European Journal of Orthodontics 22 (2000) 683–695

A comparative analysis of distal maxillary molar movement produced by a new lingual intra-arch Ni-Ti coil appliance and a magnetic appliance

Lars Bondemark
Department of Orthodontics, Faculty of Odontology, Malmö University, Malmö, Sweden

SUMMARY The aim of the study was to evaluate cephalometrically the dental and skeletal treatment effects of a new lingual intra-arch Ni-Ti coil appliance for molar distalization and to compare these with those of an established intra-arch appliance that uses repelling magnets for distal molar movement.

Two groups of 21 adolescents, all girls, participated in this retrospective study. One group was treated with the new lingual Ni-Ti coil appliance for 6.5 months and the other with the magnetic appliance for 5.8 months. The treatment effects were analysed by measurements on lateral head radiographs at the start of treatment and after the molar distalization was completed.

The mean amount of distal molar movement was 2.5 mm (SD 0.69) in the lingual coil group and 2.6 mm (SD 0.51) in the magnet group. A significantly higher degree of distal molar tipping was found in the magnet group, –8.8 degrees, compared with –2.2 degrees for the lingual coil group. Due to anchorage loss, the maxillary incisors moved forwards, and the overjet was increased by an average of 1.2 mm in the lingaul coil group and 1.7 mm in the magnet group.

The results indicate that the new lingual Ni-Ti coil appliance was better choice than the magnet appliance for distal bodily movement of maxillary molars. The benefits of the new Ni-Ti appliance were due to the design preventing molar tipping and its single activation.

Introduction

A common strategy to correct a Class II dental malocclusion or to create space in the maxillary arch by a non-extraction protocol is to move the maxillary molars distally in the initial stages of treatment, and thereby gain space and convert the Class II molar relationship to a Class I. The molars are then held in place while the premolars, canines, and incisors are retracted. A variety of modes of treatment have been suggested, including those that are dependent on patient compliance, such as extra-oral traction (Graber, 1955; Wieslander, 1975; Kurol and Bjerklin, 1984), extra-oral traction in combination with removable appliances with finger springs (Cetlin and TenHoeve, 1983) and Class II inter-maxillary elastics (Proffit, 1993). Despite their efficacy in tooth movement, all these treatments are highly dependent on patient co-operation. Therefore, various intra-arch devices that have almost eliminated reliance on the patient have been introduced. These techniques include repelling magnets (Gianelly *et al*., 1989; Bondemark and Kurol, 1992; Steger and Blechman, 1995), super-elastic coils (Jones and White, 1992; Bondemark *et al*., 1994; Carano and Testa, 1996; Gianelly, 1998; Gulati *et al*., 1998), super-elastic nickel titanium wires (Locatelli *et al*., 1992), nickel titanium appliances (Corbett, 1997), Wilson arches (Wilson, 1978), Herbst appliances (Pancherz and Anehus-Pancherz, 1993) and Hilgers' pendulum appliances (Hilgers, 1992; Ghosh and Nanda, 1996; Byloff and Darendeliler, 1997). However, most of the intra-arch maxillary molar distalizing appliances tend to tip the maxillary first molar crowns distally to an overcorrected Class I position while tipping the molar roots mesially (Bondemark and Kurol, 1992; Muse *et al*., 1993; Ghosh and Nanda, 1996; Byloff and Darendeliler, 1997). Unless a supplemental force system is used to provide a moment that torques the root distally, a significant amount of anchorage loss may occur as the molar relapses to an upright position. Thus, if the maxillary molar is moved bodily, the risk of relapse is reduced and less time may be required in stabilizing the molar in its new position. To overcome the problem of molar tipping, a new lingual Ni-Ti coil intra-arch appliance with fixed pistons and steel tubing lingually that can allow bodily movement of the maxillary molars is introduced. The aim of this study was to evaluate cephalometrically the dental and skeletal treatment effects of this new lingual intra-arch Ni-Ti coil appliance for molar distalization and to compare the treatment effects with those of an established intra-arch appliance that uses repelling magnets for distal molar movement.

Subjects and methods

Two groups of 21 adolescents, all girls, participated in the study. One group was treated for molar distalization with a new lingual intra-arch Ni-Ti coil appliance and the other with an intra-arch appliance that used repelling magnets. The subjects were selected retrospectively from the records of adolescents referred for orthodontic treatment and the treatments were provided by one operator. The mean starting age was 14.4 years (SD 1.40) for the lingual Ni-Ti coil appliance group (L) and 13.9 years (SD 1.94) for the magnet appliance group (M). All the subjects met the following criteria:

(1) no orthodontic treatment before molar distalization;
(2) both first and second maxillary molars in occlusion;
(3) a non-extraction treatment plan;
(4) use of the two appliances as the first phase of orthodontic treatment for gaining space in the maxillary arch or for bilateral distalization of the maxillary molars for correction of the Class II molar relationship, defined by at least an end-to-end molar relationship;
(5) good oral hygiene and no damage to the appliance, as determined from the treatment records;
(6) good quality lateral head radiographs taken immediately before and after removal of the appliances.

Design of the lingual intra-arch Ni-TI coil appliance

The lingual intra-arch Ni-Ti coil appliance is shown in Figure 1A. The appliance consisted of maxillary first molar and second premolar bands on the right and left sides. Lingually, on the molar band, a tube 1.1 mm in diameter and approximately 10 mm in length was soldered. A 0.9-mm lingual archwire, which united a Nance acrylic button, was soldered lingually to the second premolar band. The lingual archwire was provided with two distal pistons that passed bilaterally through the palatal tubes of the maxillary molar bands. The tubes and pistons were required to be parallel in both the occlusal and sagittal views. A Ni-Ti coil (GAC Int. Inc., Central Inslip, NY, USA), 0.012 inches in diameter, with a lumen of 0.045 inches, and cut to 10–14 mm in length, was inserted on the distal piston and compressed to half its length, when the molar band with its lingual tube was adapted to the distal piston of the lingual archwire (Figure 1B and C). When the coil was compressed two forces were produced (Figure 1A), one distally directed to move the molars distally and one reciprocal mesially directed force against which the lingual archwire and Nance button provided anchorage.

The Ni-Ti coils demonstrate a wide range of super-elastic activity with a small fluctuation of load in spite of a large deflection and exhibit small increments of deactivation over time, thus reducing the number of reactivation appointments (Miura *et al*., 1988). According to the manufacturers, the compression of the Ni-Ti coil to half its length provides approximately 200 g of maximal force. However, because of the small fluctuation of load, in spite of a large deflection of the coil, the force fell from approximately 200 to 180 g as the

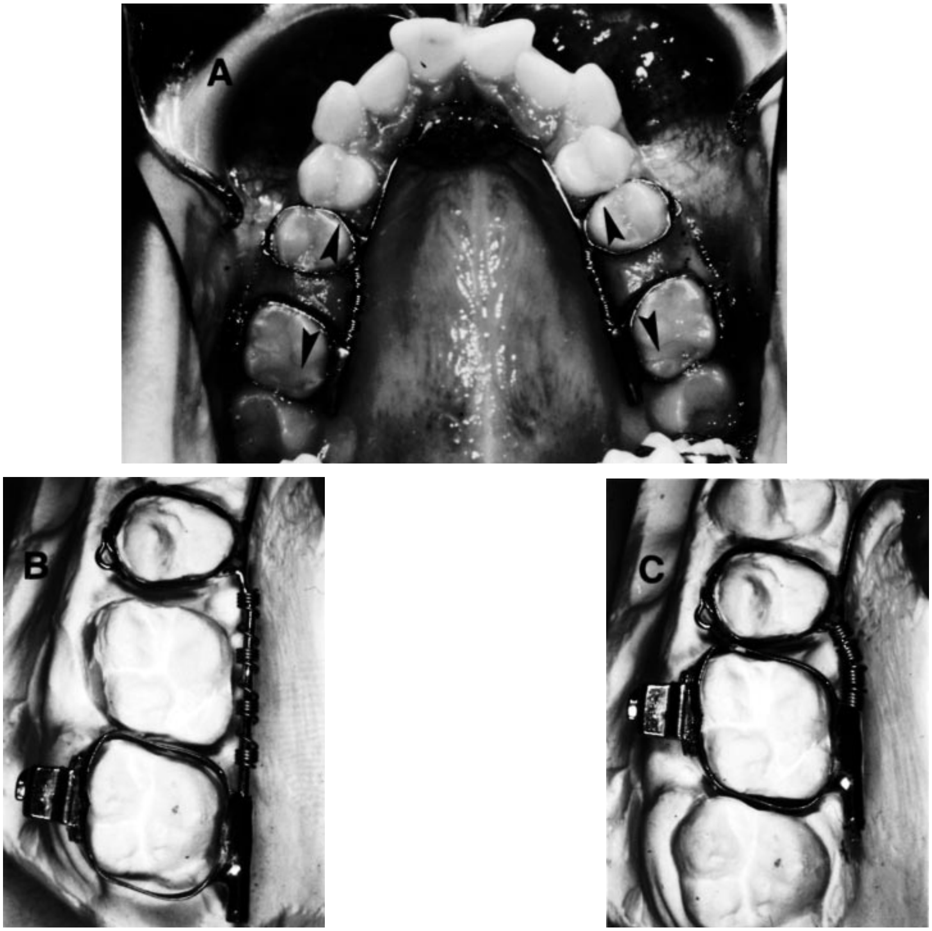

Figure 1 Occlusal view (A) of the lingual coil appliance. Arrows indicate the force directions. The occlusal detail (B) shows the inactivated Ni-Ti coil inserted on the distal piston and the steel tubing lingually on the maxillary molar band allowing the molar to slide distally. In (C) the lingually inserted Ni-Ti coil is compressed to approximately half of its length.

molars moved distally. Thus, after the appliance was inserted with its compressed Ni-Ti coils there was no need for further activation of the coils during the molar distalization period.

Design of the intra-arch magnet appliance

Prefabricated repelling samarium-cobalt magnets (Modular Magnetic Inn, New City, NY, USA), single size 4 × 5 × 2 mm, were ligated to the headgear tube of the first maxillary molar band. The buccally placed magnets were used in conjunction with a Nance acrylic button attached to a 0.9-mm lingual archwire which was soldered lingually to the second premolar band (Figure 2A). The repelling magnets were activated by a 0.25-mm ligature wire, ligated from a disto-buccal eyelet on the second premolar band to a sliding yoke mesial to the magnets (Figure 2B). When the repelling magnets were ligated together two forces were produced, one distally directed to move the molars distally, and one reciprocal mesially directed force against which the lingual archwire and Nance button provided anchorage (Figure 2A). According to the manufacturers a maximal force of 225 g was provided when the magnets were ligated together. After 4 weeks, the distance between

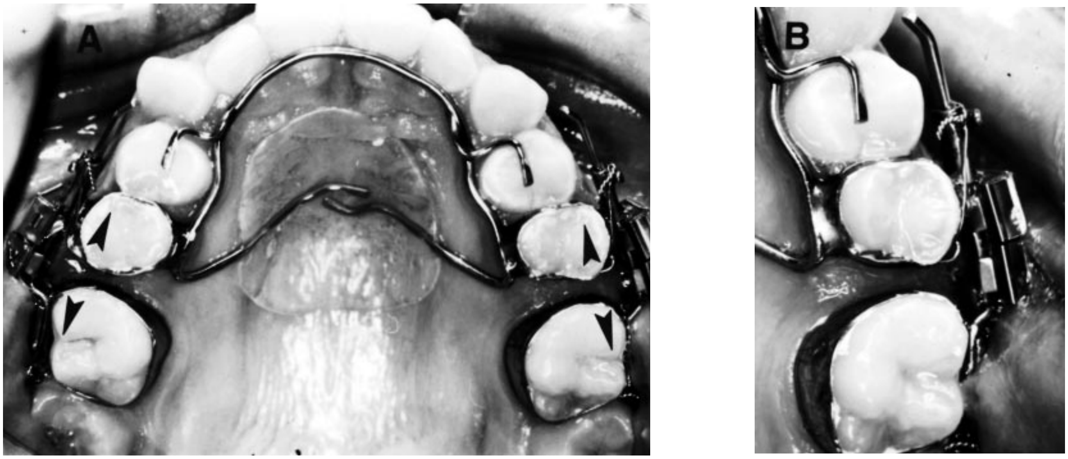

Figure 2 Occlusal view (A) of the magnet appliance. Arrows indicate the force directions. The occlusal detail (B) shows one of the repelling magnets tied in place buccally.

the magnets was about 1.5 mm and the magnetic force had declined from 225 to approximately 100 g (Bondemark and Kurol, 1992). Thus, as the magnetic force drops rapidly with increased distance between the magnets due to physical properties ($F \sim 1/d^2$), the magnets have to be re-activated, and ligated in contact with each other, every fourth week during the molar distalization period (Bondemark and Kurol, 1992).

Cephalometric analysis

Lateral head radiographs were obtained in centric occlusion at the start of treatment and after molar distalization was completed.

The measuring points, reference lines and measurements used were based on those defined and described by Björk (1960) and Pancherz (1982). Measurements were made to the nearest 0.5 mm or 0.5 degrees. Images of bilateral structures were bisected. No correction was made for linear enlargement (10 per cent). Changes in the measuring points during treatment were calculated as the difference between the start after molar distalization.

The following cephalometric variables were used (see also Figures 3 and 4):

Sagittal variables

1. A–OLp, position of the maxilla.
2. Pg–OLp, position of the mandible.
3. Is–OLp, position of the most prominent maxillary central incisor.

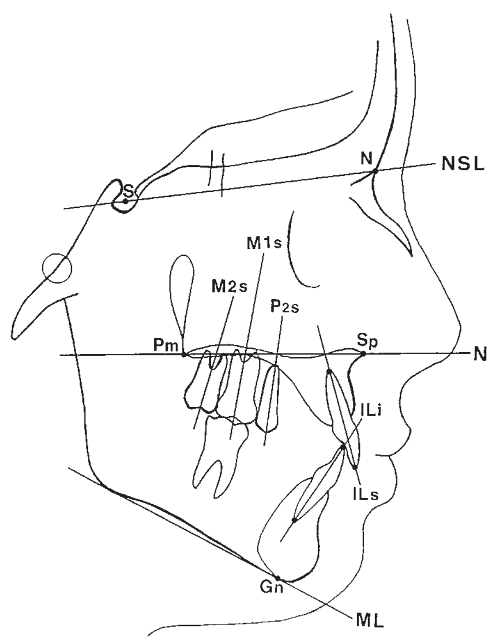

Figure 3 Reference points and lines used for the measurements on lateral headfilms. NSL, the nasion–sella line through N and S; NL, the nasal line through Sp and Pm; ML, the mandibular line, tangent to the base of the mandibular corpus through Gn; ILs and ILi, the long axis through the upper and lower incisors, respectively, from the incisal point to the apex; P2s, the long axis through the upper second premolar tip to the apex; M1s and M2s, the long axis of the upper first and second molar, respectively.

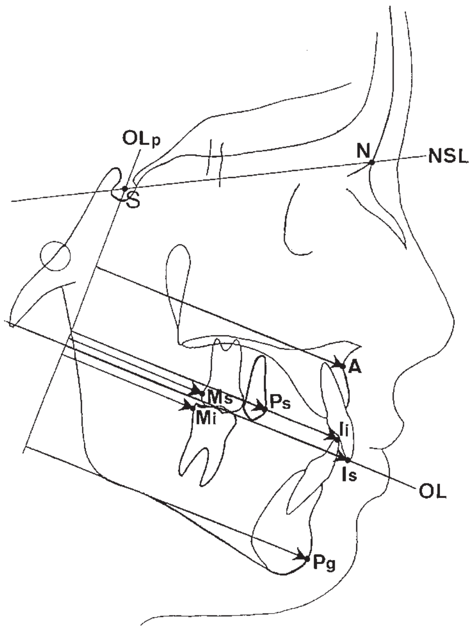

Figure 4 The landmarks and distances used in the cephalometric system devised by Pancherz (1982). The registration line (NSL) and reference grid (OL and OLp) are shown. A–OLp and Pg–OLp represent skeletal changes while changes in Is–OLp, Ii–OLp, Ms–OLp, Ps–OLp, and Mi–OLp represent a composite picture of dental and skeletal changes. The differences for dental changes within the maxilla and mandible were obtained by the following calculations: difference in Is–OLp minus difference in A–OLp—change in position of the maxillary central incisor within the maxilla. The difference in Ii–OLp minus the difference in Pg–OLp—change in position of the mandibular central incisor within the mandible. The difference in Ms–OLp minus the difference in A–OLp and the difference in Ps–OLp minus the difference in A–OLp—change in position of the maxillary first molar and second premolar within the maxilla, respectively. The difference in Mi-OLp minus the difference in Pg–OLp—change in position of the mandibular first molar within the mandible. The difference in Is–OLp minus the differnece in Ii–OLp—overjet. The difference in Ms–OLp minus the difference in Mi–OLp—molar relationship (positive value indicates distal relationship, negative value indicates normal or mesial relationship).

4. Ii–OLp, position of the most prominent mandibular central incisor.
5. Ps–OLp, position of the permanent maxillary second premolar.
6. Ms–OLp, position of the permanent maxillary first molar.
7. Mi–OLp, position of the permanent mandibular first molar.
8. Overjet, Is–OLp minus Ii–OLp.
9. Molar, Ms–OLp minus Mi–OLp (positive value indicates distal relationship relationship and negative value indicates normal or mesial relationship).
10. ILs/NL, maxillary insicor inclination.
11. ILi/ML, mandibular incisor inclination.
12. P2s/NL, second maxillary premolar inclination.
13. M1s/NL, first maxillary molar inclination.
14. M2s/NL, second maxillary molar inclination.

Vertical variables

15. NSL/NL, maxillary inclination.
16. NSL/ML, mandibular inclination.
17. OL/NSL, occlusal plane inclination.
18. N'–Sp', upper anterior facial height.
19. Sp'–Gn', lower anterior facial height.
20. Overbite, Is–NSL minus Ii–NSL.

For the sagittal linear measurements 1–9, the occlusal line (OL—a line through the tip of the central incisor and the mesiobuccal cusp tip of the first maxillary molar) and the occlusal line perpendicular (OLp) through sella from the first lateral head film were used as a reference grid (Figure 4). The grid was transferred from the first tracing to the following cephalograms by superimposition on sella and on stable anatomical structures of the anterior cranial base (Björk and Skieller, 1983). In order to facilitate blind tracing between groups, the radiographs before and after treatment were coded in pairs by an independent person, and then the radiographs from the lingual coil group (L-group) and the magnet group (M-group) were inter-mixed.

Statistical analysis

The arithmetic mean and standard deviation (SD) were calculated for each cephalometric variable. Differences in means within samples/groups were tested by paired *t*-tests and between samples/groups by unpaired *t*-tests after *F*-tests for equal and unequal variances. Associations between molar distalization, and amount of maxillary first and second molar tipping, as well as between molar distalization and mesial movement of maxillary second premolars, i.e. anchorage loss, were assessed with Pearson's product moment correlation coefficient (*r*). Differences with probabilities of less than 5 per cent ($P < 0.05$) were considered to be 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 (Dahlberg, 1940) ranged from 0.4 to 0.9 degrees and 0.4 to 0.7 mm, corresponding to coefficients of reliability (Houston, 1983) from 0.95 to 0.97 and from 0.96 to 1.00, respectively.

Results

Pre-treatment cephalometric records for the lingual coil group (L-group) and the magnet group (M-group) are summarized in Table 1. Cephalometrically, the two groups were in good accordance with each other and only one significant between-group difference was noted for the variables measured, the mandibular incisor inclination (ILi/ML). Thus, the lower incisor was more proclined in the M-group.

In the L-group the molars were distalized during a mean time of 6.5 months (SD 1.36), while in the M-group the corresponding mean time was 5.8 months (SD 0.97). The difference in molar distalization time was not significant.

The mean amount of distal molar movement was 2.5 mm (SD 0.69) in the L-group and 2.6 mm (SD 0.51) in the M-group (Figure 5 and Table 2). The mean extent of mesial movement of the second premolar, i.e. anchorage loss, was 1.2 mm (SD 1.01) and 1.8 mm (SD 0.86), respectively (Table 2). Due to the anchorage loss, the maxillary incisors moved forwards and the overjet was increased by an average of 1.2 mm (SD 0.96) in the L-group and 1.7 mm (SD 0.49) in the M-group (Figure 5 and Table 2).

The amount of distal maxillary first molar tipping was significant, but small in the L-group, mean –2.2 degrees (SD 2.53), while in the M-group the mean amount of distal maxillary first molar tipping was –8.8 degrees (SD 2.82), and thus significantly greater than in the L-group (Table 2, Figures 6 and 7). The distal tipping of the second maxillary molars as well as the mesial tipping of the second maxillary premolars was also significantly greater in the M-group than in the L-group (Table 2).

In both groups only small skeletal changs occurred. However, the mandibular plane angle and the lower anterior face height increased significantly, and thus the overbite was significantly reduced (Table 2). Also, a minor, but a significant change in forward position of the maxillary base was found in both groups (Table 2).

The association between molar movement and distal tipping of the first maxillary molar was moderate in the M-group ($r = 0.59$, $P < 0.01$), whereas in the L-group, there was no association ($r = 0.04$). However, a moderate association was found in the L-group between molar distalization and distal tipping of the second maxillary molar, ($r = 0.51$, $P < 0.05$), and in the M-group the corresponding association was 0.47 ($P < 0.05$). The inter-dependence of molar distalization and mesial movement of the maxillary second premolars, i.e. anchorage loss, was weak and not significant in either of the groups ($r = 0.37$ for the L-group and $r = 0.41$ for the M-group).

All patients in the two groups tolerated the two appliances well, and no debanding or other failures of the appliances occurred during the treatment period. All patients experienced slight inflammation of the palatal mucosa under the Nance acrylic button at the time of appliance removal, but these symptoms disappeared within one week.

Discussion

The most important findings of this study were that the new lingual Ni-TI coil intra-arch appliance created effective simultaneous distal movement of the maxillary first and second molars, and the molar movement, in contrast to the method with repelling magnets, was performed with a small amount of distal tipping of the maxillary first molar (mean –2.2 versus –8.8 degrees; Figures 6 and 7). Tipped maxillary molars have questionable stability and several studies analysing different intra-arch appliances

Table 1 Pre-treatment cephalometric records for the two treatment groups.

	Lingual coil group (L) (n = 21)		Magnet group (M) (n = 21)		Group difference L–M	
	Mean	SD	Mean	SD	Mean	P-value
Sagittal variable (mm)						
Molar relationship, Ms–OLp – Mi–OLp	1.1	1.12	1.2	1.23	–0.1	NS
Overjet, Is–OLp – Ii–OLp	5.1	1.83	5.3	2.01	–0.2	NS
Maxillary base, A–OLp	77.2	4.64	78.0	5.45	–0.8	NS
Mandibular base, Pg–OLp	82.3	5.16	82.9	6.33	–0.6	NS
Maxillary incisor, Is–OLp	85.1	4.42	85.9	4.85	–0.8	NS
Mandibular incisor, Ii–OLp	80.0	4.45	80.6	5.05	–0.6	NS
Maxillary second premolar, Ps–OLp	55.7	4.18	56.9	4.96	–1.2	NS
Maxillary molar, Ms–OLp	46.9	3.71	48.0	3.86	–1.1	NS
Mandibular molar, Mi–OLp	45.8	3.57	46.8	3.62	–1.0	NS
Sagittal variables (°)						
Maxillary incisor inclination, ILs/NL	106.3	5.95	102.1	8.16	4.2	NS
Mandibular incisor inclination, ILi/ML	90.5	7.18	94.9	5.37	–4.4	*
Maxillary second premolar inclination, P2s/NL	76.2	4.21	75.6	4.14	0.6	NS
Maxillary first molar inclination, M1s/NL	78.5	4.61	78.2	6.40	0.3	NS
Maxillary second molar inclination, M2s/NL	75.2	4.85	73.6	5.49	1.6	NS
Vertical variables (mm)						
Upper anterior facial height, N'–Sp'	53.0	3.15	52.5	2.64	0.5	NS
Lower anterior facial height, Sp'–Gn'	65.0	4.38	64.2	4.24	0.8	NS
Overbite, Is–NSL – Ii–NSL	3.9	1.62	5.0	2.27	–1.1	NS
Vertical variables (°)						
Maxillary inclination, NSL/NL	7.0	2.80	6.3	3.03	0.7	NS
Mandibular inclination, NSL/ML	32.9	6.06	31.0	5.13	1.9	NS
Occlusal plane inclination, OL/NSL	19.4	4.08	19.8	3.87	–0.4	NS

NS = not significant; *P < 0.05.

have reported that the molars tip distally between 7.4 and 14.5 degrees (Itoh *et al*., 1991; Bondemark and Kurol, 1992; Muse *et al*., 1993; Ghosh and Nanda, 1996; Byloff and Darendeliler, 1997). To overcome the problem of distal molar tipping, it has been suggested to overcorrect the

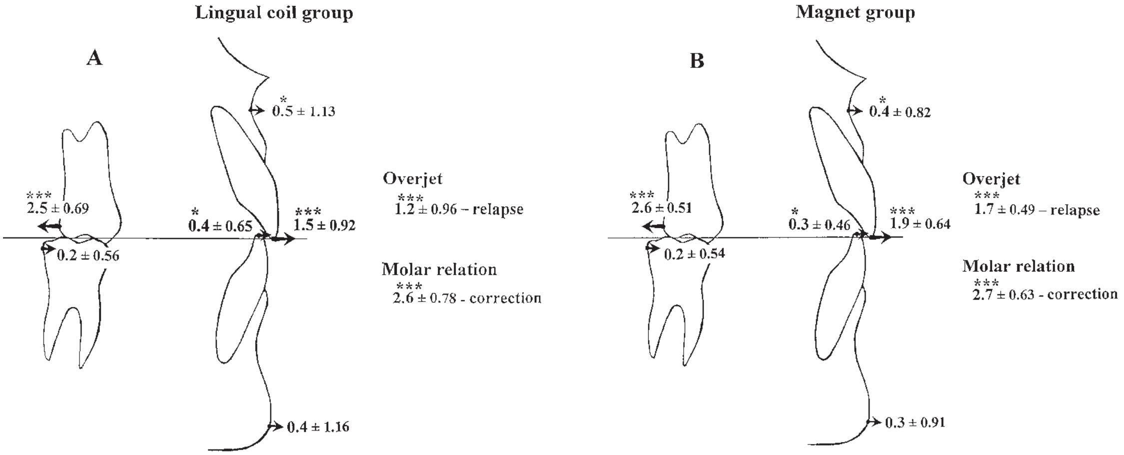

Figure 5 Sagittal dental and skeletal changes (mm) contributing to alterations in overjet and molar relationship. Registration of mean values and standard deviations during the treatment period for the lingual coil (A) and magnet group (B). $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

distal movement of the molar by approximately 2 mm since the molar crown moves mesially more than the roots when uprighting the molar (Gianelly, 1998). In this study it was shown that a new intra-arch appliance, with fixed pistons and steel tubing lingually allowing the first maxillary molar to slide and move distally, almost completely eliminated distal tipping. Thus, the risk of relapse, mesial movement of the molar, has considerably been diminished and, furthermore, there was no need for overcorrection of the molar.

Another major advantage of the coil appliance compared with the magnet appliance lies in its single activation. This is possible with Ni-Ti coils since they demonstrate a wide range of super-elastic activity with a small fluctuation of load in spite of a large deflection, and exhibit small increments of deactivation over time (Miura *et al.*, 1988), thus reducing the number of reactivation appointments during the molar distalization period. The magnetic forces, however, drop rapidly with increased distance between the magnets due to physical properties ($F \sim 1/d^2$), and the magnets therefore have to be reactivated and ligated in contact with each other, every fourth week during the molar distalization period (Bondemark and Kurol, 1992). Thus, the Ni-Ti coils produce a more constant force and despite the molars having to be moved bodily in the lingual appliance, the range of molar movement, as well as the treatment time were almost equal for the lingual coil and magnet appliance.

Even though this study has shown that the new intra-arch Ni-Ti coil appliance was superior to the established magnet appliance for distal bodily movement of maxillary molars, it is not possible to answer the question as to whether the new intra-arch Ni-Ti coil appliance is superior to other intra-arch appliance that use Ni-Ti coils. Therefore, a prospective randomized study with the objective to analyse the effectiveness of molar distalization between the new appliance described in this study and other previously reported designs (Jones and White, 1992; Carano and Testa, 1996) has been commenced.

When the molars are moved posteriorly by an intra-arch appliance, anchorage loss occurs and produces forward movement of the anterior teeth. In this study, the loss of anchorage was measured at the second premolar teeth and at the maxillary central incisor tip. The anchorage unit, which consisted of a Nance acrylic button connected by a 0.9-mm arch-wire soldered lingually to the second premolar bands, was unable to completely resist the reciprocal mesial

Table 2 Changes in cephalometric variables within and between the two groups after distal movement of maxillary molars

	Lingual coil group (L) (*n* = 21)		Magnet group (M) (*n* = 21)		Group difference L–M	
	Mean	SD	Mean	SD	Mean	*P*-value
Sagittal variables (mm)						
Molar relationship, Ms–OLp (d) – Mi–OLp (d)	–2.6***	0.78	–2.7***	0.63	–0.1	NS
Overjet, Is–OLp (d) – Ii–OLp (d)	1.2***	0.96	1.7***	0.49	–0.5	*
Maxillary base, A–OLp (d)	0.5*	1.13	0.4*	0.82	0.1	NS
Mandibular base, Pg–OLp (d)	0.4	1.16	0.3	0.91	0.1	NS
Maxillary incisor, Is–OLp (d) – A–OLp (d)	1.5***	0.92	1.9***	0.64	–0.4	NS
Mandibular incisor, Ii–OLp (d) – Pg–OLp (d)	0.4	0.65	0.3	0.46	0.1	NS
Maxillary second premolar, Ps–OLp (d) – A–OLp (d)	1.2***	1.01	1.8***	0.86	–0.6	*
Maxillary molar, Ms–OLp (d) – A–OLp (d)	–2.5***	0.69	–2.6***	0.51	0.1	NS
Mandibular molar, Mi–OLp (d) – Pg–OLp	0.2	0.56	0.2	0.54	0.0	NS
Maxillary incisor inclination, ILs/NL	4.7***	3.65	5.5***	2.52	–0.8	NS
Mandibular incisor inclination, ILi/ML	1.1**	1.36	0.5*	1.09	0.6	NS
Maxillary second premolar inclination, P2s/NL	2.1**	2.75	6.7***	2.95	–4.6	***
Maxillary first molar inclination, M1s/NL	–2.2***	2.53	–8.8***	2.82	6.4	***
Maxillary second molar inclination, M2s/NL	–5.9***	4.21	–8.9***	2.82	4.0	*
Vertical variables (mm)						
Upper anterior facial height, N'–Sp'	0.3	0.74	0.3	0.69	0.0	NS
Lower anterior facial height, Sp'–Gn'	1.3***	1.16	1.1***	0.93	0.2	NS
Overbite, Is–NSL – Ii–NSL	–1.5***	1.12	–1.6***	0.93	0.1	NS
Vertical variables (°)						
Maxillary inclination, NSL/NL	0.2	0.49	0.1	0.68	0.1	NS
Mandibular inclination, NSL/ML	0.6**	0.77	0.5**	0.65	0.1	NS
Occlusal plane inclination, OL/NSL	–0.3	0.84	–0.2	0.67	–0.1	NS

NS = not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

force of the lingual coil appliance as well as that of the repelling magnet appliance. The mean amount of mesial movement of the second premolars was 1.2 mm for the lingual coil appliance and 1.8 mm with the magnet appliance. In addition, the maxillary central incisors moved forward by an average of 1.5 mm in the L-group and 1.9 mm in the M-group. A similar amount of

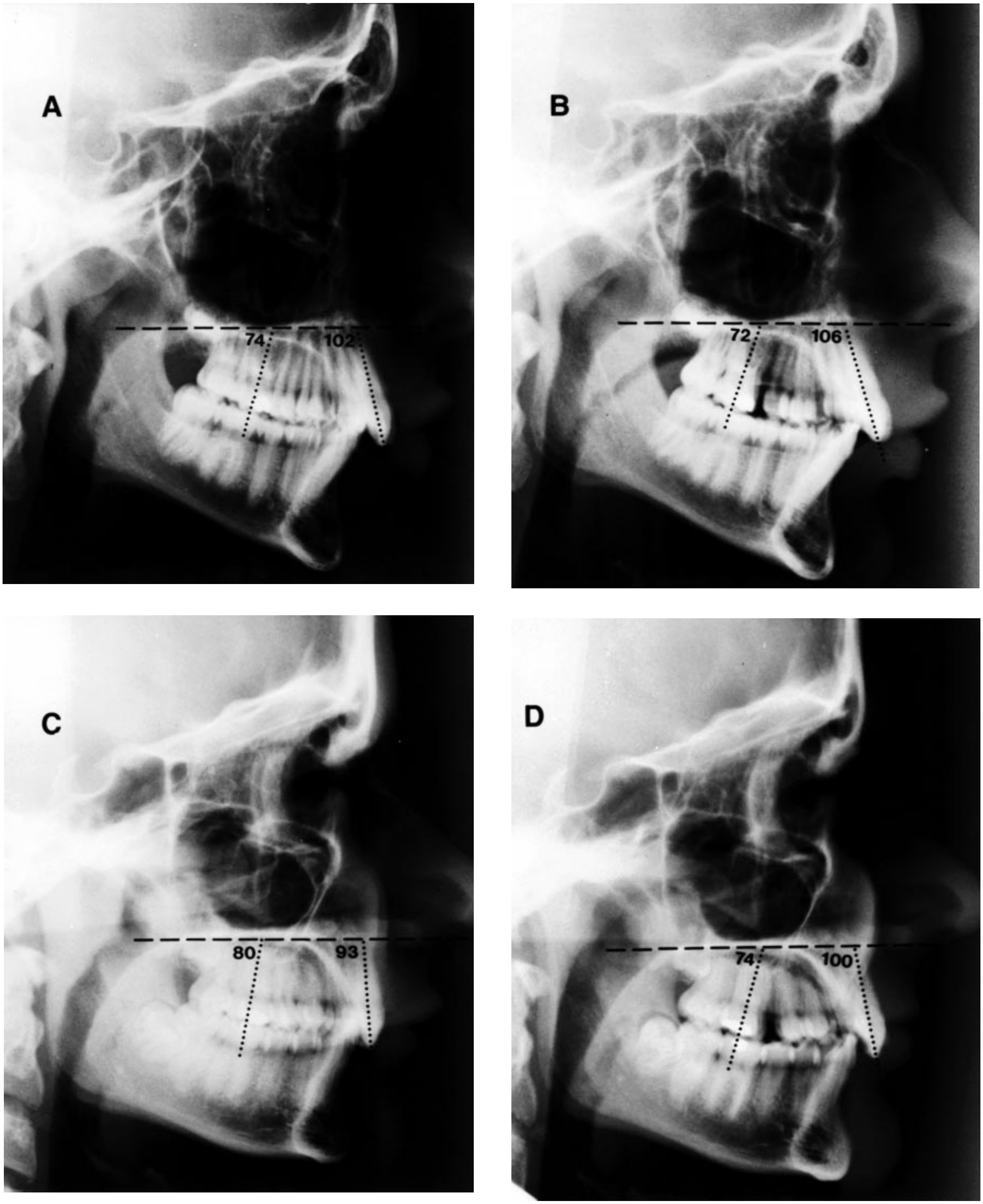

Figure 6 The inclination (degrees) of maxillary first molars and central incisors on lateral head radiographs (A) before and (B) after 7 months of treatment of a 14.7-year-old girl in the lingual coil group. In this patient the molars tipped distally 2 degrees, while the incisors proclined 4 degrees. The corresponding inclination values (C) before and (D) after 6 months of treatment of a 15.1-year-old girl in the magnet group. In this patient the molars tipped distally 6 degrees while the incisors proclined 7 degrees.

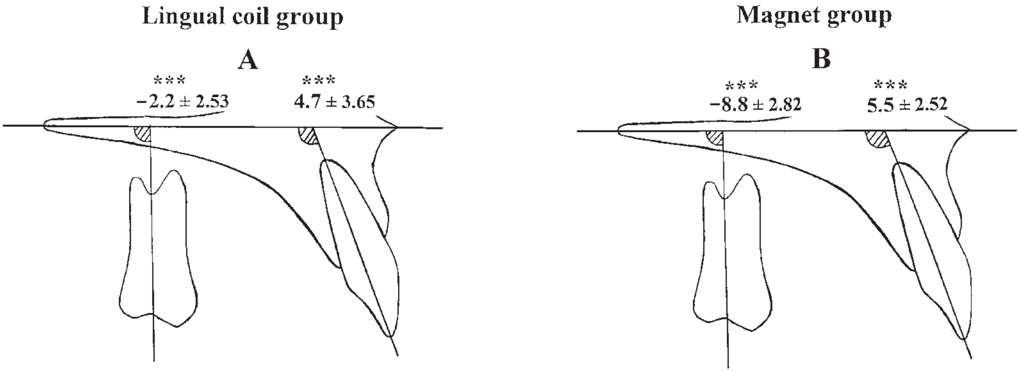

Figure 7 Schematic illustration of changes (degrees) contributing to alterations in maxillary first molar and maxillary central incisor inclination. Registration of mean values and standard deviations during the treatment period for the (A) lingual coil and (B) magnet group. ***$P < 0.001$.

forward movement of maxillary incisors has also been observed in other studies (Gianelly *et al.*, 1989; Bondemark and Kurol, 1992; Ghosh and Nanda, 1996; Byloff and Darendeliler, 1997). In most instances, the problem of forward movement of the incisors can be controlled with modest intervention. Therefore, in order to correct or reverse the forward movement of the maxillary incisors, subsequent orthodontic mechanics with Class II elastics is recommended (Muse *et al.*, 1993; Gianelly, 1998). In a recent study (Bondemark and Kurol, 1998), it was shown that forward movement of the maxillary incisors associated with distal molar movement was totally reversed and eliminated by inter-maxillary Class II elastics. On the other hand, in subjects with retroclined maxillary incisors, with a Class II division 2 malocclusion, the reciprocal effect of forces can be utilized for proclination of the incisors.

With regard to skeletal changes, the mandibular plane angle and lower anterior face height showed a significant change with treatment. A small backward mean rotation of 0.6 degrees with the coil appliance and 0.5 degrees with the magnet appliance caused a mean decrease in overbite of 1.5 and 1.6 mm, respectively (Table 2). A similar amount of backward rotation of the mandible and increase in lower anterior face height caused by distal movement of the maxillary molars has been observed with molar distalization with the pendulum appliance (Ghosh and Nanda, 1996). Since the two appliances used in this study only caused small skeletal changes and had no corrective effect on the Class II skeletal relationships, these appliances should only be used in cases of moderate dental discrepancies and arch-length deficiencies.

During the treatment period there was no damage to the appliances and for all patients the oral hygiene was good. The reason for this might be that all patients had good oral hygiene at the start of treatment and treatment time was short for the two groups, mean 6.5 months (SD 1.36) and 5.8 months (SD 0.97), respectively.

A controversy exists concerning the influence of second molars on the distal movement of the first molars. Several authors have stated that distalization of the first maxillary molar is dependent on the stage of eruption of the second maxillary molar. Maxillary first molar distalization should be accomplished before the second molars erupt and/or when the second molars have erupted, and the distalization of molars should be undertaken in stages, first the second molars and then the first molars (Graber, 1955; Cetlin and TenHoeve, 1983; Gianelly, 1998). However, in this study it was found that the first and second maxillary molars could successfully and simultaneously be moved distally during a mean treatment period of 5.8 months for the magnet group and 6.5 months for the lingual coil group. This finding is supported by other studies, which have shown that the eruption of maxillary second molars has a limited effect on first molar distalization (Bondemark and Kurol, 1992; Muse *et al*., 1993; Ghosh and Nanda, 1996; Byloff and Darendeliler, 1997). Nevertheless, in the adolescent, when the first molars are moved distally after the eruption of the second molars, the first molars tend to move more slowly if the second molars are unerupted. Cusp-to-cusp molar relationships are corrected well but full Class II relationships may be more difficult to resolve if the second molars are erupted (Gianelly, 1998).

Conclusions

The results indicate that the new lingual Ni-Ti coil appliance was a better choice than the magnet appliance for maxillary molar distalization. The benefits of the new Ni-Ti appliance were due to the design preventing molar tipping and its single activation.

Both appliances worked well as intra-oral methods and created simultaneous distal movement of the maxillary first and second molars with moderate and acceptable anchorage loss.

The two appliances did not have any corrective effect on Class II skeletal relationships, and should therefore only be used in cases of moderate dental sagittal discrepancies and arch-length deficiencies.

Address for correspondence

Dr Lars Bondemark
Department of Orthodontics
Faculty of Odontology
Malmö University
Carl Gustavs väg 34
SE-214 21 Malmö
Sweden

Acknowledgements

The research was supported by the Swedish Dental Society.

References

Björk A 1960 The relationship of the jaws to the cranium. In: Lundström A (ed.) Introduction to orthodontics. McGraw-Hill, New York, pp. 104–140

Björk A, Skieller V 1983 Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. European Journal of Orthodontics 5: 1–46

Bondemark L, Kurol J 1992 Distalization of maxillary first and second molars simultaneously with repelling magnets. European Journal of Orthodontics 14: 264–272

Bondemark L, Kurol J 1998 Class II correction with magnets and super-elastic coils followed by straight-wire mechanotherapy. Journal of Orofacial Orthopedics 59: 127–138

Bondemark L, Kurol J, Bernhold M 1994 Repelling magnets versus super-elastic nickel-titanium coils in simultaneous distal movement of maxillary first and second molars. Angle Orthodontist 64: 189–198

Byloff F K, Darendeliler M A 1997 Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. Angle Orthodontist 67: 249–260

Carano A, Testa M 1996 The distal jet for upper molar distalization. Journal of Clinical Orthodontics 30: 374–380

Cetlin N M, TenHoeve A 1983 Nonextraction treatment. Journal of Clinical Orthodontics 17: 396–413

Corbett M 1997 Slow and continuous maxillary expansion, molar rotation, and molar distalization. Journal of Clinical Orthodontics 31: 253–263

Dahlberg G 1940 Stastistical methods for medical and biological students. Interscience Publications, New York

Gianelly A A 1998 Distal movement of the maxillary molars. American Journal of Orthodontics and Dentofacial Orthopedics 114: 66–72

Gianelly A A, Vaitas A S, Thomas W M 1989 The use of magnets to move molars distally. American Journal of Orthodontics and Dentofacial Orthopedics 96: 161–167

Ghosh J, Nanda R S 1996 Evaluation of an intra-oral maxillary molar distalization technique. American Journal of Orthodontics and Dentofacial Orthopedics 110: 639–646

Graber T M 1955 Extraoral force—facts and fallacies. American Journal of Orthodontics 41: 490–505

Gulati S, Kharbanda O P, Parkash H 1998 Dental and skeletal changes after intra-oral molar distalization with sectional jig assembly. American Journal of Orthodontics and Dentofacial Orthopedics 114: 319–327

Hilgers J J 1992 The pendulum appliance for Class II non-compliance therapy. Journal of Clinical Orthodontics 26: 706–714

Houston W B J 1983 The analysis of errors in orthodontic measurements. American Journal of Orthodontics 83: 382–390

Itoh T *et al*. 1991 Molar distalization with repelling magnets. Journal of Clinical Orthodontics 25: 611–617

Jones R, White J 1992 Rapid Class II molar correction with an open coil jig. Journal of Clinical Orthodontics 26: 661–664

Kurol J, Bjerklin K 1984 Treatment of children with ectopic eruption of the maxillary first permanent molar by cervical traction. American Journal of Orthodontics 86: 483–492

Locatelli R, Bednar J, Dietz V S, Gianelly A A 1992 Molar distalization with superelastic NiTi wire. Journal of Clinical Orthodontics 26: 277–279

Miura F, Mogi M, Ohura Y, Karibe M 1988 The superelastic Japanese NiTi alloy wire for use in orthodontics. Part III. Studies on the Japanese NiTI alloy coil springs. American Journal of Orthodontics and Dentofacial Orthopedics 94: 89–96

Muse D S, Fillman M J, Emmerson W J, Mitchell R D 1993 Molar and incisor changes with Wilson rapid molar distalization. American Journal of Orthodontics and Dentofacial Orthopedics 104: 556–565

Pancherz H 1982 The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. American Journal of Orthodontics 82: 104–113

Pancherz H, Anehus-Pancherz M 1993 The headgear effect of the Herbst appliance: a cephalometric long-term study. American Journal of Orthodontics and Dentofacial Orthopedics 103: 510–520

Proffit W R (ed.) 1993 The second stage of comprehensive treatment: correction of molar relationship and space closure. In: Contemporary orthodontics, 2nd edn. Mosby, St Louis, pp. 495–515

Steger E S, Blechman A M 1995 Case reports: molar distalization with static repelling magnets. Part II. American Journal of Orthodontics and Dentofacial Orthopedics 108: 547–555

Wieslander L 1975 Early or late cervical traction therapy of Class II malocclusion in the mixed dentition. American Journal of Orthodontics 67: 432–439

Wilson R C 1978 Modular orthodontic systems. Part 1. Journal of Clinical Orthodontics 12: 259–278