was less mature than overall mandibular length, which was in turn less mature than corpus length.
- There were no significant differences in mandibular growth or maturation between Class Is and Class IIs.

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