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Maxillary Molar Distalization with Noncompliance Intramaxillary Appliances in Class II Malocclusion

A Systematic Review

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ABSTRACT

Objective: To use published data to evaluate quantitatively the dental effects of noncompliance intramaxillary appliances in individuals with Class II malocclusion.

Materials and Methods: A literature search was carried out identifing 13 prospective or retrospective clinical studies matching inclusion criteria. Only appliances with conventional anchorage designs were considered for the review. The data provided in these publications were grouped and analyzed in terms of molar distalization, tipping and vertical movements, and incisor and premolar mesialization, tipping, and vertical movements.

Results: Maxillary first molars showed distal crown movement and tipping greater than the mesial crown movement and tipping shown by incisors and premolars. Vertical movements of incisors and premolars were in general extrusive, but molars were intrusive or extrusive, depending on the study and the type of appliance used. Appliances that acted palatally seemed to display a smaller distal tipping movement, as well as smaller incisor and premolar mesial tipping movements, when compared with those that acted buccally. Friction-free appliances, namely the pendulum, produced a large amount of mesiodistal movement and tipping, if no therapeutic uprighting activation was applied.

Conclusions: Noncompliance intramaxillary molar distalization appliances all act by distalizing molars with a concomitant and unavoidable loss of anchorage, as revealed by incisor and premolar mesial movement. Buccal acting and palatal acting appliances demonstrate almost similar results, with palatal acting appliances showing less tipping. Friction-free palatal acting appliances appear to produce better molar distalizing effects, but with a concomitant notable loss of anchorage.

KEY WORDS: Class II malocclusion, Noncompliance, Molar distalization.

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INTRODUCTION Return to TOC

The creation and use of intramaxillary intraoral appliances for molar distalization in Class II malocclusion have been made possible through advancements in biomechanics and technology and materials that have allowed the delivery of light and constant forces over a wide range of deactivation.[1]

The application of force in these appliances can occur from the buccal region, the palatal region, or both. The forces applied can involve friction (sliding mechanics), as with the use of nickel-titanium (NiTi) coil springs,[2] or they can be friction free, as when the pendulum appliance is used.[3] When the efficiency of these different categories of appliances is compared, it is not clear which ones are associated with the largest molar distalization and which produce the smallest quantity of undesirable adverse effects, such as loss of anchorage and molar tipping.

A meta-analysis would better enable evidence-based decisions, but this type of study is not possible because randomized clinical trials are few. Therefore, investigators in the present study elected to collect data from existing studies on the use of noncompliance intramaxillary appliances for molar distalization for the purpose of analyzing their effects as a whole and when grouped according to types of appliances. Appliance groups were categorized as (1) those with a buccal application and those with a palatal force application, and (2) those with a friction-free mechanism and those with a sliding mechanism.

MATERIALS AND METHODS Return to TOC

Literature Search

A literature search was performed with the use of PubMed, Ovid, and the Cochrane Library to identify orthodontic articles that reported on the use of noncompliance intramaxillary molar distalization appliances for the management of Class II malocclusion. Terms used in the search included “Class II,” “noncompliance,” and “molar distalization.” The search was expanded with use of the Related Articles function in PubMed to locate lists of articles consulted, names of individual appliances used, and names of individual authors who have worked with a particular appliance. Full text sources available on the Internet for the *American Journal of Orthodontics and Dentofacial Orthopedics, European Orthodontic Journal,* and *The Angle Orthodontist* were also searched to validate that the search had identified all relevant articles.[4]

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

- Human studies
- Pertained to the use of intramaxillary noncompliance molar distalization appliances in the management of Class II malocclusion
- Treatment carried out with an appliance alone without the concomitant use of other appliances (eg, fixed appliances) and without the use of absolute or bony anchorage (eg, palatal implants, miniscrews)
- Mention of which appliance was used, along with a description if necessary
- Studies designed as prospective or retrospective studies, with the type of study mentioned (case studies/reports or case series excluded)
- Sample size mentioned (minimum, 10 patients)
- Appliances used in growing patients; age ranges and mean age at the start of treatment mentioned
- Duration of treatment mentioned (maximum duration, 12 months)
- Measurable pretreatment and posttreatment cephalometric values, as well as changes during treatment
- Measured molar distal movement and at least one other measurement from the following: incisor mesial movement, premolar mesial movement, molar distal tipping, incisor mesial tipping, premolar mesial tipping, molar vertical movement, incisor vertical movement, premolar vertical movement
- Sufficient data available for statistical calculations (mean and standard deviations for each measurement presented)
- Error of the method values stated and calculated by retracing radiographs with the use of Dahlberg's formula[5]; statement of how many radiographs/patients were used to calculate this. When using Dahlberg's formula $\sqrt{\Sigma\ d^2/2n}$, Σd^2 denotes the sum of the squared differences between pairs of recordings, and n denotes the number of duplicate measurements
- When more than one publication about the same patient group was identified, the most informative and relevant article was selected for inclusion

Data Analysis

The data provided in selected studies were collected and analyzed with no distinction made between different types of appliances. From the identified studies, investigators examined molar distal movement, premolar mesial movement, incisor mesial movement, molar distal tipping, premolar mesial tipping, incisor mesial tipping, molar vertical movement, premolar vertical movement, and incisor vertical movement.

The data from each group were compared with a constant that had a mean of zero and a standard deviation equal to the error of the method. According to the authors' assumptions, without treatment, the mean changes in the variables looked at would have been zero or negligible after a period of a few months, with a variance around the zero due to methodologic error. The error of the method was thus taken into account by using this as the standard deviation of the constant.

Data were subsequently entered into the meta-analysis program of the Cochrane Collaboration Review Manager Software (RevMan Version 4.2 for Windows. Copenhagen, Denmark. The Nordic Cochrane Centre. The Cochrane Collaboration, 2003). With the use of the random effects model, forest plots were drawn, mean and confidence interval values calculated, and significance tests carried out (to calculate *P* values). The results of individual studies thus were statistically combined into a single outcome measure, a feature distinctive of meta-analyses,[6] but the studies included were not only prospective controlled studies; thus, the term “meta-analysis” is not used here.

Studies were divided into those with buccal force application and those with palatal force application, and data were grouped accordingly. Once again, in accordance with the random effects model, forest plots were drawn, mean and confidence interval values calculated, and significance tests carried out (to calculate *P* values) for the different variables. Studies were not formally divided into friction and (sliding) friction-free mechanisms as was initially planned because the number of studies in which a friction-free appliance was used was limited.

RESULTS Return to TOC

Results of Search

The original search located 395 articles, including 376 human studies. Of these, 64 pertained to molar distalization of Class II malocclusion with an intraoral intramaxillary appliance. The articles that contained relevant and sufficient data for this study were further narrowed down to 13 (Table 1) by application of the inclusion criteria (Figure 1).[7–19] The results described below are summarized in Table 2 and in Figures 2 through 4.

Overall Treatment Effects

Sagittal treatment effects, namely, mesiodistal movement and tipping, were detected for molars, incisors, and premolars. When all appliances were considered together, first molars were noted to demonstrate a mean of 2.9 mm of distal movement with an associated 5.4° of distal tipping. Incisors showed a mean of 1.8 mm of mesial movement with 3.6° of mesial tipping, and premolars showed a mean of 1.7 mm of mesial movement.

Vertical movements of incisors and premolars were in general extrusive, and movements for molars were not statistically significant. Incisors revealed a mean extrusion of 0.4 mm and premolars of 1.1 mm.

Treatment Effects of Buccal and Palatal Acting Appliances

When buccal acting appliances were studied, molars demonstrated a distal movement of 2.6 mm and a distal tipping of 8.3°; for palatal appliances, these figures were 3.1 mm and 3.6°, respectively. The incisors showed a mesial movement of 1.9 mm and mesial tipping of 5.0° for buccal appliances and a 1.8 mm mesial movement and 2.9° mesial tipping for palatal appliances. For premolars, mesial movement of 2.0 mm and 7.0° mesial tipping were observed for buccal appliances, as was 1.3 mm mesial movement for palatal appliances.

When buccal appliances were used, a premolar extrusion of 0.7 mm and an incisor extrusion of 0.2 mm were observed. For palatal appliances, incisors revealed an extrusion of 0.7 mm and premolars an extrusion of 1.0 mm.

DISCUSSION Return to TOC

The present study showed that the use of noncompliance intramaxillary appliances produces distal molar movement, which is a combination of distal crown movement and tipping. This was accompanied by loss of anchorage, as can be seen by incisor and premolar movements. Premolars showed mesial crown movement and extrusion, and incisors showed mesial crown movement, tipping, and extrusion.

Palatal acting appliances consistently show less tipping for all teeth than do buccal acting appliances, as is demonstrated by a lack of overlap of their confidence intervals. A possible reason for this is that the moment arm of the force produced by palatally acting appliances is smaller because its line of action is closer to the center of resistance of the specific tooth.

The use of a Nance button to reinforce anterior anchorage does not serve as absolute anchorage during and after molar distalization.[2,9,20] The anchorage unit as a whole is unable to completely resist mesial forces; this is seen often as an increase in overjet and a proclination of maxillary incisors. Therefore, in patients who present with an already increased overjet, care must be exercised, and the use of these appliances should not be prescribed in every case of poor or reduced patient cooperation.

The reduced dependence on patient cooperation noted with the use of these appliances is not absolute in that patients may well need to comply later on in treatment. Therefore, one must consider alternative treatment options or, even more important, must try to improve patient motivation and cooperation.

Crown distal movement of maxillary molars is always accompanied in some degree by distal tipping. Some authors claim that the distal jet[21] produces better bodily molar movement.[20] The pendulum appliance, when used without accessory bends, can achieve a larger amount of molar tipping than is attained with other appliances.[22] This has been correlated with the amount of distalization.[22,23] In spite of this, large tipping movements can be corrected with maxillary molar uprighting bends. Byloff et al[24] suggested the use of 10° to 15° molar uprighting bends. The exactness of these bends, if done intraorally, may not be possible to measure, so approximations are made in practice.

It should be mentioned here that Kinzinger's modified pendulum, included in this review, employs slightly different biomechanics[25,26] such as extraoral preactivation, toe-in bend, and uprighting activation in the area of the pendulum springs, along with intraoral adjustment of the incorporated distal screw and, as a consequence thereof, reactivation of the distalizing force, the uprighting activation, and the toe-in bend.

In the present study, the greatest amount of molar distal tipping was found in a study in which the pendulum appliance was used. Conversely, this was associated with the greatest amount of distal crown movement. Apart from these observations, no other obvious differences between friction-free and sliding mechanics appliances could be seen or interpretations made; to a large extent, this was a result of the small number of included studies in which the pendulum appliance (ie, with a friction-free mechanism) was used.

One problem with combining data in the present study is that many methodologic differences were noted among the selected studies. Besides the use of different appliances, other factors that may influence the results obtained include teeth used for anchorage and the anchorage setup, the type of attachment, the size of the Nance button, the amount of force applied, and the frequency of reactivation.

Patient differences also can influence treatment results. Age may play a role, and only studies carried out on growing patients were included in this paper. Mean ages in the studies ranged from 11.2 to 14.9 years. Initial molar relationships also can affect results. Commonly, the amount of movement needed is different in a cusp-to-cusp relationship as compared with a full Class II molar relationship. Studies mention often that a Class II molar relationship is a prerequisite for inclusion in the study, but the extent may not be mentioned.

The eruption of second maxillary molars and the presence of third maxillary molar buds represent other important factors. One study by Karlsson and Bondemark[15] looked at the presence or absence of second molars and found that it is more effective to distalize the first maxillary molars before the second molars have erupted. Kinzinger et al[27] reported similar results, maintaining that appliances are more efficient when second molars are unerupted, but distal movement is still possible with erupted second molars. This was associated with a longer treatment time, the need for greater force, and greater anchorage loss, but with less tipping if the second molar was erupted. Investigators suggested that when second molars are in place, it is best to do a germectomy of any neighboring third molar that is present. These two studies do not support the previous claim that the presence of second molars does not significantly affect first molar distalization.[24,28]

The choice of cephalometric landmarks used to take measurements may also contribute to the heterogeneity of the results. Horizontal movements can be measured with the pterygoid vertical (PtV),[17] the occlusal line perpendicularly drawn through the sella (OLp),[15] or the vertical plane (VP)[19] as the reference point. Tipping movements can be measured with the sella-nasion plane (SN),[17] the palatal plane (ANS-PNS),[7] or the horizontal plane (HP)[19] used as the reference point. Vertical movements can be measured with ANS-PNS[17] or the HP[19] as the reference point. Apart from the reference point, different points on the tooth itself such as the incisal edge,[10] the cementoenamel junction (CEJ),[16] or the centroid[18] and others can be used for measurements.

The question of the influence of noncompliance intramaxillary Class II appliances on mandibular dental measurements is beyond the scope of this paper (it has been reported that mesial movements of mandibular molars also occur[28]). Similarly, a comparison was not made between different groups of patients, for example, high-angle and low-angle patients, as was done in the study of Toroğlu et al.[29]

A critical aspect of treatment with these appliances, also beyond the scope of this paper, is the long-term stability of dental movements achieved. Apart from some relapse in molar distalization, which may be expected during the stabilization phase of treatment, one common clinical observation is that some posterior anchorage loss is visible when retraction of anterior teeth is carried out in the second phase of treatment. The question of stability is an area that has not been investigated enough, and further work is needed if we are to gain a better understanding and an improved ability to quantify long-term changes.

Ideally, the results of such a study should be based on randomized, controlled clinical trials. Because of the small number of these, investigators had to compromise and chose to include prospective and retrospective clinical studies and to compare their results versus a constant. This constant, which was defined as zero, assumes that no significant tooth movement would take place in untreated individuals during a short period of less than a year, and that the standard deviation is the error of the method. If randomized, controlled trials cannot be carried out because of the nature of the treatment provided with these appliances, investigators consider that the error of the method based on double recordings could be a valuable element in the evaluation of relevant publications.

CONCLUSIONS Return to TOC

- Noncompliance intramaxillary molar distalization appliances used for the correction of Class II molar relationships all act by distalizing molars with a concomitant and unavoidable loss of anchorage.
- Simultaneous distal crown and tipping movements contribute to molar distalization.
- Anchorage loss is observed through premolar mesial movement and incisor mesial crown and tipping movements.
- Vertical movements are also present, and extrusion of incisors and premolars is observed.
- Buccal acting and palatal acting appliances demonstrate similar results, but palatal appliances act more closely to the center of resistance of the teeth, resulting in less tipping movements.

- Friction-free appliances (pendulum appliance) seem to be associated with a large amount of distal molar movement and concomitant substantial tipping when no therapeutic uprighting activation is applied.

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Table 1. Details of Studies Included for Data Analysis[a]

Study	Type of Study	Appliance	Buccal or Palatal	Anchorage Premolars	Tx Duration, m	n	N, Error of Method	Age at Start, y	7s Present
Bondemark, 2000[7]	Retrospective	Superelastic NiTi coils with Nance button	Palatal	2	6.5	21	20	14.4	Yes
		Repelling magnets with Nance button	Buccal	2	5.8	21	20	13.9	Yes
Bondemark and Karlsson, 2005[8]	Prospective randomized	Superelastic NiTi coils with Nance button	Palatal	2	5.2	20	20	11.4	No
Bondemark and Kurol, 1992[9]	Prospective	Repelling magnets with Nance button	Buccal	2	3.9	10	10	13.4	Yes
Bondemark and Kurol, 1998[10]	Prospective	Superelastic NiTi coils/ magnets, with Nance button	Buccal	2	6	18	10	14.7	Yes
Bondemark et al, 1994[11]	Prospective	Superelastic NiTi coils/ magnets, with Nance button	Buccal	2	6	18	10	14.9	Yes
Chaqués-Asensi and Kalra, 2001[12]	Retrospective	Pendulum	Palatal	2	6.5	26	10	11.2	11 Yes, 15 No
Erverdi et al, 1997[13]	Prospective	Repelling magnets with Nance button	Buccal	2	3	15	15	12.3	Yes
		NiTi coil appliance with Nance button	Buccal	2	3	15	15	12.3	Yes
Ferguson et al, 2005[14]	Retrospective	Distal Jet	Palatal	2	8	25	10	12.5	Not stated
		GMD appliance	Palatal and buccal	2	11	25	10	11.5	Not stated
Karlsson and Bondemark, 2006[15]	Retrospective	NiTi coil appliance with Nance button	Palatal	2	5.2	20	20	11.4	No
		NiTi coil appliance with Nance button	Palatal	2	6.5	20	20	14.6	Yes
Kinzinger et al, 2005[16]	Prospective	Modified Pendulum	Palatal	4	5.5	10	30	12.8	No
Mavropoulos et al, 2005[17]	Prospective	Superelastic NiTi coils with Nance button	Buccal	2	4.1	10	10	13.2	Yes
Papadopoulos et al, 2004[18]	Retrospective	Superelastic NiTi coils with Nance button	Buccal	2	3.8	14	14	13.4	Yes
Sayinsu et al, 2006[19]	Prospective	Modified Keles	Palatal	2	6	17	10	13.6	Not stated

[a] Studies are listed in alphabetic order by first author. Listed for each study are the type of study, the appliance used, whether force application was buccal or palatal, the number of premolars that were made part of the anchorage setup, treatment (Tx) duration in months (m), sample size (n), sample size (N) of the retracings used for the error of the method, mean age at start of treatment in years, and whether or not second molars (7s) were present. The numeric difference between the sample size (n) and the sample size (N) of the retracings used for the error of the method measurements is due to the fact that for some studies, not all radiographs were retraced to calculate the error of the method, only a selected number were chosen at random, and other studies retraced a larger patient sample.

Table 2. Summary of Results[a]

	All Appliances	Buccal Appliances	Palatal Appliances
Molar distal movement (mm)			
Mean change	2.9***	2.6***	3.1***
95% CI	[2.4, 3.3]	[2.1, 3.0]	[2.3, 3.8]
Molar distal tipping (°)			
Mean change	5.4***	8.3***	3.6***
95% CI	[4.0, 6.8]	[7.3, 9.3]	[2.4, 4.7]
Incisor mesial movement (mm)			
Mean change	1.8***	1.9***	1.8***
95% CI	[1.7, 2.0]	[1.7, 2.1]	[1.5, 2.1]
Incisor mesial tipping (°)			
Mean change	3.6***	5.0***	2.9***
95% CI	[2.4, 4.8]	[4.4, 5.7]	[1.5, 4.3]
Premolar mesial movement (mm)			
Mean change	1.7***	2.0***	1.3***
95% CI	[1.2, 2.2]	[1.6, 2.5]	[0.7, 2.0]
Premolar mesial tipping (°)			
Mean change	2.5	7.0***	0.1
95% CI	[−0.3, 5.2]	[5.9, 8,2]	[−3.1, 3.2]
Molar vertical movement (mm)			
Mean change	−0.5	0.2	−1.4
95% CI	[−1.5, 0.5]	[−0.6, 1.1]	[−3.1, 0.2]
Incisor vertical movement (mm)			
Mean change	0.4***	0.2	0.7***
95% CI	[0.2, 0.6]	[0.0, 0.5]	[0.3, 1.0]
Premolar vertical movement (mm)			
Mean change	1.1***	0.7***	1.0**
95% CI	[0.6, 1.5]	[0.4, 1.0]	[0.4, 1.7]

[a] Shown are mean changes and 95% confidence intervals (CIs) to the nearest decimal point for all appliances grouped together, as well as for buccal acting and palatal acting appliance groups, when compared with the constant. Changes in mesial/distal and vertical movements are expressed in millimeters, and changes in tipping are expressed in degrees. A positive value for vertical movements indicates extrusion, and a negative value indicates intrusion. Statistical significance is denoted by * $P < .01$; ** $P < .001$; *** $P < .0001$.

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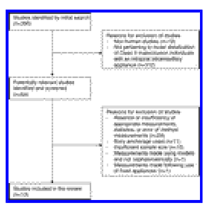

Click on thumbnail for full-sized image.

Figure 1. Flow diagram summarizing literature search

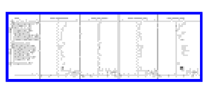

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Figure 2. Forest plots representing the sagittal effects of noncompliance intramaxillary molar distalizing appliances on incisors and molars (namely, mesiodistal and tipping movements). The studies are listed in order of the type of appliance used and are summarized in Table 1. Shown for every study is the weighted mean difference (WMD) between the treatment and the constant according to the random effects meta-analysis model, as well as the 95% confidence interval (95% CI) for each variable. The diamonds represent the overall WMD and the 95% CI, and the exact values are stated below each diamond. For each forest plot, *P* values (for statistical significance) are also shown

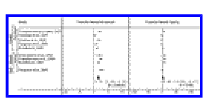

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Figure 3. Forest plots representing the sagittal effects of noncompliance intramaxillary molar distalizing appliances on premolars. For further information, see Figure 2

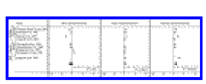

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Figure 4. Forest plots representing the vertical effects of noncompliance intramaxillary molar distalizing appliances on molars, incisors, and premolars. Positive values indicate extrusion and negative values intrusion. For further information, see Figure 2

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