Systematic Review Article

Efficiency of molar distalization associated with second and third molar eruption stage
A systematic review

Carlos Flores-Mir[a]; Lisa McGrath[b]; Giseon Heo[c]; Paul W. Major[d]

ABSTRACT

Objective: To evaluate the efficiency of molar distalization associated with the second and third molar eruption stage.

Materials and Methods: A systematic computerized database search was conducted using several databases. Adaptations of the terms molar distalization and distalizing appliances were used. The reference lists of all the selected articles were also searched for any potential articles that might have been missed in the electronic search. The data provided in the selected publications were grouped and analyzed in terms of molar distalization with respect to various eruption stages of maxillary second and third molars.

Results: Out of the 13 initially identified articles only four fulfilled the final selection criteria. Three of the four studies showed no statistical significance in linear molar distalization based on the eruptive stage of the second and/or third molars, while one study found that the amount of distal movement of the first molars was significantly greater in the group with unerupted second molars. Only one study found that the amount of molar tipping that occurred as a result of distalization was related to the eruption stage of the maxillary molars. Similarly, three of the four studies found that molar distalization time was not significantly affected by eruption of the second or third molars.

Conclusion: The effect of maxillary second and third molar eruption stage on molar distalization—both linear and angular distalization—appears to be minimal. This conclusion is only based on low–level of evidence clinical trials. The large variability in the outcomes should be considered clinically. (*Angle Orthod.* 2013;83:735–742.)

KEY WORDS: Systematic review; Molar distalization; Eruption stage

INTRODUCTION

Maxillary molar distalization, a common treatment modality used to correct Class II malocclusions, is particularly indicated when maxillary skeletal or dentoalveolar protrusion is present. The success of molar distalization has been reported[1] to depend on two main factors: (1) the type of movement and (2) the timing of treatment. It has been argued[2] that when the second molar has not yet erupted, distalization of the first molar occurs by tipping rather than by bodily movement. Several other authors[1,3,4–9] agreed that the eruption stage of the second molar had an impact on the distalization of the first molar. Duration of therapeutic treatment has also been shown to increase if second molars have erupted, and therefore distalization is often recommended prior to the eruption of the full permanent dentition.[2]

On the other hand, there have also been a few investigations[10–14] that have concluded that the position of the second molar when distalizing the first molar is of little significance. The authors of these studies all found that there is no connection among second molar budding stages, magnitude of molar distalization, and duration of therapy. A clinical study[3] further argued that the success of first molar distalization varies according to the stage of development of the second and third molars. As a result, germectomy of wisdom teeth was recommended to achieve bodily distalization of both molars.

[a] Associate Professor and Head of the Division of Orthodontics, Department of Dentistry, University of Alberta, Edmonton, Alberta, Canada.

[b] Private Practice, St Johns, Newfoundland, Canada.

[c] Associate Professor, Department of Dentistry, University of Alberta, Edmonton, Alberta, Canada.

[d] Professor and Department Chair, Department of Dentistry, University of Alberta, Edmonton, Alberta, Canada.

Corresponding author: Dr Carlos Flores-Mir, Room 5-528, Edmonton Clinic Health Academy, University of Alberta, Edmonton, Alberta T6G 1C9, Canada
(e-mail: carlosflores@ualberta.ca)

Accepted: October 2012. Submitted: August 2012.
Published Online: Novermber 20, 2012

Although a large number of studies reporting on maxillary molar distalization have been published over the years, considerable controversy exists regarding upper first molar distalization with respect to second and third molar eruption stage. The aim of the present systematic review is therefore to investigate the efficiency of maxillary first molar distalization according to the stage of dental development of the second and/or third molars.

MATERIALS AND METHODS

To the extent feasible, reporting of this systematic review was done in accordance with the PRISMA statement checklist.[15]

PICO Question

Among orthodontic patients who require upper molar distalization, does the eruption stage of the second molar influence the magnitude and direction of dental movement?

Eligibility Criteria

Articles were selected when maxillary molar distalization was studied in human subjects with Class II malocclusions with measurable pretreatment and posttreatment cephalometric values. Every clinical study that included a comparison group was acceptable (no case reports or series of cases). No language restriction was set.

Articles were selected for final inclusion and analysis if all of the following criteria were met:

- Appliance used reported*
- Sample size identified*
- Duration of treatment reported*
- Eruption stage of maxillary second molars clearly defined along with a comparison of distalization pertaining to second and/or third molar eruption*
- No skeletal anchorage used

(Note: The asterisk indicates that when more than one publication about the same patient group was identified, the most informative and relevant article was selected for inclusion.)

Information Sources and Search

A systematic computerized database search was conducted using several databases to identify articles related to molar distalization. The following electronic databases were searched: Ovid Medline (1950 through week of April 15, 2012), all EBM reviews including Cochrane DSR, ACP Journal Club, DARE, CCTR, CMR, HTA and NHSEED, (1980 through week of April 15, 2012), PubMed (1966 through week of April 15, 2012), and Thomsen's ISI Web of Science, (1900 through week 15 of April, 2012). Terms related to "molar distalization" were used. Specific selection terms were chosen for each individual database with the guidance of a senior librarian with expertise in health science database searches. Details of the PubMed search and the definition of the acronyms can be found in Appendix 1. The reference lists of all the selected articles were also searched for any potential articles that might have been missed in the electronic search of the databases.

Study Selection

Once the computerized search was complete, potentially pertinent articles were selected from the abstracts and/or titles by two researchers. The chosen articles were then retrieved and independently reviewed, again by two researchers. Cases involving discrepancies in the selection process were settled by consensus.

Data Items and Collection Process

Information regarding several variables (publication year, sample size, comparison group, average age, study type, appliances used, reference plane, mean distalization and tipping, and treatment duration) was collected from each selected article (Tables 1 through 3). Data collection was conducted by one author and cross-checked by another.

Risk of Bias in Individual Studies

Some key methodological variables were assessed for each study (Table 1). The identified limitations were considered when analyzing and consolidating the available information in the discussion.

Summary Measures

Mean first molar distalization and tipping in relation to the eruption stage of the second molar were the outcome variables.

Synthesis of Results and Risk of Bias Across the Studies

Significant differences in the methodology of the included studies precluded a meta-analytic approach.

RESULTS

Study Selection

The original search located 588 potential articles. From the abstracts and/or titles of these articles, only 13 articles were found to be potentially relevant for this study. A hand search of the reference lists from the selected articles provided two additional articles. Out

Table 1. Description of Studies Included in the Final Selection[a]

Study	Year	Comparison Groups According to Molar Eruption	Sample Size, n	Average Age, y	Selection	Appliance Used
Kinzinger et al.[3]	2004		36	12.03	Prospective	Pendulum K
		Group 1 = incomplete eruption of second molars	18			
		Group 2 = second molars erupted to level of occlusal plane and third molars at budding stage	15			
		Group 3 = germectomy of wisdom teeth and second molars erupted	3			
Karlsson and Bondemark[9]	2006		40	11.4	Retrospective	NiTi Coil appliance with Nance to provide anchorage
		Group 1 = before eruption of the second molars	20			
		Group 2 = first and second molars fully erupted	20			
Bussick and McNamara[13]	2000		101	12.1	Retrospective	Pendulum
		Group 1 = erupted second molars	57			
		Group 2 = unerupted second molars	44			
Ghosh and Nanda[11]	1996		41	12	Retrospective	Pendulum
		Group 1 = erupted second molars	18			
		Group 2 = unerupted second molars	23			

[a] Listed for each study are the year of publication, the sample size (n) (and the subsequent sample size of each group defined by molar eruption stage), the average age of all subjects (in years) at the beginning of treatment, the type of study, and the appliance used to gain molar distalization. In all studies, total distalization was defined after the distalization appliance was no longer active and before full fixed appliances were implemented. NiTi indicates nickel titanium.

of the 15 articles initially chosen, only four fulfilled the final selection criteria. The remaining 11 articles were rejected because they reflected the use of skeletal anchorage systems and because the molar distalization methods used were not clearly defined (Appendix 2).

Study Characteristics

Out of the four chosen articles only one was prospective; three of the four used the pendulum appliance. Key information for the selected studies can be found in Table 1, which provides methodological details of the selected articles and the types of appliance used to gain distalization of the molars.

Study Characteristics and Risk of Bias

Kinzinger et al.[3] divided all subjects into three groups according to the stage of eruption of the second and third molars, while Karlsson and Bondemark[9] and

Table 2. Molar Horizontal Distalization for Various Stages of Second and Third Molar Eruption[a]

Study	Group Classifications (and Subheadings) According to Molar Eruption	Reference Plane for Linear Distalization	Mean Linear Distalization, mm (Standard Deviation)	Mean Treatment Duration, wk	Significance of Linear Distalization
Kinzinger et al.[3]	Group 1 = second molars incompletely erupted or unerupted	PTV	M1 = 3.16 (0.77)	12.8	NS
	Group 2 = second molars erupted to level of occlusal plane and third molars at budding stage	PTV	M1 = 3.21 (1.01) M2 = 2.26 (0.84)	17.6	NS
	Group 3 = second molars erupted and germectomy of third molars	PTV	M1 = 2.70 (1.55) M2 = 2.27 (0.75)	24	NS
Karlsson and Bondemark[9]	Group 1 = second molars not erupted (second and third molars were present in alveolar bone)	OLp vertical	M1 = 3.00 (0.64)	22	***
	Group 2 = second molars erupted and distalized simultaneously with first molars (third molars were present, but unerupted, in the left and right sides of all patients)	OLp vertical	M1 and M2 = 2.20 (0.84)	26	***
Bussick and McNamara[13]	Group 1 = second molars unerupted	Fiducial lines[13]	M1 and M2 = 5.70 (1.60)	28	NS
	Group 2 = second molars erupted	Fiducial lines[13]	M1 and M2 = 5.60 (2.00)	28	NS
Ghosh and Nanda[11]	Groups were differentiated according to second molar eruption for discussion purposes only. No numerical differences were given other than stating that differences were not statistically significant	PTV	M1 = 3.37 (2.10) M2 = (SD not reported) M3 = (SD not reported)	24.8	NS

[a] PTV indicates that relative distal movement of the first and second molars were measured to the vertical of the pterygoid; M1, maxillary first molar; M2, maxillary second molar; and OLp vertical, perpendicular from Sella to the occlusal line.

*** $P \leq .001$. NS indicates not statistically significant.

Table 3. Molar Tipping (Distal Crown Tip) for Various Stages of Second and Third Molar Eruption[a]

Study	Group Classifications (and Subheadings) According to Molar Eruption	Reference Plane for Angular Distalization	Mean Angular Distalization, ° (Standard Deviation)	Mean Treatment Duration, wk	Significance of Angular Distalization
Kinzinger et al.[3]	Group 1 = second molars incompletely erupted or unerupted	SN	M1 = 5.36 (3.49) M2 = 4.06 (2.15)	12.8	** *
	Group 2 = second molars erupted to level of occlusal plane and third molars at budding stage	SN	M1 = 0.80 (3.40) M2 = 7.92 (5.83)	17.6	** *
	Group 3 = second molars erupted and germectomy of third molars	SN	M1 = 0.67 (2.08) M2 = 2.00 (1.73)	24	NS NS
Karlsson and Bondemark[9]	Group 1 = second molars not erupted (second and third molars were present in alveolar bone)	NA	M1 = 3.00 NR	22	NS
	Group 2 = second molars erupted and distalized simultaneously with first molars (third molars were present, but unerupted, in the left and right sides of all patients)	NA	M1 and M2 = 3.00	26	NS
Bussick and McNamara[13]	Group 1 = second molars unerupted	FH	M1 = 11.70 (5.60)	28	NS
	Group 2 = second molars erupted	FH	M1 = 9.80 (5.60)	28	NS
Ghosh and Nanda[11]	Groups were differentiated according to second molar eruption for discussion purposes only. No numerical differences were given other than stating that differences were not statistically significant	SN	M1 = 8.36 (8.37) M2 = 11.99 NR M3 = 2.49 NR	24.8	NS

[a] SN indicates degrees of distal molar tipping determined by measuring the angle between the longitudinal tooth axis and the anterior cranium floor (SN); M1, maxillary first molar; M2, maxillary second molar; NA, not available; and FH, Frankfort horizontal.

* $P \leq .05$; ** $P \leq .01$. NS indicates not statistically significant.

Bussick and McNamara[13] divided all subjects into two groups, one with second molars erupted and one without second molars erupted, for statistical purposes. Ghosh and Nanda[11] did not specifically report the amount of distalization for the groups with maxillary second molars either erupted or unerupted, but they did report whether or not there was any statistical significance between these two groups.

Treatment times for distalization in all studies ranged from 12.83 to 28 weeks, with a mean of 22.9 weeks. One study[3] found treatment times to be longer, although not significantly, when first and second molars were distalized simultaneously, while another[9] found that molar distalization time was significantly shorter in patients with unerupted second molars.

Table 2 explores the quantitative differences in horizontal distalization for first and second maxillary molars for all chosen studies. Two[3,11] of the four studies used the same method to measure linear differences while the others[9,13] differed and were somewhat less clear on the methodology used. Three[3,11,13] of the four studies showed no statistical significance in horizontal molar distalization based on the eruptive stage of the second and/or third molars, while one study[9] found that the amount of distal movement of the first molars was significantly greater in the group with unerupted second molars. In this study, the mean amount of distal molar movement was 0.8 mm more for the group without erupted second molars.

The amount of molar tipping that occurred as a result of distalization is detailed in Table 3. Kinzinger et al.[3] found that during distalization the maxillary first molars tipped more when the second molars were unerupted and that the erupted second molars tipped more when the third molars were unerupted (ie, at the budding stage). The group with second molars unerupted showed that the maxillary first molars tipped 5° more (to the palatal plane) as they were distalized. Similarly, the group with third molars at the budding stage showed that the maxillary second molars tipped 5.9° more as they were distalized. No other study[9,11,13] found significant results for molar tipping with respect to second or third molar eruption stage. The effect of distalization on the maxillary third molars was extremely variable.[11]

DISCUSSION

This is the first review to systematically evaluate the efficiency of molar distalization related to second and third molar eruption stage. There does not appear to be consistent evidence supporting claims that second or third molar eruption stage has any clinically significant influence on molar distalization.

Summary of the Evidence

Intuitively, the recommendation to move molars distally with intraoral appliances in the mixed or late mixed dentition (ie, prior to second molar eruption) largely relies on the theory that when the second molar is erupted there is a larger root surface area imbibed in the bone that must be distalized, making movement in that direction more difficult.[3] Only one[9] of the four studies in this investigation showed a statistically

significant difference in the amount of maxillary first molar horizontal distalization with respect to the stage of eruption of the second molar. This particular study found that the amount of distal movement of the maxillary first molars was significantly greater (3 mm vs 2.2 mm) and that the distalization time was significantly shorter (5.2 months vs 6.5 months) in subjects with unerupted second molars. None of the other three studies[3,11,13] included in this review showed a statistically significant difference in the amount of linear distalization or the time in treatment and the stage of dental development. Importantly, the one study[9] that did show a difference in horizontal distalization may have suffered from inadequate statistical analysis. With numerous outcome measurements, the authors of the study performed multiple *t*-tests, as opposed to a single multivariate analysis of variance, which is designed for numerous outcome variables. Because of this, the chance of false-positive test results may have been inflated in this study.

Further exploration of the theoretical effect of early distalization when second molars are not yet completely erupted warrants attention. Kinzinger et al.[3] concluded that first molar distalization should commence prior to the eruption of second molars despite the fact that an unerupted second molar causes a significant amount of more pronounced distal tipping of the first molar. The authors' reasons for concluding this included the fact that when the first and second molars are distalized simultaneously there is a slightly greater loss of anchorage and the duration of therapy and the number of distal screw activations also increase. This study also found that the degree of distal tipping of first molars was smaller in patients with erupted second molars than in those whose second molars were not yet erupted. Similarly, when eruption of the second molar was complete, tipping of the first molar was greater when a third molar bud was located in the direction of movement.[3] Based on these results, the authors of this study theorized that when distalizing a molar, a tooth bud acts on the mesial neighboring tooth in the same manner as a fulcrum. Because the axis of rotation of a maxillary molar is near the trifurcation of its roots, a second molar bud will likely cause more pronounced distal tipping of the first molar if it has not yet erupted beyond this vertical level of the axis of rotation. This pattern of thinking is very akin to that of Graber,[2] who came to very similar conclusions on molar distalization tipping as early as 1955. Considering these facts, Kinzinger et al.[3] suggested that when tipping of the first molar needs to be kept to a minimum one can either wait for eruption of the second molar or apply additional torque to the first molar. These considerations are especially important with respect to stabilization, as tipped teeth are known to be less stable than those that are upright.[3] Controversially, the available evidence does not sustain these theoretical assumptions.

Other reasons have been given for early distalization. Bussick and McNamara[13] advised that for maximum first molar distalization with minimal increase in lower anterior facial height, distalization was most effective in patients with unerupted permanent maxillary second molars. This particular study found that the amount of horizontal and angular distalization was not statistically different in patients with erupted and unerupted second molars but that patients with unerupted second molars showed a smaller increase in lower anterior face height and mandibular plane angle and a slightly smaller decrease in overbite. If proven, the associated increase in facial height related to the eruption of maxillary second molars could be quite disadvantageous for some patients, as the downward and backward positioning of the chin point could exacerbate the Class II clinical appearance.[13] It has to be noted that this study had the largest sample size by over 50%.

The remaining article[11] reviewed in this article indicated that the eruption stage of maxillary second molars had minimal effect on the distalization of first molars. No statistical differences were found in either linear or angular distalization measurements. Notably, only appliances that resulted in no complications during treatment were included in the results of this study.

The effect of distalization on the maxillary third molars and the maxillary third molars' effect on distalization were determined to be extremely variable by Ghosh and Nanda[11] in 1996. In their study, no patients had more than half of root formation on the third molar teeth, and none of these teeth had a significant amount of horizontal or vertical change in position after distalization. Kinzinger et al.[3] disagreed with these results. Furthering their "fulcrum theory" of molar tipping, these authors found that if germectomy of the wisdom teeth had previously been carried out, almost exclusively bodily distalization of both molars was possible, even when the second molar was not banded. Since only three people were present in the group of patients with previous germectomy of the wisdom teeth, the authors of this article advise caution in interpreting the results of this study with respect to the presence or absence of third molars.

Limitations

No meta-analysis was executed because of the many methodological differences evident among the selected studies. While three studies used the pendulum appliance, one used nickel-titanium coil springs, and

the mechanisms of action of these appliances are quite different. Similarly, the choice of cephalometric landmarks used for construction of the reference planes offers the potential for heterogeneity of the results.

In addition, three of the four reviewed articles[9,11,13] retrospectively investigated cases that were treated in several different orthodontic offices, while one article[13] investigated as many as 101 cases from 13 practitioners. Sample size and intention-to-treat analysis were not adequately reported in any of the selected studies. Differences in treatment rendered under each of these practitioners could be a potential bias in comparing results obtained from their patients. Other factors that may influence the conclusions obtained include the number of teeth used for anchorage and the anchorage setup, the amount of force applied, and the frequency of reactivation of distalizing appliances.

As pointed out in a review[16] of maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion, the initial molar relationships can also affect results in this type of study. Full-cusp Class II relationships often require a different amount of movement (and likely a different force and duration of time in treatment) as compared with a cusp-to-cusp relationship. The extent of pretreatment Class II molar relationship is often not clearly stated in studies.

Ideally, the studies used for this type of a systematic review should be randomized, controlled clinical trials with a sufficient number of subjects. Because of the small number of prospective clinical trials available on this topic, investigators had to compromise and chose to include retrospective trials as well. Future studies, ideally prospective with larger sample sizes, are required to add further insight into this discussion. Future studies could also focus on loss of anchorage in molar distalization treatment with respect to second and third molar eruption. This query, anterior anchorage loss, is obviously very clinically relevant but was beyond the scope of this review. In addition, the long-term stability of dental movements achieved is a critical aspect of this type of movement (especially when distal molar tipping is noted), but it too was beyond the scope of this article. Another consideration for future research would be to compare the efficiency of distalization with respect to more clearly defined eruptive stages of the first and second molars. Finally, the use of bony-anchoraged distalization appliances should be explored. No study involving these appliances and evaluating the effect of second molar eruption stage was identified.

It is possible that the critical timing of distalization has less to do with gaining more horizontal and less angular distalization and more to do with minimizing deleterious side effects (such as increased molar tipping, increased loss of anchorage, increased treatment duration time, and increased lower anterior face height) in some selective cases.

CONCLUSION

- The effect of maxillary second and third molar eruption stage on molar distalization—both horizontal and angular distalization—appears to be minimal. This conclusion is based only on low–level of evidence clinical trials. The large variability in the outcomes should be considered clinically.

REFERENCES

1. Gianelly AA, Vaitas AS, Thomas WM, Berger OG. Distalization of molars with repelling magnets. *J Clin Orthod*. 1988; 22:40–44.
2. Graber TM. Extraoral forces—facts and fallacies. *Am J Orthod*. 1955;41:490–505.
3. Kinzinger GS, Fritz UB, Sander FG, Diedrich PR. Efficiency of a pendulum appliance for molar distalization related to second and third molar eruption stage. *Am J Orthod Dentofacial Orthod*. 2004;125:8–23.
4. Ten Hoeve A. Palatal bar and lip bumper in nonextraction treatment. *J Clin Orthod*. 1985;19:272–291.
5. Jeckel N, Rakosi T. Molar distalization by intra-oral force application. *Eur J Orthod*. 1991;3:43–46.
6. Hilgers JJ. The pendulum appliance for Class II noncompliance therapy. *J Clin Orthod*. 1992;226:706–714.
7. Bondemark L, Kurol J, Bernhold M. Repelling magnets versus superelastic nickel-titanium coils in the simultaneous distal movement of maxillary first and second molars. *Angle Orthod*. 1994;64:189–198.
8. Gianelly AA. Distal movement of the maxillary molars. *Am J Orthod Dentofacial Orthop*. 1998;114:66–72.
9. Karlsson I, Bondemark L. Intraoral maxillary molar distalization—movement before and after eruption of second molars. *Angle Orthod*. 2006;76:923–929.
10. Muse DS, Fillman MJ, Emmerson WJ, et al. Molar and incisor changes with Wilson rapid molar distalization. *Am J Orthod Dentofacial Orthop*. 1993;104:556–565.
11. Ghosh J, Nanda RS. Evaluation of an intraoral maxillary molar distalization technique. *Am J Orthod Dentofacial Orthop*. 1996;110:639–646.
12. Byloff FK, Darendeliler MA. Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. *Angle Orthod*. 1997;67:249–260.
13. Bussick TJ, McNamara JA Jr. Dentoalveolar and skeletal changes associated with the pendulum appliance. *Am J Orthod Dentofacial Orthop*. 2000;117:333–343.
14. Joseph AA, Butchart CJ. An evaluation of the pendulum distalizing appliance. *Semin Orthod*. 2000;6:129–125.
15. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Checklist (2009), Available at: http://www.prisma-statement.org/. Accessed October 8, 2012.
16. Antonarakis GS, Kiliaridis S. Maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion—a systematic review. *Angle Orthod*. 2008;78: 1133–1140.

APPENDIX 1
PubMed Electronic Database Search Terms and Strategy

No.	Keywords/Search Strategy
1	Molar distalization
2	Maxillary molar distalization
3	Upper molar distalization
4	First molar distalization
5	(#1) OR (#2) OR (#3) OR (#4)

Definition of acronyms:
EBM = Evidence Based Medicine.
DSR = Database of Systematic Reviews.
ACP = American College of Physicians.
DARE = The Database of Abstracts of Reviews of Effectiveness.
CCTR = Cochrane Controlled Trials Register.
CMR = Cochrane Database of Methodology Reviews.
HTA = Health Technology Assessments.
NHSEED = NHS Economic Evaluation Database.

APPENDIX 2
Flow diagram of Literature search and Selection Criteria