Original Article

Mandibular rotation during the transitional dentition

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ABSTRACT

Objective: To determine whether dentoalveolar changes or vertical condylar growth is more closely related to the true forward rotation of the mandible during the transition between the late primary and early mixed dentition stages of development.

Materials and Methods: The sample included 50 subjects (25 males and 25 females) with Class I ($N = 25$) and Class II ($N = 25$) molar relationships. They were selected based on the availability of lateral cephalograms at two developmental stages: T1: last film with complete primary dentition (5.8 ± 0.4 years) and T2: first film with permanent incisors and permanent molars fully erupted (8.0 ± 0.2 years). Seventeen landmarks were identified and 22 measurements were calculated. The mandibles at T1 and T2 were superimposed using natural reference structures in order to measure true mandibular rotation.

Results: The mandible underwent $-2.4^\circ \pm 2.6^\circ$ of true rotation, $1.9^\circ \pm 2.4^\circ$ of remodeling, and $-0.6^\circ \pm 1.8^\circ$ of apparent rotation. There were no significant sex or Class differences in true rotation, remodeling, and apparent rotation. There was a moderate correlation ($r = 0.76$) between true rotation and remodeling and a moderately low correlation ($r = 0.40$) between true rotation and apparent rotation. There was a weak correlation between true rotation and SNA ($r = 0.28$). True rotation was most closely associated with the increases in U1/S-N ($r = -0.34$), increases in U1/PP ($r = -0.36$), and decreases in Id-Me ($r = 0.36$).

Conclusions: Independent of sex and Class, the true mandibular rotation that occurred between the late primary and early mixed dentition was mostly masked by angular remodeling, resulting in limited amounts of apparent rotation. True rotation was significantly related to anterior dentoalveolar changes but not to the vertical growth changes that occurred. (*Angle Orthod.* 2013;83:29–35.)

KEY WORDS: True rotation; Vertical growth; Transitional dentition; Dentoalveolar changes; Caucasians, Whites

INTRODUCTION

Significant amounts of true mandibular rotation takes place during childhood and adolescence.[1–6] True rotation, which refers to the angular changes of the mandibular core relative to the anterior cranial base, is typically in a forward and upward direction.[7] Increasing amounts of true forward rotation and proclination of the lower incisors have been associated with greater and more anterior condylar growth.[1,7] As a result of angular remodeling along the lower border, there is only limited rotation of the mandibular plane, which is referred to as apparent rotation.[7–9]

True mandibular rotation provides important information for understanding facial growth changes, especially changes of the horizontal chin position. Since most skeletal Class II patients have mandibular deficiencies, improvements in anterior-posterior (AP) chin position are crucial for the treatment of such patients. Since true rotation is the primary determinant of AP chin position,[10] greater amounts of true forward rotation of mandible result in more horizontal displacement of the chin. Headgear appliances, which have traditionally been used to treat Class II occlusions,[9,10]

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have been shown[10,11] to have little or no effect on AP chin position. While functional appliance therapy can alter the growth of the mandible, the orthopedic effects are limited and unpredictable[12,13]; whether functional appliances produce meaningful orthopedic improvement in AP chin position remains questionable.[10,13–16] Mechanics that produce forward mandibular rotation have been recently incorporated into Class II treatment to improve AP chin position in adults.[17–21]

It has been well established[3–5] that greater amounts of true mandibular rotation occur during childhood than during adolescence. Most recently, it was shown[6] that greater true rotation occurs during the transition from the late primary to the early mixed dentition than at any time thereafter. This indicates that true rotation may be related to the dentoalveolar changes that occur during the transitional dentition. True rotation during the transition from primary to permanent dentition could be associated with temporary decreases in anterior alveolar bone height that occur between 5.5 and 7.5 years of age.[22] Assuming that the center of mandibular rotation is located at the premolars, vertical space created anteriorly could result in greater anterior or forward rotation.[1] It is also possible that greater posterior vertical growth occurs during this transitional period, which could also explain the observed increases in true rotation.

To date, no study has been specifically designed to better understand why such relatively large amounts of mandibular rotation occur during the transition from late primary dentition to early mixed dentition. The purpose of this study was to evaluate if and how dentoalveolar changes and vertical condylar growth are related to the true forward rotation of the mandible during this transitional period. Understanding the mechanism controlling true mandibular rotation holds great potential in terms of facilitating Class II treatment.

MATERIALS AND METHODS

Subjects

The sample included 50 subjects (25 males and 25 females) who were followed longitudinally through the Bolton-Brush Growth Study. The Bolton Study population consists of individuals from the Cleveland area who were selected on the basis of recommendations by their family physicians and their overall good health. The sample included untreated males and females with Class I (N = 25) and Class II (N = 25) molar relationships (Table 1). The subjects were selected consecutively until the requisite sample sizes of males and females had been obtained based on the following criteria: (a) Longitudinal cephalograms available during the late primary dentition (T1; 5.8 ± 0.4 years) and early mixed dentition after the first molars and incisors had erupted into functional occlusion (T2; 8.0 ± 0.2 years). (b) Cephalograms had to be of sufficient quality to identify all of the structures necessary for landmark identification and regional superimposing. (c) Patients were rejected if they had received prior orthodontic treatment or had major craniofacial anomalies.

Table 1. Mean Ages for Late Primary (T1) and Early Mixed (T2) Dentition[a]

	Class I				Class II			
	T1		T2		T1		T2	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male	5.83	0.35	8.08	0.24	5.80	0.36	7.98	0.04
Female	5.65	0.46	8.14	0.32	5.91	0.75	7.97	0.05

[a] SD indicates standard deviation.

Cephalometric Methods

Each cephalogram was traced and 17 landmarks were digitized with Dolphin® software (Dolphin Imaging & Management Solutions & Patterson Technology, Lake Oswego, Ore). Traditional measurements were computed from the digitized data (Table 2).

Mandibular rotation was measured using cranial base and mandibular superimpositions, as described by Björk and Skieller.[9] Anterior and posterior fiducial landmarks were recorded on the first (T1) tracing and transferred to the T2 tracing following superimpositions of the mandible. True rotation was defined as the angular change between the two planes defined by the cranial base and mandibular fiducial landmarks. Changes in the angle S-N/Go-Gn defined apparent rotation. Angular remodeling was defined as the difference between true rotation and apparent rotation.

Statistical Methods

The skewness and kurtosis statistics showed that the distributions were approximately normal. Reliability was judged using the Dahlberg's statistic (Table 3).[23] Group differences were calculated using independent *t*-tests. Paired *t*-tests were used to evaluate changes within subjects (ie, changes over time). Pearson product moment correlations were used to compute the relationship between true rotation and the other morphological measurements.

RESULTS

The mandible underwent −2.4° ± 2.6° of true rotation, 1.9° ± 2.4° of remodeling, and −0.6° ± 1.8° of apparent rotation between T1 and T2 (Figure 1). There were no statistically significant sex or Class differences in true rotation, remodeling, and apparent

Table 2. Measurements, Abbreviations, Definitions Used, and Error Analysis[26]

Measurements[a]	Abbreviations	Definitions	Method Error
AP skeletal	SNA, °	Maxillary protrusion/retrusion	0.973
	SNB, °	Mandibular protrusion/retrusion	0.658
	ANB, °	AP relationship between maxilla and mandible	0.566
Vertical skeletal	S-N/Go-Gn, °	Mandibular plane inclination	0.991
	N-Me, mm	Anterior facial height	1.266
	ANS-Me, mm	Lower facial height	0.912
	S-Go, mm	Posterior facial height	0.819
	Co-Go, mm	Ramus height	1.431
	Ar-Go, mm	Mandibular height	1.130
	Co-Go-Me, °	The gonial angle	1.735
	S-Go/N-Me	Posterior facial height/anterior facial height	–
AP dental	U1/S-N, °	Maxillary incisor inclination	1.721
	U1/PP, °	Maxillary incisor inclination	1.944
	IMPA (L1-MP), °	Mandibular incisor inclination	2.057
	Overjet, mm	Horizontal distance from facial surface of lower central incisor to lingual surface of upper central incisor	0.487
Vertical dental	Overbite, mm	Vertical overlap of central incisor	0.582
	ANS-Pr, mm	Measurement of vertical alveolar height	0.476
	Id-Me, mm	Measurement of vertical alveolar height	0.808
	U1-PP, mm	Upper incisor distance from palatal plane	0.546
	L1-MP, mm	Lower incisor height from mandibular plane	0.789
	U6-PP, mm	Upper molar height from palatal plane	0.356
	L6-MP, mm	Lower molar height from mandibular plane	0.445

[a] AP indicates anterior-posterior.

rotation. There was a moderate correlation ($r = 0.76$; $P < .001$) between true rotation and angular remodeling and a moderately low correlation ($r = 0.40$; $P < .001$) between true rotation and apparent rotation.

Most skeletal measurements showed significant ($P < .05$) changes (Table 3). The ANB and S-N/Go-Gn angles decreased by 0.5° and 0.6°, respectively. Anterior face height (N-Me) increased 5.5 mm, and lower face height (ANS-Me) increased 2.5 mm. Posterior face height (S-Go), ramus height (Ar-Go), and Co-Go increased by 4.3 mm, 2.5 mm, and 3.0 mm, respectively. The ratio of posterior and anterior facial height decreased slightly (2%); the gonial angle decreased 1.3°.

Most dental measurements also changed significantly (Table 4). U1/S-N, U1/PP, and IMPA increased 10.8°, 11.1°, and 5.1°, respectively. Overjet increased 0.8 mm. ANS-Pr decreased 4.8 mm and Id-Me decreased 2.3 mm, resulting in a total dentoalveolar height (ANS-Pr+Id-Me) decrease of 6.7 mm. The linear distances of the lower incisor to the mandibular plane (L1-MP) increased 2.0 mm, and the distance of the upper molar to the palatal plane (U6-PP) decreased 1.1 mm. There were no statistically significant changes in the vertical distances between the upper incisor and the palatal plane (U1-PP) or between the lower molar and the mandibular plane (L6-MP).

Table 3. Changes in Skeletal Variables from Late Primary (T1) to Early Mixed (T2) Dentition[a]

		T1		T2		Difference	
		Mean	SD	Mean	SD	Mean	SD
AP skeletal	SNA, °	81.25	2.86	80.96	2.98	−0.30	1.49
	SNB, °	76.22	2.46	76.43	2.64	0.22	1.60
	ANB, °	5.04	2.22	4.54	2.21	−0.50*	1.41
Vertical skeletal	S-N/Go-Gn, °	35.05	3.42	34.39	3.51	−0.62*	1.78
	N-Me, mm	99.06	4.55	104.58	4.95	5.52**	2.63
	ANS-Me, mm	54.16	3.43	56.61	3.93	2.46**	1.72
	S-Go, mm	62.14	3.82	66.43	4.25	4.29**	1.96
	Co-Go, mm	45.12	2.76	48.13	3.44	3.01**	3.24
	Ar-Go, mm	36.92	2.74	39.40	3.44	2.48**	2.44
	Co-Go-Me, °	130.44	4.30	129.18	4.33	−1.26*	0.48
	S-Go/N-Me, °	0.63	0.31	0.64	0.34	0.01**	0.01

[a] SD indicates standard deviation; AP, anterior-posterior.

** Paired t-test for equality of means was significant at the 0.01 level (two-tailed);

* Paired t-test for equality of means was significant at the 0.05 level (two-tailed).

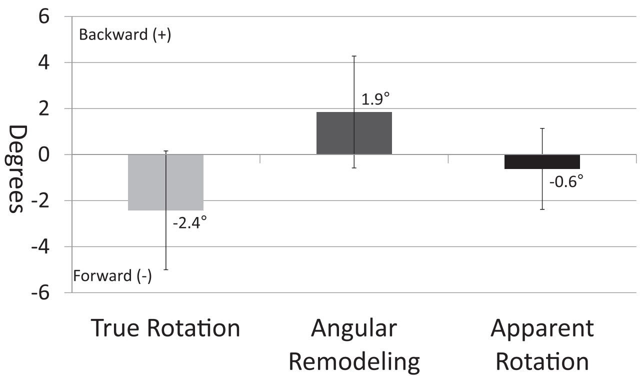

Figure 1. Mean and standard deviation of mandibular rotation from T1 to T2.

The only skeletal measure related to true rotation comprised changes in the mandibular plane angle (S-N/Go-Gn) and SNA (Table 5). Individuals with greater true rotation also showed greater decreases in S-N/Go-Gn (r=0.40) and greater increases in SNA ($r = 0.28$). True forward rotation showed moderately low correlations with the increases in U1/S-N ($r = -0.34$) and increases in U1/PP ($r = -0.36$), indicating greater rotation for those individuals who had greater upper incisor proclination (Table 6). True rotation was most closely related to changes in dentoalveolar height. The greater the decreases in Id-Me ($r = 0.36$), and especially total dentoalveolar height ($r = 0.41$), the greater the true rotation.

DISCUSSION

The mandible underwent substantial true rotation during the transition from late primary to early mixed dentition. There was almost 2.5° of true forward rotation, which amounts to 1.1°/y. This is similar to the 1.3°/y (age 6–8 years) reported by Wang et al.,[6] the 1.3°/y (age 5–10 years) reported by Miller and Kerr,[4] and the 0.9°/y (age 6–11 years) reported by Spady et al.[5] The high rates of true rotation that occur during this transition explain why previous studies[3–5] have reported greater amounts of true rotation during childhood than during adolescence. Annual rates of the true rotation during adolescence have been reported to range from 0.8°/y (age 10–15 years)[4] to 0.4°/y (age 11–15 years).[5]

The remodeling that occurred along the lower mandible border "covered up" the true rotation that occurred, resulting in little change in the mandibular plane angle. The current study showed approximately 1.9° of remodeling and 0.6° of apparent rotation. Greater amounts of remodeling than apparent rotation have been previously reported during the transition from late primary to early mixed dentitions,[6] during childhood,[4,5] and during adolescence.[5] Björk and Skieller[9] were among the first to emphasize the substantial amounts of resorption at the posterior aspect of the lower border of the mandible associated with true rotation.

True forward rotation indicates that there was more inferior displacement of the posterior mandible than of the anterior mandible. However, the growth changes in anterior face height (Na-Me) were greater than the increases in posterior facial height (S-Go). This discrepancy can be explained by the relatively large amounts of resorption that occur at the gonial angle, which cause the growth of posterior facial height measurements based on landmarks such as a gonion (S-Go or Co-Go) to be underestimated. Using mandibular superimpositions, Buschang and Gandini[2] showed that over 40% of the growth at the condylion between 10 and 15 years of age was negated by resorption at the gonion. This indicates that the posterior facial growth in the present study could well have been greater than the growth changes in anterior face height. Moreover, the increase in anterior facial height was partially due to deposition at the menton,

Table 4. Changes in Dental Variables from Late Primary (T1) to Early Mixed (T2) Dentition[a]

		T1		T2		Difference	
		Mean	SD	Mean	SD	Mean	SD
AP dental	U1/S-N, °	88.56	6.40	99.39	6.72	10.84**	7.26
	U1/PP, °	96.05	6.77	106.90	6.60	11.08**	7.12
	IMPA, °	86.80	7.09	91.91	6.12	5.11**	5.86
	Overjet, mm	3.03	1.47	3.85	1.59	0.81**	1.79
Vertical dental	Overbite, mm	1.79	1.61	2.11	1.90	0.31	2.30
	ANS-Pr, mm	17.21	1.79	12.56	2.11	−4.75**	1.83
	Id-Me, mm	28.11	2.39	26.03	2.00	−2.34**	1.44
	ANS-Pro + In-Me, mm	45.32	3.73	38.59	3.56	−6.72**	3.15
	U1-PP, mm	24.44	1.88	24.80	2.55	0.36	2.10
	L1-MP, mm	30.27	2.27	32.23	2.49	1.95**	1.79
	U6-PP, mm	18.50	1.51	17.37	1.51	−1.13**	−0.12
	L6-MP, mm	25.38	1.83	25.27	1.88	−0.12	1.32

[a] SD indicates standard deviation; AP, anterior-posterior.
** Paired *t*-test for equality of means was significant at the 0.01 level (two-tailed).

Table 5. Correlations between True Rotation and Late Primary (T1)-Early Mixed (T2) Dentition Changes in Skeletal Variables[a]

		True Rotation	
		Pearson Correlation	Significance
AP skeletal	SNA, °	−0.284*	0.046
	SNB, °	−0.233	0.103
	ANB, °	−0.006	0.966
Vertical skeletal	S-N,Go-Gn, °	0.398**	0.004
	N-Me, mm	0.244	0.088
	ANS-Me, mm	0.191	0.184
	S-Go, mm	−0.037	0.8
	Co-Go, mm	−0.095	0.51
	Ar-Go, mm	−0.278	0.051
	Co-Go-Me, °	0.060	0.681
	S-Go/N-Me	−0.289*	0.042

[a] AP indicates anterior-posterior.
** Correlation was significant at the 0.01 level (two-tailed);
* Correlation was significant at the 0.05 level (two-tailed).

indicating that the distance N-Me overestimated the actual amount of displacement.

The upper and lower permanent incisors were tipped significantly more labially than the deciduous incisors. U1/S-N and U1/PP increased significantly during the transitional dentition phase of dental development. The proclination of the upper incisors, which was significantly greater than that of the lower incisors, was probably due to the size differences of the primary and permanent crowns, especially of the central incisor, amounting to approximately 2 mm.[24] They compensated for the size discrepancy by proclining, which explains the increases in arch depth that have been associated[25] with the eruption of the permanent incisors. Wang and coworkers[6] also showed that true mandibular rotation during the transition from the primary to mixed dentition was associated with maxillary incisor proclination. The more flared upper incisors might be creating more room for the mandible to rotate forward. The changes in overjet and overbite from T1 to T2 were masked by the larger size of the permanent incisors. Proclination of the lower incisors had been previously related to forward mandibular rotation,[8] presumably as a compensation to their posterior displacement with forward mandibular rotation.

Table 6. Correlations between True Rotation and Late Primary (T1)-Early Mixed (T2) Dentition Changes in Dental Variables[a]

		True Rotation	
		Pearson Correlation	Significance
AP dental	U1/S-N, °	−0.339*	0.016
	U1/PP, °	−0.360*	0.010
	IMPA (L1-MP), °	0.042	0.774
	Overjet, mm	0.043	0.769
Vertical dental	Overbite, mm	0.213	0.138
	ANS-Pr, mm	0.264	0.064
	Id-Me, mm	0.360*	0.010
	ANS-Pr + Id-Me, mm	−0.413**	0.003
	U1-PP, mm	0.241	0.092
	L1-MP, mm	0.219	0.126
	U6-PP, mm	0.136	0.345
	L6-MP, mm	−0.110	0.449

[a] AP indicates anterior-posterior.
** Correlation was significant at the 0.01 level (two-tailed);
* Correlation was significant at the 0.05 level (two-tailed).

Anterior alveolar height decreased significantly during the transition between the late primary and early mixed dentition. ANS-Pr and Id-Me decreased a total of 7.1 mm between 5.8 and 8.0 years of age. Buschang and coworkers[22] showed that anterior upper alveolar height decreases more than lower alveolar height during the transition of the dentition. They found that anterior alveolar height had attained over 100% of its adult size by 5.5 years of age and decreased to approximately 80% of its adult size during the transition. This decrease in height is probably a compensation for the larger clinical crown height of permanent incisors. Interestingly, there was no significant change in the distance U1-PP over the 2.2 years, which is unexpected given the amount of vertical growth that occurred. On the other hand, L1-MP increased significantly during the transition from T1 to T2. It should be noted that the overall increases in lower facial height previously described were probably associated with the increases in lower incisor to mandibular plane (L1-MP) observed.

The decreases in anterior alveolar height were closely correlated with true forward rotation. Of all the dental variables evaluated, the decreases in overall alveolar height, which combined upper and lower alveolar height, were most closely associated with true mandibular rotation. Wang et al.[6] reported a lower, but significant, correlation ($r = 0.250$) between true forward mandibular rotation and the decrease in ANS-Pr. Björk[1] argued that Type III rotation, the center of which is located at the premolar and molars, was related to large overjet, suggesting that it is the existing space, or the space created, in the anterior segment that allows the mandible to rotate forward to a greater extent.

Between approximately 6 and 8 years of age the upper and lower deciduous central and lateral incisors are lost and the permanent incisors erupt. Importantly, up to 4 years are required for the central incisors to attain 100% of their clinical crown height.[26] More specifically, it takes 3.0–3.5 months for the upper and lower permanent central incisors to erupt 50% of their respective intraoral heights, 6.0–7.5 months to erupt

70%, and 19 months to erupt 90%.[26] This provides more than enough time for the space created by decreases in anterior alveolar height to accommodate a forward-rotating mandible.

Importantly, vertical skeletal growth was not related to the true rotation that occurred. According to Björk,[1] forward rotation takes place as a result of a marked increase in ramus height and a normal increase in anterior face height. However, the present study showed that rotation was not significantly correlated with growth changes of S-Go, Co-Go, or Ar-Go. In other words, individuals with greater forward rotation did not exhibit greater amounts of posterior growth. Enlow[27] suggested that as the mandible grows vertically, simultaneous resorption occurs along the posterior border of the mandible. Hans et al.[28] indicated that seven out of their 30 cases exhibited resorption along the inferior border of the ramus and a superior-anterior redirection of ramus growth; four of the seven cases showed this growth pattern at 6 years of age. As previously suggested, it is possible that this resorption along the posterior border of the mandible negated some of the vertical growth that occurred during the transitional period.

Finally, the forward growth of the maxilla was also correlated with true forward rotation. Subjects who showed greater increases in SNA also showed greater forward true rotation. Wang and coworkers[6] also found a significant correlation ($r = -0.376$) between true forward rotation and the increases in SNA between 8.4 and 15.4 years of age, but not during the transitional dentition phase. Importantly, the increases in SNA were not correlated to proclination of the upper incisors. Forward displacement of the maxilla might be creating space at the anterior region to allow the mandible to rotate forward. As previously discussed, Björk[1] argued that greater forward mandibular rotation takes place when space, such as overjet, exists in the anterior region because it moves the center of rotation posteriorly toward the occluding molars. Space created by the forward displacement of the maxilla certainly contributed to the observed true forward rotation of the mandible.

CONCLUSIONS

- Substantial amounts of true mandibular forward rotation of the mandible took place during the transition from late primary to early mixed dentition, which was largely masked by remodeling along the lower border.
- There were no significant differences in true mandibular rotation, remodeling, and apparent rotation between males and females or between subjects with Class I and Class II occlusions.
- True mandibular rotation was significantly associated with the decrease in anterior alveolar height, increases in SNA, and proclination of the upper incisors, all of which could have created space for the mandible to rotate forward.
- True mandibular rotation was not significantly associated with the increases in posterior face height.

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