Original Article

Mandibular Rotation and Remodeling Changes during Early Childhood

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ABSTRACT

Objective: To describe the mandibular rotation and remodeling of younger children.

Materials and Methods: The sample included 43 males and 43 females who participated in the Bolton-Brush Growth Study at Case Western Reserve University in Ohio. They were chosen on the basis of having Class I (n = 45) or Class II (n = 41) molar relationships and longitudinal lateral cephalograms at three developmental stages of the dentition: late primary (T1: 5.7 ± 0.5 y), early mixed (T2: 8.4 ± 0.6 y), and full permanent dentition (T3: 15.4 ± 0.5 y). Each subject's cephalograms were traced and four landmarks were digitized. Cranial base and mandibular superimpositions were performed with the use of natural reference structures.

Results: Yearly rates of true rotation, apparent rotation, and angular remodeling showed significant ($P < .05$) changes throughout. True rotation was moderately correlated with angular remodeling and apparent rotation. Although no significant sex differences in annual rates of rotation were noted, subjects with Class I molar relationships showed significantly more angular remodeling from T2-T3 than did subjects with Class II molar relationships. Rates of true forward rotation were significantly greater with T1-T2 than with T2-T3 (1.3 and 0.7 degrees/y, respectively).

Conclusion: Although significant amounts of true mandibular rotation and angular remodeling occur during childhood and adolescence, true rotation is greatest during the transition from late primary to early mixed dentition. (*Angle Orthod.* 2009:79;)

KEY WORDS: Rotation; Mandible; Early childhood; Reference data

INTRODUCTION

Mandibular rotation includes three components: *apparent rotation*, which describes the angular change in the mandibular plane relative to the anterior cranial base; *angular remodeling,* which quantifies remodeling changes in the lower mandibular border; and *true rotation,* which refers to rotation of the mandibular body relative to the anterior cranial base that can be assessed only with the use of stable mandibular reference structures.[1] The mandible undergoes only limited amounts of apparent rotation because larger amounts of true rotation are typically camouflaged by angular remodeling.[2–5]

True mandibular rotation provides important information for an understanding of facial growth changes.[6] It has been related directly to both the direction and the amount of condylar growth, with increasing amounts of true forward rotation associated with greater and more anterior condylar growth.[2–5,7] Greater true forward rotation has been associated with greater decreases in the gonial angle,[8,13–15] more horizontal displacement of the chin,[16–19] greater increases in posterior facial height,[4,5] smaller increases in relative anterior facial height,[4,5,12,26] and greater reductions in the ANB and mandibular plane angles.[9] True forward rotation also has been associated with bony modeling changes, including increased deposition at the posterior ramus, increased resorption at the posterior lower border of the ramus, and increased deposition at the anterior lower border.[21,22] Increased amounts of true forward rotation also have been related to greater mesial migration of the molars, greater molar than incisor eruption, and greater incisor proclination.[5,23] Depending on the location of the mandible's center of rotation,

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Table 1. Annual Rates (degree/yr) of True Rotation, Apparent Rotation, and Angular Remodeling

	N	Age Range, yr	True Rotation, Degrees	Apparent Rotation, Degrees	Angular Remodeling, Degrees
Odegaard[8,13]	25	7–14	−0.8	0.2	1.0
Lavergne and Gasson[9]	30	7–19	−0.9	−0.4	0.5
Skieller et al[7]	21	PHV ± 3 yr	−1.0	−0.3	0.7
Spady et al[10]	81	6–11	−0.9	−0.1	0.8
	81	11–15	−0.4	0.2	0.6
Miller and Kerr[11]	42	5.2–10	−1.3	−0.1	1.2
	42	10–15	−0.8	−0.4	0.4
	42	15–20	−0.4	−0.3	0.1
Karlsen[12]	15	6–12 (high)[a]	−0.7	<0.1	0.6
	15	6–12 (low)[b]	−1.3	−0.4	0.9
	15	12–15 (high)[a]	−0.7	−0.6	0.1
	15	12–15 (low)[b]	−1.3	−0.5	0.7

[a] High MPA angle of 40.5 degrees at 12 years; [2] Low MPA angle of 22.9 degrees at 12 years.

Table 2. Mean Ages (yr) for Late Primary (T1), Early Mixed (T2), and Permanent Dentition (T3)

	Class I						Class II					
	T1		T2		T3		T1		T2		T3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male	5.60	0.55	8.39	0.50	15.32	0.48	6.00	0.35	8.53	0.61	15.33	0.47
Female	5.43	0.62	8.28	0.64	15.40	0.57	5.76	0.44	8.24	0.43	15.40	0.64

excessive true forward rotation can give rise to a deep bite malocclusion.[6]

The mandible typically rotates in a forward direction, with greater rates of true rotation noted during childhood than during adolescence (Table 1). Skieller et al[7] reported an average change of 1.0 degree/y during the 6 years surrounding the pubertal growth spurt. Ødegaard[8] showed that the mandible rotates forward 0.8 degree/y in subjects 7 to 14 years of age; Lavergne and Gasson[9] reported 0.9 degree/y forward rotation between 7 and 19 years of age. Based on longitudinal data, Spady et al[10] reported 0.9 degree/y of true forward rotation per year between 6 and 11 years and 0.4 degree/y between 11 and 15 years of age. Miller and Kerr[11] also reported higher rates of true rotation during childhood (1.3 degrees/y) than during adolescence (0.4 degree/y). Karlsen[12] showed similar rates of true forward mandibular rotation (1.3 degree/y) during childhood (6 to 12 y) and adolescence (12 to 15 y), perhaps related to the age spans of the samples.

To date, no study has been specifically designed to evaluate the true rotation and remodeling that occur during the transition from late primary to early mixed dentitions. On the basis of limited data, Spady and coworkers[9] have suggested that greater rates of true rotation occur during the transition from late primary to early mixed dentition than during later childhood or adolescence. The relatively high rates of true rotation reported by Miller and Kerr[11] for children 5 to 10 years of age might have been, at least partially, associated with dental changes that occurred. Unfortunately, neither study selected samples on the basis of dental development.

Given the potentially important growth and remodeling implications, the primary purpose of this study was to describe true mandibular rotation and remodeling during the transition from late primary to early mixed dentition. To determine relative magnitudes, these early changes will be compared with later rotational changes.

MATERIALS AND METHODS

The sample included 86 subjects (43 males and 43 females) who participated in the Bolton-Brush Growth Study. The Bolton study population consisted of individuals from the Cleveland area selected on the basis of a recommendation by their family physician and overall good health. The sample included equal numbers of untreated males and females with Class I (n = 45) or Class II (n = 46) molar relationships (Table 2). Subjects were selected according to the following criteria:

- Longitudinal cephalograms had to be available during the late primary dentition (5.7 ± 0.5 y), during the early mixed dentition when the first molars and incisors had fully erupted into functional occlusion (8.4 ± 0.6 y), and during the full permanent dentition (15.4 ± 0.5 y).
- Cephalograms had to be of sufficient quality that all

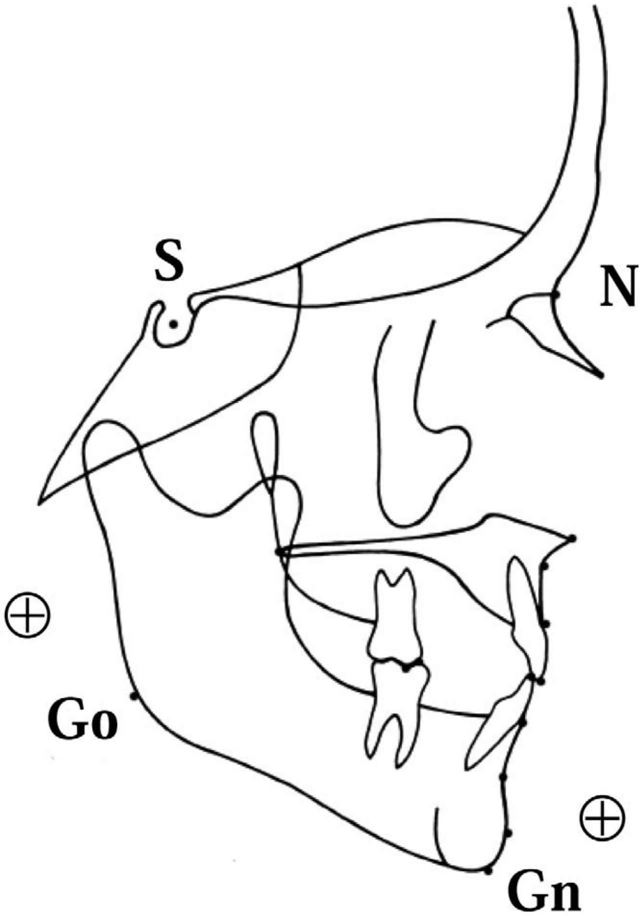

Figure 1. The four cephalometric and two fiducial (⊕) landmarks used to evaluate rotation and remodeling.

structures necessary for landmark identification and regional superimpositioning could be identified.
- Patients were rejected if they had received prior treatment or had experienced major craniofacial anomalies.

Cephalometric Methods

Each cephalogram was traced and four landmarks were located and digitized with Dentofacial Planner software (Dentofacial Software Inc, Toronto, Ontario, Canada) (Figure 1). Replicate analyses showed that landmark method errors ranged between 0.1 and 0.4 mm. Mandibular rotation was measured with the use of cranial base and mandibular superimposition methods outlined by Björk and Skieller.[4] For the cranial base, tracings were superimposed on the anterior wall of the sella turcica, the wing of the sphenoid, and the cribriform plate; the mandible was superimposed on the anterior contour of the chin just above the pogonion, the inner contour of the lower border of the symphysis, and the mandibular canal. The sella and nasion landmarks identified on the first tracing served as fiduciary cranial base landmarks that were transferred to the other tracings following cranial base superimpositions. Similarly, fiducial landmarks were recorded anterior and posterior to the mandibular corpus on the first tracing and were transferred to later tracings following mandibular superimpositions. True rotation was defined as the angular change between the fiduciary cranial base landmarks (SN) and the line connecting the anterior and posterior fiducial landmarks on the mandible. The angle between the SN and the mandibular plane (Go-Gn) was used to describe apparent rotation. Angular remodeling was defined as the difference between true rotation and apparent rotation.

Statistical Methods

Analyses were based on yearly rates of rotation and remodeling. Skewness and kurtosis statistics showed that all distributions were approximately normal. Group differences were calculated with two-way analysis of variance (ANOVA). Paired *t*-tests were used to evaluate changes within subjects over time. Pearson product-moment correlations were used to compute the relationship between true rotation and the other morphologic measurements.

RESULTS

Yearly rates of true rotation, apparent rotation, and angular remodeling were significant ($P < .05$) during the transition between the primary and mixed dentitions (T1-T2), as well as during the transition between mixed and permanent dentitions (T2-T3). ANOVA showed no significant interaction between sex and class and no significant sex differences in annual rates of rotation. Subjects with Class I molar relationships showed significantly more angular remodeling from T2-T3 than did subjects with Class II molar relationships (Table 3). Rates of true rotation and angular remodeling were significantly greater with T1-T2 than with T2-T3 (Table 4).

True rotation was moderately correlated with angular remodeling from T1-T2 ($r = 0.69$; $P < .001$) and from T2-T3 ($r = 0.59$; $P < .001$). True rotation was also correlated with apparent rotation from T1-T2 ($r = 0.43$; $P < .001$) and from T2-T3 ($r = 0.62$; $P < .001$). Annual rates of true rotation, angular remodeling, and apparent rotation during T1-T2 were not related to rates during T2-T3.

DISCUSSION

Rates of true rotation were almost twice as great during the transition between primary and early mixed dentition (−1.3 degrees/y) than during the period between early mixed and permanent (0.7 degree/y) den-

Table 3. Annual Rates (degrees/yr) of True Rotation, Apparent Rotation, and Angular Remodeling Based on Molar Relationships (Class I vs Class II) and Gender

	T1-T2		T2-T3		T1-T2		T2-T3		Group Differences *P* Value	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	T1-T2	T2-T3
	Class I				Class II					
True rotation	−1.33	0.98	−0.81	0.41	−1.23	0.87	−0.66	0.52	0.63	0.15
Apparent rotation	−0.40	0.70	−0.35	0.39	−0.41	0.70	−0.37	0.40	0.93	0.80
Angular remodeling	0.93	0.89	0.46	0.40	0.82	0.82	0.29	0.46	0.59	0.02
	Male				Female					
True rotation	−1.33	0.98	−0.73	0.55	−1.24	0.89	−0.74	0.39	0.65	0.94
Apparent rotation	−0.46	0.69	−0.31	0.43	−0.36	0.71	−0.41	0.36	0.51	0.23
Angular remodeling	0.87	0.86	0.42	0.48	0.88	0.86	0.33	0.36	0.99	0.19

Table 4. Annual Changes (degrees/yr) in True Rotation, Apparent Rotation, and Angular Remodeling From T1-T2 and From T2-T3 as Well as Differences Between Time Periods

	T1-T2		T2-T3		Differences		
	Mean	SD	Mean	SD	Mean	SD	*P* Value
True rotation	−1.28	0.93	−0.73	0.47	−0.55	1.05	< .001
Apparent rotation	−0.41	0.69	−0.36	0.40	−0.05	0.85	.609
Angular remodeling	0.88	0.89	0.38	0.38	−0.50	1.03	< .001

tition. Greater amounts of rotation have previously been reported during childhood than during adolescence.[10,11]

The rates of rotation observed in this study for 5- to 8-year-old children were similar to those previously reported for 5- to 10-year-olds[11] and for 6- to 12-year-olds with low mandibular plane angles[12]; they were slightly higher than rates reported for 6- to 11-year-old children by Spady and coworkers.[10] The rates of true rotation observed between early mixed and permanent dentition compare closely with those reported by Ødegaard[8,13] for children 7 to 14 years of age. Sample differences in true rotation may be due to the different age ranges used, to samples that included individuals with extreme dysmorphology,[4] or to treatments rendered.[8,9,13,14] It is important to note that these findings establish for the first time that the transition from primary to early mixed dentition is an important and potentially sensitive period with respect to mandibular rotation. The increased rates of true rotation that were observed could be associated with space created by the loss of the primary incisors. Buschang et al[25] have reported substantial decreases in alveolar bone height between 5.5 and 7.5 years of age for the lower incisor (≈5%) and especially for the upper incisor (≈20%).

The lack of association between times suggests that an independent control mechanism is operating during the transition to early mixed dentition. Spady and coworkers[10] also showed no correlation between rotational and remodeling changes that occur during the primary dentition stage and adolescence. However, they did report a low negative association between true rotation during adolescence and the true rotation that occurs for children in mixed dentition. The rotation associated with the transition from primary to early permanent dentition—a unique event—might be expected to be independent of the true rotation associated with normal growth changes.

The true mandibular rotation that occurred was consistently camouflaged by angular remodeling, resulting in only limited amounts of apparent rotation (i.e., decreases in the mandibular plane angle). Larger amounts of angular remodeling than are seen with apparent rotation typically occur during childhood than during adolescence.[5,8–14] The positive association between true rotation and angular remodeling during the early transition has been previously established[10] and indicates that subjects undergoing greater rotation will also under greater remodeling. This suggests that the lower border of the mandible is compensating to maintain its orientation in response to faster rates of true rotation. Angular remodeling associated with true forward rotation usually includes apposition of bone along the lower anterior border and resorption along the lower posterior border of the mandible.[5] The apposition that occurs along the anterior border might represent a response to tension from the suprahyoid musculature, and the resorption that occurs along the posterior border might be due to compression forces from the masticatory muscular sling as the posterior aspect of the mandible rotates downward.[10,24] These findings further demonstrate that true mandibular rotation is closely related to mandibular morphology, particularly during the transition from primary to mixed dentition.

It is interesting to note that no sex differences were observed in rates of true rotation, remodeling, and apparent rotation. This finding supports previous studies that showed no sex differences in rates of rotation and remodeling during childhood or adolescence.[9,10,14] Ødegaard[13] reported greater rotation in boys than in girls, but no sex differences in remodeling. However, sample sizes were small and subjects had been treated orthodontically. With the exception of angular remodeling from T2-T3, no differences were noted between subjects with Class I and Class II malocclusion in rates of true rotation, remodeling, and apparent rotation. Class II showed less rotation and remodeling than Class I, but the differences were not statistically significant. This supports the work of Ødegaard,[13] who was unable to establish a relation between rotation and degree of facial prognathism. The lack of difference between Class I and II may have been due to lack of specificity in sample selection. Larger differences might have been expected if the Class II sample had been restricted to subjects with division 1 malocclusion, who tend to have greater potential for hyperdivergent growth patterns. Karlsen[12] has shown that males with steep mandibular plane angles undergo significantly less forward true rotation than do males with flatter plane angles, during both childhood and adolescence.

CONCLUSIONS

- Rates of true rotation and remodeling during the transition from late primary to early mixed dentition are significantly greater than during the transition from early mixed to permanent dentition.
- Rotation, angular remodeling, and apparent rotation that occur at any given period are intercorrelated.
- The true rotation and remodeling that occur during the transition to early mixed dentition are independent of later rotational and remodeling changes.

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