Original Article

Intraoral Maxillary Molar Distalization

Movement before and after Eruption of Second Molars

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ABSTRACT

Objective: To evaluate the maxillary molar distalization and anchorage loss in two groups, one before (MD 1 group) and one after (MD 2 group) eruption of second maxillary molars.

Materials and Methods: After a sample size calculation, 20 patients were recruited for each group from patients who fulfilled the following criteria: no orthodontic treatment before distal molar movement, Class II molar relationship defined by at least end-to-end molar relationship, space deficiency in the maxilla, and use of an intra-arch NiTi coil appliance with a Nance appliance to provide anchorage. Patients in the MD 1 group were without any erupted second molars during the distalization period, whereas in the MD 2 group both the first and second molars were in occlusion at start of treatment. The main outcome measures to be assessed were: treatment time, ie, time in months to achieve a normal molar relation, distal movement of maxillary first molars, and anterior movement of maxillary incisors (anchorage loss). The mean age in the MD 1 group was 11.4 years; in the MD 2 group, 14.6 years.

Results: The amount of distal movement of the first molars was significantly greater ($P < .01$) and the anchorage loss was significantly lower ($P < .01$) in the group with no second molars erupted. The molar distalization time was also significantly shorter ($P < .001$) in this group, and thus the movement rate was two times higher.

Conclusions: It is more effective to distalize the first maxillary molars before the second molars have erupted.

KEY WORDS: Distal molar movement; Intraoral appliance; First and second molars

INTRODUCTION

Using intraoral appliances, maxillary molars can routinely be moved distally with little or no patient cooperation. A distal movement rate of approximately 1 mm per month of the first molars' crowns has been reported, but there is marked individual variation.[1–9] One factor that influences the movement rate is the type of movement and another factor is the timing of treatment.[4] Usually faster movement occurs when the molars are tipped whereas bodily movement takes longer time.[2]

A favorable time to move molars distally appears to be in the mixed dentition before the eruption of the second molars.[4] Furthermore, when molars are moved distally by intraoral mechanisms, anchorage loss will be evident as an increase in overjet of 1 to 2 mm.[2,4,6,8,9] The problem of increased overjet can be totally reversed and eliminated in most instances by subsequent multibracket appliance and intermaxillary Class II elastics.[10] However, the problem with anchorage loss is regarded as less before second molar eruption when compared with treatment after the eruption of the second molars.

Consequently, the usual recommended time to move maxillary molars distally with intraoral appliances is in the mixed or late mixed dentition.[4,11] However, good treatment results have been presented when second maxillary molars have erupted,[2,3,5,6,8] and obviously, there is need for more investigation on this topic. Thus, using an intraoral nickel titanium (NiTi) coil appliance for distal movement of maxillary molars, the

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Accepted: December 2005. Submitted: November 2005.

aim of this study was to evaluate distal molar movement, including anchorage loss, before and after eruption of second maxillary molars. It was hypothesized that intraoral movement of maxillary first molars before eruption of second maxillary molars will result in more effective molar movement and less anchorage loss than after eruption of second molars.

MATERIALS AND METHODS

In this study, subjects were divided into two groups. In one group, distal movement was performed on maxillary first molars, ie, before eruption of second maxillary molars (MD 1 group), and in the other group both first and second maxillary molars were simultaneously moved distally (MD 2 group). The sample size for each group was calculated and based on an alpha significance level of 0.05 and a beta of 0.1 to achieve 90% power to detect a mean difference of 0.2 mm per month (±0.15 mm per month) in distal molar movement rate between the MD 1 and MD 2 groups. The sample size calculation showed that 12 patients in each group were needed, and to increase the power even more it was decided to select 20 patients for each group.

The patients were retrospectively recruited from the Orthodontic Clinic in Malmoe and Hassleholm, both at the National Health Service, County Council Skane, Sweden. Two experienced orthodontic specialists had treated all the patients in the National Health Service system, in which the specialists are salaried and the treatment provided at no costs to the patient and the parents. The ethics committee of Lund/Malmoe University, Sweden, which follows the guidelines of the Declaration of Helsinki, had approved the protocol and informed consent form.

The inclusion criteria for all patients were: (1) the use of an intra-arch NiTi coil appliance with a Nance appliance to provide anchorage; (2) a nonextraction treatment plan; (3) a Class II molar relationship, defined by at least an end-to-end molar relationship; (4) a space deficiency in the maxilla; and (5) no orthodontic treatment before distal molar movement.

Besides the criteria above, the patients in the MD 1 group had to have all their maxillary first permanent molars in occlusion and no erupted maxillary second permanent molars during the distalization period, whereas in the MD 2 group both the first and second maxillary molars had to be in occlusion at the start of treatment. According to panoramic radiographs, all maxillary second and third molars were present in the alveolar bone in the MD 1 group. In the MD 2 group, the maxillary third molars were present in both the right and left sides in 17 of the 20 patients.

The 20 patients (10 boys and 10 girls) in the MD 1 group were identical to a group of patients earlier randomized for treatment using an intraoral NiTi coil appliance for distal movement of maxillary molars and had a mean age of 11.4 years (SD 1.37).[9] The MD 2 group included 20 patients randomly selected (through a random table) among 87 patients earlier treated using an intraoral NiTi coil appliance for simultaneous distal movement of maxillary first and second molars. The patients were matched to the patients in the MD 1 group regarding gender and had an average age of 14.6 years (SD 1.10).

The main outcome measures to be assessed in the trial were:

- Treatment time, ie, the time in months to achieve a normal molar relation.
- Distal movement and distal tipping of maxillary first permanent molars.
- Anterior movement and inclination of maxillary central incisors, ie, anchorage loss.
- Skeletal sagittal position changes of the maxilla and the mandible.
- Bite opening effect.

Appliance Design

The appliance in the MD 1 group (Figure 1) consisted of bands placed bilaterally on the maxillary first molars and either the second deciduous molars or the first or second premolars (this because some of the patients still had deciduous teeth left). There were nine patients with bands on second premolars, two with bands on first premolars, and nine with bands on second deciduous molars. The MD 2 group had their bands placed bilaterally on the first maxillary molars and on the second premolars (Figure 2). In both groups a 1.1-mm-diameter tube, approximately 10 mm in length, was soldered on the lingual side of the molar band. A 0.9 mm lingual arch wire that united a Nance acrylic button was soldered on the lingual side of the second deciduous molar or to the first or second premolar in the MD 1 group and to the lingual of the second premolar in the MD 2 group. The lingual arch wire also provided two distal pistons that passed bilaterally through the palatal tubes of the maxillary molar bands (Figures 1 and 2). The tubes and the pistons were required to be parallel in both the occlusal and the sagittal views.

A NiTi coil (GAC Int Inc, Central Islip, NY), 0.012 inches in diameter, with a lumen of 0.045 inches and cut to 10 to 14 mm in length, was inserted on the distal pistons and compressed to half its length when the molar band with its lingual tube was adapted to the distal piston of the lingual arch wire (Figures 1 and 2).[6] When the coil was compressed, two forces were produced, one distally directed force to move the molars

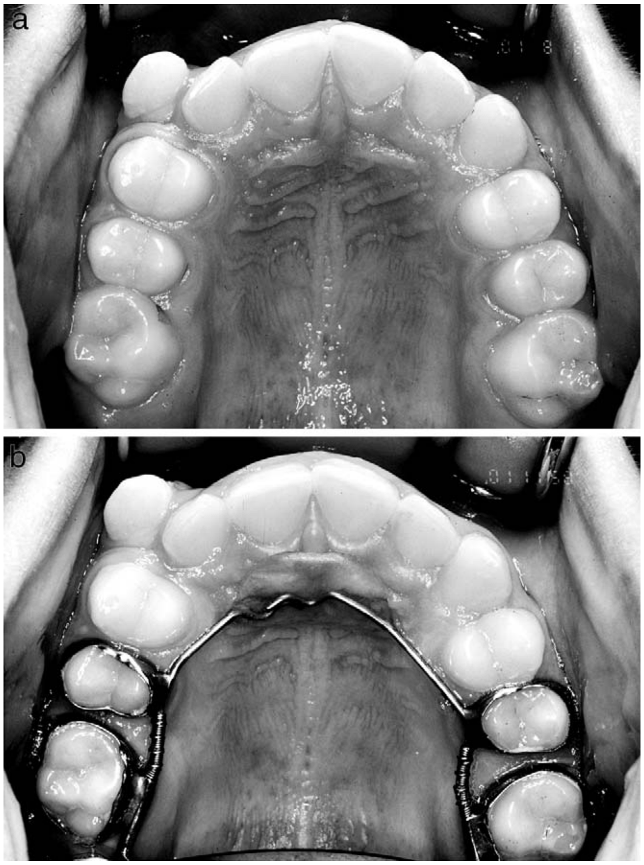


Figure 1. (a) Occlusal view before treatment of one patient in the MD 1 group with no second molars erupted. (b) Occlusal view of the intraoral appliance inserted in the same patient.

Figure 2. Occlusal view of the intraoral appliance in one patient in the MD 2 group with both second molars erupted.

distally and one reciprocal mesially directed force against which the Nance button provided anchorage. NiTi coils demonstrate a wide range of superelastic activity with a small fluctuation of load in spite of a large deflection. They also exhibit small increments of deactivation over time, and therefore the number of reactivation appointments can be reduced.[12]

Because the compression of the NiTi coil to half its length provided about 200 g of maximal force, and because of the small fluctuation of load in spite of a large deflection of the coil, the force fell from approximately 200 g to 180 g as the molars moved distally. Thus, after the appliances were inserted with the compressed NiTi coils, there was no need for further activation of the coils during the molar distalization period.[6] Two orthodontic technicians made the appliances and efforts were made to construct the Nance button with equal size and dimension for all patients.

Data Collection

The time in months to achieve normal molar relation by distal molar movement was recorded. Lateral head radiographs in centric occlusion were obtained at the start and after completion of molar distalization. The radiographs were taken with the same kind of equipment (Proline PM 2002 cc cephalostat, Planmeca OY, Finland) and under equivalent conditions. The measuring points, reference lines, and measurements used were based on those defined and described by Björk[13] and Pancherz.[14] Dental and skeletal changes as well as dental changes within maxilla and mandible were obtained by the Pancherz analysis. Measurements were made manually and by one author (Dr Bondemark) to the nearest 0.5 mm or 0.5°. Images of bilateral structures were bisected. No correction was made for linear enlargement (10%). Changes in the different measuring points during the treatment were calculated as differences between positions before and after treatment (after − before). An intention-to-treat approach was performed, and results from all patients were analyzed regardless of the outcome of treatment.

Statistical Analysis

The arithmetic mean and standard deviation were calculated for each variable. Differences in means within samples/groups were tested by paired *t*-tests and between samples/groups by unpaired *t*-tests. Differences with probabilities of less than 5% ($P < .05$) were considered statistically significant.

Error of the Method

Twenty randomly selected cephalograms were traced on two separate occasions. No significant mean differences between the two series of records were found by employing paired *t*-tests. The method error[15] ranged from 0.5 to 1.0° and 0.5 to 0.8 mm, except for the variables inclination of lower incisors and first maxillary molar inclination, for which errors were 1.5° and 1.4° respectively. The coefficients of reliability[16] ranged from .92 to .97 and from .94 to .98, respectively.

TABLE 1. Pretreatment Cephalometric Records

	MD 1 (n = 20)		MD 2 (n = 20)		Group Difference
	Mean	SD	Mean	SD	P
Sagittal variables (mm)					
Maxillary base, A-OLp	79.0	4.06	77.1	4.85	NS
Mandibular base, Pg-OLp	82.8	5.88	83.7	5.26	NS
Maxillary incisor, Is-OLp	85.9	4.78	83.6	5.51	NS
Mandibular incisor, Ii-OLp	82.0	5.32	79.5	5.54	NS
Maxillary molar, Ms-OLp	41.6	3.91	42.3	3.82	NS
Mandibular molar, Mi-OLp	41.6	4.03	42.0	3.73	NS
Molar relationship, Ms-OLp minus Mi-OLp	−0.1	1.27	−0.3	0.87	NS
Overjet, Is-OLp minus Ii-OLp	3.9	1.59	4.5	1.74	NS
Sagittal variables (°)					
Maxillary base inclination, SNA	79.6	2.82	78.1	4.20	NS
Mandibular base inclination, SNB	76.2	2.64	76.0	3.48	NS
Interjaw base inclination, ANB	3.4	1.63	2.1	2.29	NS
Maxillary incisor inclination, ILs/NSL	100.1	6.36	104.6	4.47	$<.05$
Mandibular incisor inclination, ILi/ML	91.4	4.01	88.9	6.61	NS
Maxillary first molar inclination, M1s/NSL	68.6	3.59	72.1	5.19	$<.05$
Vertical variables (mm)					
Overbite, Is-NSL minus Ii-NSL	3.1	1.87	3.3	2.24	NS
Vertical variables (°)					
Maxillary inclination, NSL/NL	5.8	3.01	4.7	3.76	NS
Mandibular inclination, NSL/ML	33.3	3.63	31.2	5.36	NS
Occlusal plane inclination, OL/NSL	19.0	4.06	17.1	4.00	NS

[a] MD 1 indicates one-molar distalization group; MD 2, two-molar distalization group; and NS, not significant. * $P < .05$; ** $P < .01$; *** $P < .001$.

RESULTS

No significant difference in treatment effects was found between girls and boys, and consequently, the data for girls and boys were pooled and analyzed together.

Pretreatment cephalometric records are summarized in Table 1. Cephalometrically the two groups were in good accordance with each other. There were no significant between-group difference for the variables measured except for the maxillary incisor inclination and the maxillary first molar inclination.

The average molar distalization time for the MD 1 group was 5.2 months (SD 1.00) and in the MD 2 group the corresponding time was 6.5 months (SD 0.83). Accordingly, the treatment time for the distal molar movement was significantly shorter for the MD 1 than for the MD 2 group ($P < .001$). The mean amount of distal molar movement within the maxilla was significantly greater in the MD 1 group than in the MD 2 group ($P < .01$), 3.0 mm (SD 0.64) vs 2.2 mm (SD 0.84; Table 2). Thus, the movement rate was almost two times higher in the MD 1 than in the MD 2 group, 0.63 vs 0.34 mm per month ($P < .001$). The average correction of molar relation was 3.3 mm in the MD 1 group and 2.5 mm in the MD 2 group (Figure 3).

The mean amount of distal tipping was small (below 3°) in both groups, with no significant difference between the groups (Table 2).

Because of anchorage loss, the maxillary incisors in both the MD 1 group and the MD 2 group proclined and moved forward 0.8 mm (SD 0.88) vs 1.8 mm (SD 0.97). Hence, a significantly greater anchorage loss occurred in the MD 2 group and, for every millimeter of distal molar movement, the anchorage loss was 0.27 mm in the MD 1 group and 0.82 mm in the MD 2 group. Also, the overjet was significantly increased in both groups, although no significant difference was found between the groups (Table 2).

Overbite was significantly reduced, by 0.8 mm (SD 0.80) in the MD 1 group and 1.2 mm (SD 1.01) in the MD 2 group (Table 2). During the trial period, the maxilla and mandible in both groups moved forward small amounts, and the mandibular as well as the maxillary inclination increased (Table 2; Figure 3). During the treatment period, the occlusal plane inclination was stable in the MD 1 group, but in the MD 2 group a change of 1.2° in a counterclockwise direction was found (Table 2).

DISCUSSION

The main findings of this study were that the amount of distal movement of the maxillary first molars was

TABLE 2. Changes in Cephalometric Variables within and between the Two Groups after Distal Movement of Maxillary Molars

	MD 1 (n = 20)		MD 2 (n = 20)		Group Difference
	Mean	SD	Mean	SD	*P*
Skeletal sagittal variables (mm)					
Maxillary base, A-OLp	0.8***	0.47	0.6**	0.71	NS
Mandibular base, Pg-OLp	0.8***	0.70	0.6**	0.86	NS
Skeletal + dental sagittal variables (mm)					
Maxillary molar position, Ms-OLp	−2.2***	0.78	−1.6***	0.75	<.05
Mandibular molar position, Mi-OLp	1.1***	0.87	0.9***	0.73	NS
Maxillary incisor position, Is-OLp	1.6***	0.99	2.4***	1.01	<.05
Mandibular incisor position, Ii-OLp	0.7***	0.75	0.9**	1.28	NS
Dental sagittal variables within the maxilla and mandible					
Maxillary molar, Ms-OLp (d) minus A-OLp (d)	−3.0***	0.64	−2.2***	0.84	<.01
Mandibular molar, Mi-OLp (d) minus Pg-OLp	0.3**	0.49	0.3*	0.72	NS
Maxillary incisor, Is-OLp (d) minus A-OLp (d)	0.8**	0.88	1.8***	0.97	<.01
Mandibular incisor, Ii-OLp (d) minus Pg-OLp (d)	−0.1	0.41	0.4	1.21	NS
Molar relationship, Ms-OLp (d) minus Mi-OLp (d)	−3.3***	0.89	−2.5***	0.81	<.05
Overjet, Is-OLp (d) minus Ii-OLp (d)	0.9***	0.88	1.5***	1.03	NS
Sagittal variables (°)					
Maxillary base inclination, SNA	0.2*	0.44	0.5*	0.96	NS
Mandibular base inclination, SNB	0.1	0.32	0.3	0.88	NS
Interjaw base inclination, ANB	0.1	0.52	0.2	1.09	NS
Maxillary incisor inclination, ILs/NSL	2.0**	2.66	3.9***	3.17	NS
Manibular incisor inclination, ILi/ML	0.1	0.81	0.2	2.18	NS
Maxillary first molar inclination, M1s/NSL	−2.9***	1.92	−3.0***	4.27	NS
Vertical variables (mm)					
Overbite, Is-NSL minus Ii-NSL	−0.8***	0.80	−1.2***	1.01	NS
Vertical variables (°)					
Maxillary inclination, NSL/NL	0.3*	0.71	0.7**	1.10	NS
Mandibular inclination, NSL/ML	0.5**	0.74	0.5*	1.08	NS
Occlusal plane inclination, OL/NSL	−0.1	0.60	−1.2***	1.17	<.01

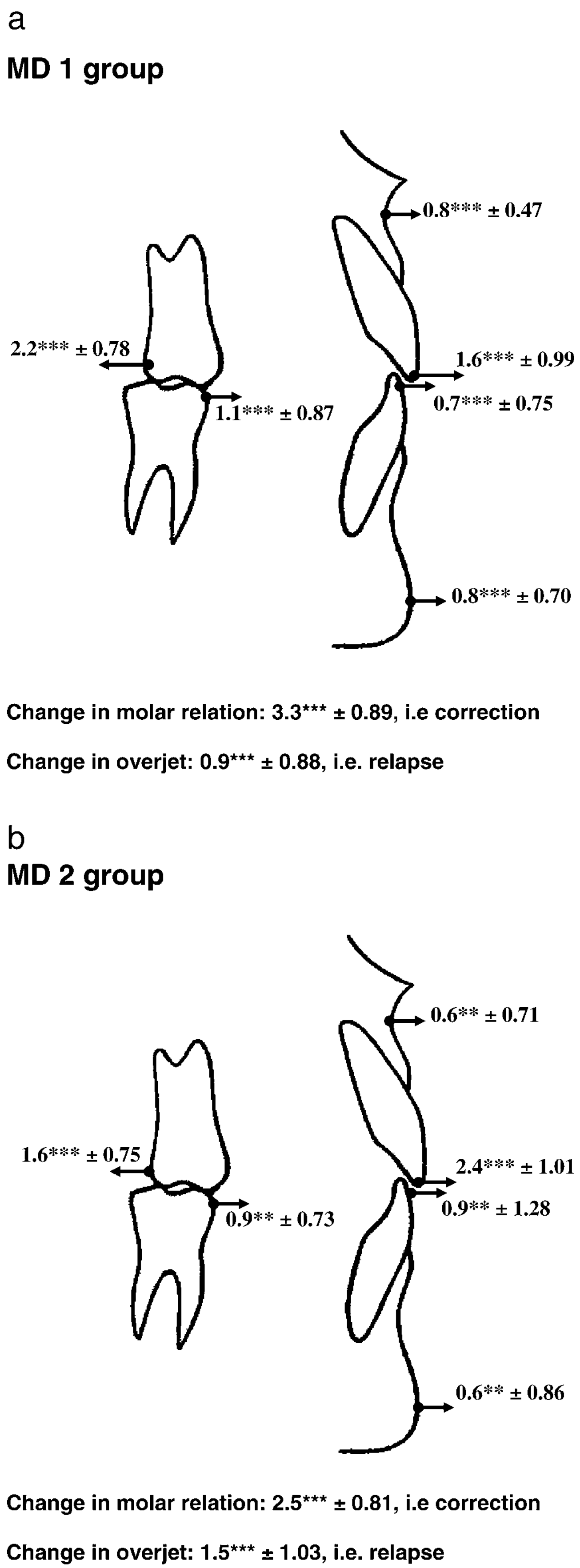
[a] Changes were calculated as the difference between positions before and after treatment (after − before). MD 1 indicates one-molar distalization group; MD 2, two-molar distalization group; and NS, not significant. * $P < .05$; ** $P < .01$; *** $P < .001$.

significantly greater and the anchorage loss was significantly lower in the group with no second molars erupted. The molar distalization time was also significantly shorter in this group, and thus the movement rate was two times higher. This leads to the conclusion that intraoral movement of maxillary first molars before eruption of second maxillary molars will result in more effective molar movement and less anchorage loss, as our opening hypothesis suggested. Thus, if there is an option to choose to move the maxillary molars distally in the mixed dentition or in the permanent dentition, it is an advantage to make this intervention as an early treatment.

The reason why it is more effective to move the maxillary first molars distally before the second molars have erupted is, of course, that there is one more tooth, and thus, a larger area of root surface to be moved when the second molars have erupted. Conceivably, this also implies that the strain on the anchorage teeth will increase when the first and second molars are moved simultaneously. Thus, the anchorage loss (forward movement of the maxillary incisors) will be lower if the molars are moved before eruption of the second molars. Even if the anchorage loss can be corrected with modest intervention,[4,10] the amount of lower anchorage loss will result in less time-consuming correction.

The findings in this study are similar to and are supported by another study, in which the efficiency of a pendulum appliance for distal molar movement was related to second and third molar eruption stage.[11]

It has been reported that the first molar crowns can be moved distally at the rate of approximately 1 mm per month, although there is marked individual variation.[1–9] In this study the mean rate of distal molar movement was 0.63 mm/mo in the MD 1 group. The lesser movement rate found in this study was because of the bodily movement of the molars, whereas in those studies that showed higher movement rates, the



movement consisted in considerable part of distal tipping.[17–19]

However, it can be pointed out that even if bodily movement takes a longer time, it seems more appropriate to move the molars bodily during a somewhat longer treatment time than move them quickly involving a distal tipping component, which will result in questionable stability and will later require another 4 to 6 months of rather difficult orthodontic molar uprighting.

The ultimate methodological design to evaluate the efficiency of distal molar movement before and after eruption of second molars has been to randomize the patients into two groups—one that started treatment in the mixed dentition with no erupted second molars, and one for which the intervention began later, when the second molars had erupted. The consequence of this strategy has been that the later group (ie, the MD 2 group) had to wait some years before treatment could start. In such circumstances, there is risk that new malocclusions will occur during the "waiting period" implying that the later group (MD 2 group) will not be comparable with the early intervention group (MD 1 group). Moreover, it can be claimed that postponement of the intervention when indicated will be unethical to the patients. Thus, for that reason a study design was used in which patients were retrospectively selected into two groups according to predefined inclusion criteria, except that the second molars were erupted in one group.

From an evidence-based view, it can be argued that the scientific evidence drawn from results of a retrospective study can be ranked only as low. However, even if a randomized controlled trial is the "gold standard," it has been claimed that sound methodology in a well-designed prospective or retrospective studies shall not be ignored when assessing scientific literature.[20]

CONCLUSIONS

- Intraoral movement of maxillary first molars before eruption of second maxillary molars will result in more effective molar movement and less anchorage loss than movement after eruption of second molars.
- Consequently, the most opportune time to move maxillary first molars distally is before eruption of the second molars.

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Figure 3. Skeletal and dental mean changes (in mm) and standard deviations contributing to alterations in sagittal molar relationship and overjet. N = 20 in each group. *$P < .05$; **$P < .01$; ***$P < .001$.

ACKNOWLEDGMENTS

The Swedish Dental Society and Skane County Council, Sweden, supported the research.

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