Treatment effects of quad-helix on the eruption pattern of maxillary second molars

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ABSTRACT

Objective: To evaluate the effects of quad-helix treatment on the eruption pattern of maxillary second molars in patients with maxillary incisor crowding.

Materials and Methods: The lateral cephalograms of 40 consecutively treated patients in the early mixed-dentition group (treatment group) were examined in comparison with those of the same number of untreated patients with a similar form of malocclusion (control group). The cephalograms of the treated patients were taken at the start (T0) and at the end (T1) of treatment, and those of the untreated patients were also taken at about the same time as T0 and T1. The mean ages at T0 and T1 in the two groups were about the same.

Results: Distal tipping and movement and impeded extrusion of the maxillary first molars were notable in the treatment group compared with the control group. The actual treatment changes with the use of the quad-helix found expression in distal tipping and impeded vertical eruption of maxillary second molars. The more the maxillary first molars were tipped distally and the less the maxillary first molars extruded, the more the vertical eruption of the maxillary second molars was impeded.

Conclusion: Quad-helix treatment gives rise to spontaneous distal tipping and impeded vertical eruption of the maxillary second molars. (*Angle Orthod.* 2012;82:676–681.)

KEY WORDS: Quad-helix; Maxillary second molar eruption

INTRODUCTION

The quad-helix appliance has long since come into common use to correct posterior crossbites and relieve the tooth size–arch length discrepancy in the mixed dentition by dint of slow maxillary expansion.[1–3] Previous studies reported that quad-helix treatment caused the maxillary first molars to tip buccally,[1,2,4,5] lingually,[3] or distally[3] and to rotate mesiobuccally,[5,6] contrary to the primary intent of the expansion protocol. Clinical experience shows that in almost all patients treated with a quad-helix appliance, a delay in the eruption of the maxillary second molars causes a postponement of phase 2 orthodontic treatment to a later date. The distal tipping of the maxillary first molars during the quad-helix appliance treatment may result in the delayed eruption of the maxillary second molars.

No study on an association between the eruption pattern of maxillary second molars and quad-helix treatment was found in a PubMed search. Several studies have found that headgears and pendulum appliances are effective and reliable methods for distalizing the maxillary first molars.[7–10] These findings are similar to what we found in our previous quad-helix study.[3] Some studies reported that headgears and pendulum appliances caused the maxillary second molars to tip and move distally following the distalization of maxillary first molars.[7–9] Moreover, Abed and Brin[10] found a delayed eruption concurrent with spontaneous distal movement of the maxillary second molars following maxillary first molar distalization with a combination headgear treatment. The purpose of this study was to evaluate the effects of quad-helix treatment on the eruption pattern of maxillary second molars in patients with maxillary incisor crowding.

MATERIALS AND METHODS

The treatment group comprised 40 consecutive, nonrandomized patients (15 boys and 25 girls) who had been treated to relieve maxillary incisor crowding

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Table 1. Mean Ages at the Start (T0) and End (T1) of Treatment/Observation and Mean Treatment/Observation Time (T1–T0)

	Treatment Group				Control Group			
	Boys (n = 15)		Girls (n = 25)		Boys (n = 15)		Girls (n = 25)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age at the start of treatment/observation (T0)	9 y 8 mo	1 y 4 mo	9 y 6 mo	1 y 6 mo	9 y 10 mo	1 y 4 mo	9 y 2 mo	1 y 4 mo
Age at the end of treatment/observation (T1)	10 y 8 mo	1 y 4 mo	10 y 8 mo	1 y 4 mo	11 y 3 mo	11 mo	10 y 5 mo	1 y 4 mo
Treatment/observation time (T1–T0)	1 y 1 mo	5 mo	1 y 2 mo	7 mo	1 y 5 mo	9 mo	1 y 3 mo	10 mo

SD indicates standard deviation.

with a quad-helix appliance at the orthodontic clinic in the Nippon Dental University Niigata Hospital (Niigata, Japan). The materials were lateral cephalograms obtained at the start (T0) and at the end (T1) of quad-helix treatment. The changes that occurred during the T0–T1 period were compared with those that occurred during the corresponding period in a control group of patients who had not undergone any orthodontic treatment but were placed under observation. The lateral cephalograms for the control patients were taken at T1 to observe tooth development and eruption. The observation was made once every 2 or 3 months.

The control group consisted of 40 consecutive, nonrandomized patients (15 boys and 25 girls). The two groups were also well matched with respect to mean ages at T0 and T1. All cephalograms were coded by a person who was not directly involved in this study. The selection criteria in the treatment and control groups were (1) moderate maxillary incisor crowding (<3 mm) with positive overjet and overbite, (2) fully erupted maxillary first molars and incisors, (3) presence of maxillary deciduous second molars at T0, (4) unerupted or incompletely erupted maxillary second molars at T1, (5) consecutive good-quality lateral cephalograms at T0 and T1, (6) no tooth agenesis exclusive of third molars, (7) no extraction of permanent teeth during treatment/observation, and (8) no previous orthodontic or prosthodontic treatment. The subjects in the treatment and control groups were selected retrospectively. Table 1 shows the mean ages at T0 and T1 and the mean treatment/observation time (T1–T0). As shown in Table 2, a two-way analysis of variance did not find any significant differences in the mean ages at T0 and T1, in the mean treatment/observation time between sexes or between groups, or significant interactions between two variables.

The quad-helix appliance used in this study was made of 0.8-mm stainless-steel wire soldered to maxillary first molar bands, and its lingual arms were extended mesially to the deciduous canines. It was activated primarily to correct the distobuccal rotation of the maxillary first molars and then expand the maxillary first molars and posterior teeth in that order. Prior to cementation, the molar bands were kept parallel to each other and the lingual arms were kept apart from the lingual surfaces of the posterior teeth for correcting molar rotation and torque and expanding the first molars. During treatment, the patients visited us once a month, and further activation was performed on the lingual arms and lateral bridges with a pair of three-jawed pliers intraorally and sometimes extraorally. Following the correction of molar rotation, the lingual arms were kept in touch with the lingual surfaces of the posterior teeth for expansion. After adequately relieving the arch length discrepancy, the quad-helix appliance was used as a retention appliance and then removed at T1.

To avoid any measurement bias, a single investigator measured the coded cephalograms blindly to group, sex, and time of taking them (at T0 or T1). Afterward, the results of the measurements were sorted by these parameters for statistical comparisons.

Table 2. Results of Two-Way Analysis of Variance for Comparisons of Mean Ages at T0 and T1 and Mean Treatment/Observation Time (T0–T1)

	Source	*F* Value	*P* Value		Power
Age at T0	Sexes	1.579	.213	NS	.237
	Groups	0.071	.790	NS	.058
	Interaction	0.729	.396	NS	.135
Age at T1	Sexes	1.920	.170	NS	.277
	Groups	0.297	.587	NS	.084
	Interaction	2.233	.139	NS	.314
Treatment/observation time (T1–T0)	Sexes	0.000	1.000	NS	.050
	Groups	2.369	.128	NS	.330
	Interaction	1.029	.314	NS	.171

NS indicates not significant.

Table 3. Definition of Reference Points and Lines and Measurements Used

	Definition
Reference point	
ANS	Anterior nasal spine, tip of anterior nasal spine seen from norma lateralis
PNS	Posterior nasal spine, tip of posterior spine of palatine bone in hard palate
T	The most superior point of the anterior wall of the sella turcica at the junction with the tuberculum sella
U6MC	The midpoint between the most convex mesial and distal points on the crown of the maxillary first molar
U7MC	The midpoint between the most convex mesial and distal points on the crown of the maxillary second molar
Reference line	
U6	The long axis of the maxillary first molar, a perpendicular to a line connecting the most convex mesial and distal points on the crown of the maxillary first molar through U6MC
U7	The long axis of the maxillary first molar, a perpendicular to a line connecting the most convex mesial and distal points on the crown of the maxillary second molar through U7MC
x-axis	The palatal plane connecting ANS and PNS
y-axis	A perpendicular to the x-axis (the palatal plane) through point T
Measurement	
U6-x (°)	The angle between U6 and the x-axis
U6MC-x (mm)	The distance from U6MC to the x-axis
U6MC-y (mm)	The distance from U6MC to the y-axis
U7-x (°)	The angle between U7 and the x-axis
U7MC-x (mm)	The distance from U7MC to the x-axis
U7MC-y (mm)	The distance from U7MC to the y-axis

Cephalometric Measurement

All cephalograms were taken with the same cephalostat and with the standardized settings. Each coded lateral cephalogram was traced and measured. When a double image of the molars was present, all measurements were made of the smaller image seen distally. Five reference points, four reference lines, and two angular and four linear measurements were selected to evaluate orthodontic movement of the maxillary first and second molars, after the methods described by Tortop and Yuksel[9] and Abed and Brin[10] (Table 3; Figure 1). The angular measurements were made to the nearest 0.5° using a protractor, and the linear measurements were made to the nearest 0.1 mm using a pair of digital sliding calipers.

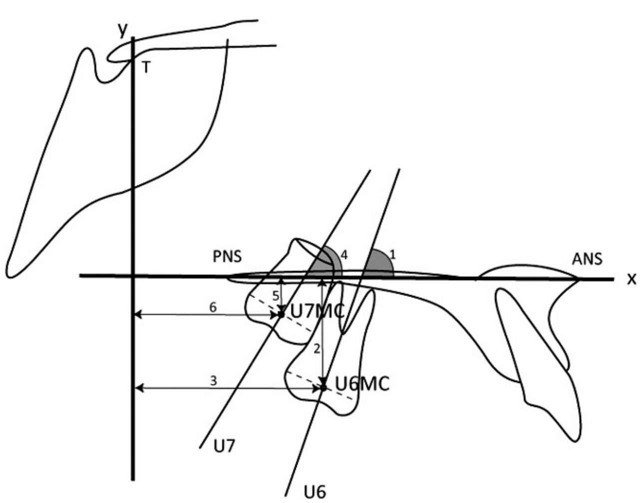

Figure 1. Reference points and lines and measurements used: 1, U6-x (°); 2, U6MC-x (mm); 3, U6MC-y (mm); 4, U7-x (°); 5, U7MC-x (mm); 6, U7MC-y (mm).

Statistical Analysis

Statistical analyses were performed with a commercially available statistical package (SPSS, version 17, Chicago, Ill). Means and standard deviations were calculated for each measurement in each sex and each group. As shown in Tables 4 and 5, unpaired *t*-tests did not reveal any significant differences in any measurements at T0 (S1) nor any changes in measurements during treatment/observation (S4) between sexes in each group. Therefore, all subjects were merged for the rest of the analyses.

Unpaired *t*-tests were used to test the significance of differences in measurements at T0 and treatment changes (T1–T0) between the treatment and control groups. Paired *t*-tests were used to determine the significance of differences in measurements between T0 and T1 in each group. Pearson's correlation analysis was used to investigate the relationships between treatment changes in the measurements of the maxillary first and second molars. The correlation analysis was performed between three measurements at U6-x, U6MC-x, and U6MC-y and two measurements at U7-x and U7MC-x, which showed significant treatment changes (Table 6; S4).

Measurement Error

To assess measurement errors, 50 cephalograms were randomly selected and remeasured by the same examiner (Dr Kobayashi) for a second time 1 month

Table 4. Results of Cephalometric Measurements for Each Sex and Statistical Comparisons Between Sexes in the Treatment Group

	Boy (n = 15)						Girl (n = 25)						S1		S4	
	T0		T1		T1–T0		T0		T1		T1–T0					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* Value		*P* Value	
U6-x (°)	74.40	4.14	73.10	3.36	−1.30	4.76	73.44	3.52	73.36	4.38	−0.08	3.49	.439	NS	.357	NS
U6MC-x (mm)	15.77	1.82	17.30	2.05	1.53	1.59	15.86	2.62	16.76	2.52	0.90	1.53	.895	NS	.218	NS
U6MC-y (mm)	28.30	3.96	28.23	2.68	−0.07	2.99	26.60	3.45	26.56	2.63	−0.04	2.46	.162	NS	.976	NS
U7-x (°)	62.53	4.94	62.20	4.44	−0.33	1.54	60.64	4.12	59.96	3.55	−0.68	2.44	.200	NS	.625	NS
U7MC-x (mm)	2.67	1.45	4.53	2.20	1.87	1.25	3.52	2.35	5.64	2.81	2.12	1.81	.163	NS	.636	NS
U7MC-y (mm)	22.40	3.31	22.80	3.14	0.40	1.24	22.00	2.93	22.48	3.42	0.48	1.26	.693	NS	.846	NS

NS indicates not significant; S1, statistical comparison at T0 between sexes; S4, statistical comparison of treatment change (T1–T0) between sexes.

later. Student's *t*-test with a 95% confidence interval did not reveal any systematic errors. Random errors, determined by calculating the standard deviations of the differences between the first and second measurements, were less than 0.55 mm and less than 0.44°, which were unlikely to spoil the significant results in this study.

RESULTS

There were no significant differences in any of the measurements at T0 or in any measurement changes during the T1–T0 period between sexes in each group (Tables 4 and 5).

Of all cephalometric measurements, the U6-x angle showed a significant difference at T0 between the treatment and control groups (Table 6; S1).

The U6MC-x, U7MC-x, and U7MC-y dimensions significantly increased during the treatment/observation period in both groups (Table 6; S2, S3). The U6-x and U7-x angles and the U6MC-y dimension significantly increased during the period under observation in the control group (Table 6; S3).

The U6-x and U7-x angles and the U6MC-x, U6MC-y, and U7MC-x dimensions showed significantly different changes between the treatment and control groups, which implied the actual treatment changes after the quad-helix treatment (Table 6; S4). The maxillary first molars (U6-x, U6MC-y) tipped and moved distally in the treatment group (mean 0.54° and 0.05 mm, respectively) and mesially in the control group (mean 2.8° and 2.73 mm, respectively), thus indicating that the mean amounts of actual treatment changes in distal tipping and movement of the maxillary first molars were 3.34° and 2.78 mm, respectively. The maxillary second molars (U7-x) were tipped distally in the treatment group (mean 0.55°) and mesially in the control group (mean 2.13°), thus indicating that the mean amount of actual treatment changes in distal tipping of the maxillary second molars was 2.68°. The maxillary first and second molars (U6MC-x, U7MC-x) were extruded in the treatment group (1.14 mm and 2.03 mm, respectively) and the control group (2.16 mm and 4.89 mm, respectively), thus demonstrating that the vertical eruption of the maxillary first and second molars was significantly impeded by 1.02 mm and 2.86 mm with the quad-helix treatment, respectively.

Correlation Analysis

As shown in Table 7, the change in the U7MC-x dimension had significantly positive correlations with those in the U6-x angle and U6MC-x dimension, thus implying that the more the maxillary first molars tipped distally and the less the maxillary first molars erupted,

Table 5. Results of Cephalometric Measurements for Each Sex and Statistical Comparisons Between Sexes in the Control Group

	Boy (n = 15)						Girl (n = 25)						S1		S4	
	T0		T1		T1–T0		T0		T1		T1–T0					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* Value		*P* Value	
U6-x (°)	72.50	3.77	75.73	3.95	3.23	4.67	70.18	4.93	72.72	4.82	2.54	3.83	.126	NS	.613	NS
U6MC-x (mm)	16.17	1.53	18.17	2.05	2.00	1.96	15.28	1.40	17.54	2.13	2.26	2.45	.069	NS	.730	NS
U6MC-y (mm)	27.93	2.34	31.33	2.89	3.40	2.20	26.40	2.53	29.20	3.20	2.80	3.32	.064	NS	.538	NS
U7-x (°)	62.60	1.06	64.60	2.72	2.00	2.17	61.20	3.30	63.40	2.75	2.20	3.08	.059	NS	.827	NS
U7MC-x (mm)	3.20	1.37	7.80	2.78	4.60	2.50	2.44	1.45	7.50	3.04	5.06	3.22	.109	NS	.638	NS
U7MC-y (mm)	23.67	3.52	24.67	3.13	1.00	1.41	21.80	3.20	22.64	3.16	0.84	2.37	.093	NS	.814	NS

NS indicates not significant; S1, statistical comparison at T0 between sexes; S4, statistical comparison of treatment change (T1–T0) between sexes.

Table 6. Results of Cephalometric Measurements for Combined Sexes and Statistical Comparisons Between the Treatment and Control Groups

	Treatment Group (n = 40)						Control Group (n = 40)									
	T0		T1		T1–T0		T0		T1		T1–T0		S1	S2	S3	S4
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* Value	*P* Value	*P* Value	*P* Value
U6-x (°)	73.80	3.74	73.26	3.98	−0.54	4.00	71.05	4.63	73.85	4.70	2.80	4.12	.005 **	.400 NS	.000 ***	.000 ***
U6MC-x (mm)	15.83	2.33	16.96	2.34	1.14	1.56	15.61	1.50	17.78	2.10	2.16	2.26	.629 NS	.000 ***	.000 ***	.021 *
U6MC-y (mm)	27.24	3.70	27.19	2.74	−0.05	2.63	27.13	2.87	29.85	3.30	2.73	2.88	.713 NS	.905 NS	.000 ***	.000 ***
U7-x (°)	61.35	4.48	60.80	4.01	−0.55	2.14	61.72	2.75	63.85	2.77	2.13	2.75	.654 NS	.111 NS	.000 ***	.000 ***
U7MC-x (mm)	3.20	2.08	5.23	2.63	2.03	1.61	2.73	1.45	7.61	2.91	4.89	2.94	.240 NS	.000 ***	.000 ***	.000 ***
U7MC-y (mm)	22.15	3.04	22.60	3.28	0.45	1.24	22.50	3.40	23.40	3.26	0.90	2.05	.629 NS	.027 *	.008 **	.239 NS

NS indicates not significant; S1, statistical comparison at T0 between the treatment and control groups; S2, statistical comparison of treatment change (T1–T0) in the treatment group; S3, statistical comparison of treatment change (T1–T0) in the control group; S4, statistical comparison of treatment change (T1–T0) between the treatment and control groups.

* $P < .05$; ** $P < .01$; *** $P < .001$.

the more the vertical eruption of the maxillary second molars was impeded.

DISCUSSION

Our results showed that distal movement (2.78 mm) of the maxillary first molars with distal tipping (3.34°) and impeded extrusion (1.02 mm) in the treatment group were actually significant treatment changes. These findings were confirmed by the study of Shundo et al.[3] although they, as well as Erdinc et al.[2] found no significant differences in the extrusion of the maxillary first molars between the quad-helix and untreated control groups. The significantly impeded extrusion of the maxillary first molars in the quad-helix group was probably due to the distal movement and tipping of the maxillary first molars, because the maxillary first molars were moved and tipped mesially in the untreated controls.

No literature was found on the association between the eruption pattern of the maxillary second molars and the quad-helix treatment in a PubMed search on the Internet. Therefore, our results for the maxillary second molars were discussed in comparison with those of several other studies using headgears and pendulum appliances, which caused delayed eruption and/or distal movement of the maxillary second molars following maxillary first molar distalization.[7–10] Our results showing a 0.45-mm mesial movement of the maxillary second molar with a distal tipping of 0.55° in the quad-helix treatment group were in marked contrast to the findings of their studies of the headgears and pendulum appliances, although there was no control group of untreated subjects in their studies. Ghosh and Nanda[7] reported that in the pendulum appliance group, the mean maxillary second molar distalization was 2.27 mm, with a distal tipping of 11.99°. Taner et al.[8] found that in the cervical headgear and pendulum groups, the maxillary second molars were moved distally 2.27 mm and 2.04 mm and tipped distally 4.3° and 11.04°, respectively. Tortop and Yuksel[9] reported a 2.3-mm distal movement with a distal tipping of 9.3° in the combination headgear group. The amount of distal tipping (0.55°) of the maxillary second molar in our study was smaller than that found in their studies.[7–9]

In this study, the actual treatment changes with the quad-helix were a significant distal tipping of 2.68° and impeded vertical eruption of the maxillary second molars by 2.86 mm. It has been reported that distalization of the maxillary first molars causes spontaneous distal tipping of the maxillary second molars,[7–9,11,12] which was confirmed in this study and evidenced by the fact that the more the maxillary first molars are tipped distally, the more the maxillary second molars are tipped distally, although there is no statistically significant correlation (Table 7).

The significantly impeded vertical eruption of the maxillary second molars in our study can be explained by impeded extrusion of the maxillary first molars with distal tipping. This explanation could be warranted by our results of the correlation analyses, which showed that the more the maxillary first molars tipped distally and the less the maxillary first molars extruded, the more the vertical eruption of the maxillary second molars was impeded. The distal tipping of the maxillary first molars after the quad-helix treatment might block the eruption path of the maxillary second molars in the present study. Abed and Brin[10] put forward a hypothesis that the more distal eruption of the maxillary second molars pointed to a longer eruption path, which needed

Table 7. Results of Correlation Analysis

	U7-x (°)		U7MC-x (mm)	
U6-x (°)	.181	NS	.317	*
U6MC-x (mm)	.062	NS	.336	*
U6MC-y (mm)	.016	NS	.009	NS

NS indicates not significant.

* $P < .05$.

a longer period of intra-alveolar eruption. This hypothesis was borne out by our study. The impeded vertical eruption of the maxillary second molars of 2.86 mm (4.89–2.03) amounted to about 58% (2.86/4.89) of the normal vertical eruption in the controls. From a clinical perspective, this impeded vertical eruption of the maxillary second molars may cause a delay in starting phase 2 orthodontic treatment following the quad-helix treatment, because the orthodontists generally await the eruption of the second molars.[10]

Visual evaluation of the subjects used in this study did not reveal the impaction of the maxillary second molars at the start of phase 2 orthodontic treatment. Abed and Brin[10] found that the impaction of the maxillary second molars was a possible but rare occurrence following distalization of the maxillary first molars, which was supported by our visual evaluation.

Our results showing no significant sex differences in any cephalometric measurements at T0 in each group were supported by Broadbent et al.[13] who stated that there is no sex difference in maxillofacial morphology before the appearance of secondary sexual characteristics, which occur after puberty and during the adolescent years. No isolated subjects according to sex were used in several studies on the effects of maxillary expansion[1,2,4,6] or molar destalization[7–12] on dentofacial morphology. This might have been due to the small sample size of either sex or in conformity with this statement by Broadbent et al.[13]

CONCLUSION

- The quad-helix treatment in the mixed-dentition patients with maxillary incisor crowding gives rise to spontaneous distal tipping and impeded vertical eruption of the maxillary second molars with distalization and impeded extrusion of the maxillary first molars.

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