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Nickel-titanium Coil Springs and Repelling Magnets: a Comparison of Two Different Intra-oral Molar Distalization Techniques

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Abstract. *The aim of this study was to compare two intra-oral molar distalization procedures, involving 15 cases with Class II molar relationships. Magnetic devices were applied to the upper right first molars in each case, while nickel-titanium coil springs were used against the upper left first molars, for a period of 3 months. Measurements were made from lateral cephalograms and from photocopies of models taken before and after the distalization procedure. Although upper molar distalization was achieved with ease in both techniques, nickel-titanium coil springs were found to be the more effective in terms of movement achieved.*

Index words: Magnets, Molar Distalization, Ni-Ti Coil Springs.

Refereed Paper

Introduction

The effectiveness of extra-oral forces in molar distalization is widely accepted, but it is well known that its disadvantage is in the need for patient co-operation. Due to this and the increasing tendency towards non-extraction treatment, much work has been put into developing new intra-oral molar distalization procedures, including the use of magnetic forces and nickel-titanium coil springs. With their excellent properties, such as high energy product values and high coercive forces, rare earth magnets have been used in orthodontic tooth movements (Blechman and Smiley, 1978). An important disadvantage of rare earth magnets is their low corrosion resistance, but by means of stainless steel coatings, the resistance against corrosion is increased (Kawata *et al.*, 1987).

Various investigators have studied the biological effects of static magnetic fields on living tissues. Changes in osteoblastic and osteoclastic activities, a decrease in epithelial thickness and an increase in blood flow rate have been accepted by several investigators as the biological effects of magnetic fields (Aronson and Lindskog, 1991; Itoh *et al.*, 1991). However, there is no agreement as to whether the effects reported were produced by the magnetic alloy or the magnetic field.

In two different studies, Gianelly *et al.* (1988, 1989) achieved effective molar distalization using repelling magnets. They suggested weekly activation of the magnets in order to maximize the force and stated that in cases with second molars in complete occlusion, distalization took longer. Anchorage loss in this study was calculated as 20 per cent. Itoh *et al.* (1991), also have used repelling magnets for molar distalization; they recommended activation of the magnets at intervals of 2 weeks and reported an anchorage loss of about 30 per cent. Using repelling magnets, Bondemark and Kurol (1992), reported effective molar distalization, together with disto-buccal rotation.

Open coil springs are commonly used in orthodontic practice; but there have been few experimental studies on their clinical effects. Chaconas *et al.* (1984) investigated the effects of wire thickness, length and radius of open coil springs on the forces produced. It was found that more linear force was produced in open coil springs with a large lumen and in order to obtain an optimum force, open coil springs had to be compressed by about a third of its original length, producing a force value of between 270 and 540 g.

In 1988, Miura *et al.* (1988) compared the mechanical properties of Japanese nickel-titanium and stainless steel coil springs, in both closed and open types. They found that Japanese nickel-titanium coil springs exhibited superior spring-back and super elastic properties. Additionally, it was shown that the load value of super elastic activity could be effectively controlled by changing the diameter of the wire, the size of the lumen, the Martensitic transformation temperature, and the pitch of the open coil spring. The most important characteristic of Japanese nickel-titanium alloy coil springs was the ability to exert a very long range of constant, light, and continuous force. Gianelly *et al.* (1991), obtained an average of 1–1·5 mm molar distalization in one month by 8–10 mm activation of super elastic nickel-titanium coil springs. To maintain anchorage, a modified Nance appliance was cemented to the upper first premolars. An additional means of anchorage reinforcement involved the incorporation of uprighting springs to tip the crowns of these

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teeth distally and as a result, effective molar distalization was obtained. In cases with second molars in total occlusion, the use of Class II elastics was recommended to avoid anchorage loss. Fraunhofer *et al.* (1993) compared nickel-titanium coil springs with stainless steel coil springs. These authors concluded that the light and continuous forces necessary for optimum tooth movement could be produced by means of nickel-titanium coil springs.

The aim of the present study was to compare the clinical effectiveness of repelling magnets and nickel-titanium coil springs in molar distalization.

Materials and Methods

The study involved 15 patients: 12 girls and three boys. The mean age was 12·2 years for females and 12·7 years for males. The total mean age of the patients was 12·3 years. The following criteria were used in selection:

(1) Class I molar relationship;
(2) second molars in occlusion;
(3) sagitally directed or normal growth pattern;
(4) overbite at least 2 mm;
(5) well aligned lower dental arch.

Appliance design

A modified Nance appliance soldered to the upper first premolars was used, as described by Gianelly *et al.* (1988) (Fig. 1). With this design, it was possible to observe any movement of the second premolars. Prefabricated magnetic devices (Medical Magnetics, Inc., Ramsey, N.J. U.S.A.) were used on the upper right quadrant (Fig. 2A). These produced 225 g of repelling force, when the magnets were in tight contact.

Nickel-titanium (Ortho. Organizer Inc. U.S.A.) open coil springs size 0·014 × 0·037-inch, were used on the left only. In order to select the appropriate length of coil spring to produce 225 g of force in each case, an intra-oral gauge was used. Coil springs were used (Ortho. Organizer Inc. U.S.A.) only on the right side of the patients (Fig. 2B).

For the activation procedure, the repelling surfaces of the magnets were brought into contact by passing an 0·014″ ligature wire through the loop on the auxiliary wire then tying back a washer anterior to the magnets (Fig. 1). Magnets were re-activated every week as recommended by Gianelly *et al.* (1989) in order to standardize the force level. Coil springs were activated every month by adding a piece of a tubing (of equal length to the amount of molar distalization) onto the archwire at the end of the spring.

A Class I molar relationship was observed in all cases at the end of the 3 months, with both molar distalization techniques. Figure 3A and B show molar distalizations with each method at the end of 3-month period. Lateral cephalograms, study models and photocopies of the models were obtained from each case before and after the treatment, and from these first molar locations were measured.

FIG. 1. Modified Nance appliance as viewed on a demonstrative model.

Cephalometric method

In order to distinguish the right and the left molars on the lateral cephalogram, wire markers were applied to the free tubes of the molar bands. On the right side, the tip of the wire was bent mesially and on the left side, distally. These wire markers were also used in the measurement of molar tippings. Cephalograms were traced and the following two cephalometric measurements were made in the present study (Fig. 4).

1-U6-PTV Distance between the pterygoid vertical plane and the wire marker mesial to the molar band.

2-U6-ANS PNS Anterior angle formed at the intersection of the palatal plane and the axis of wire marker on the upper first molar.

Model analysis

Palatal rugae and median palatal suture of the study models were defined by tracing them with a 0·5-mm point drawing pencil (Fig. 5). The most prominent rugae close to the midline was marked in order to construct the reference plane used in the analysis. To evaluate the locations of the first molars and second premolars before and after treatment, the cusp tips of these teeth were marked as well. Model photocopies were obtained as described by Champagne (1992). On model photocopies, a midline was drawn along median palatal suture and a reference plane was constructed by drawing a perpendicular line from the mark on the most prominent rugae to the midline (RP). A line was drawn between the buccal and palatal cusp tips of the second premolars and the midpoint was marked. Two diagonal lines were drawn between the cusp tips of the first molars and their point of intersection was marked, too. These points were used in the model analysis in order to eliminate any misleading results that might arise due to rotational effects during tooth movement.

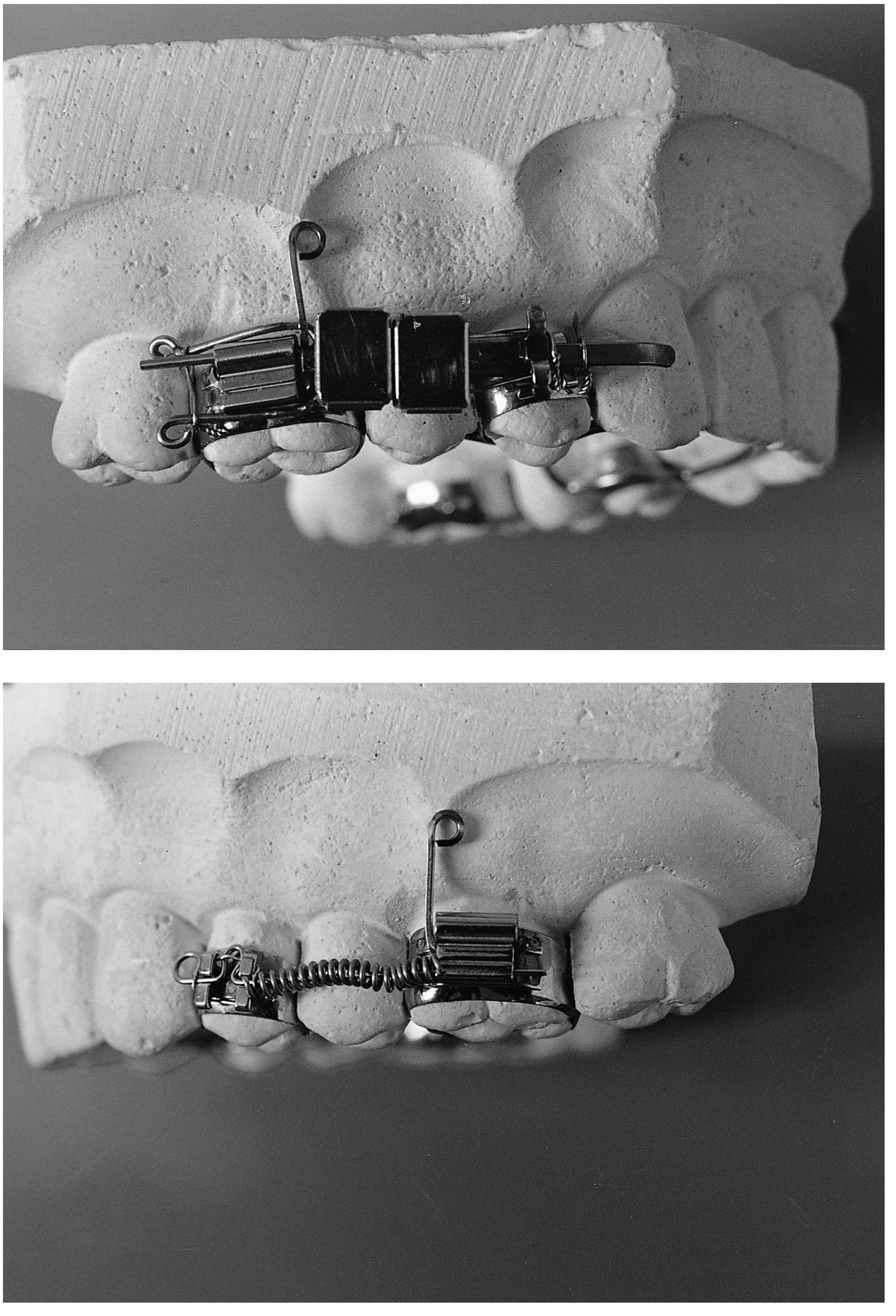


FIG. 2. Magnet (A) and Ni-Ti open coil spring (B) application viewed on a demonstration model.

Model measurements were as follows (Fig. 5):

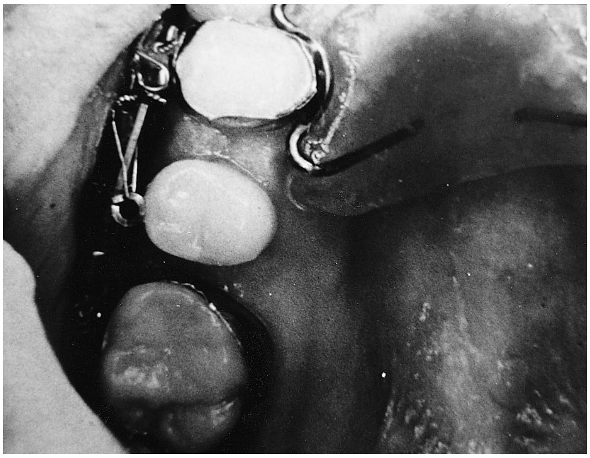
1. Location of the upper first molar (U6-RP): the perpendicular distance between the reference plane and the intersection point of the two diagonals joining the cusp tips of the upper first molar.
2. Location of the upper second premolar (U5-RP): the perpendicular distance between the reference plane, and the mid-point of the line joining the buccal and palatal cusp tips of the upper second premolar.
3. Rotation of the upper first molar (U6-ML): the angle between the midline and the line passing through the mesiobuccal and distopalatal cusp tips of the upper first molar.

Statistical methods

Non-parametric tests were used in statistical evaluation. Intergroup differences were evaluated with Mann–Whitney *U*-test (NCSS program), and intra-group differences with Wilcoxon test. Method error also was calculated.

Results

The greatest method error was found in the measurement U6-ANS PNS (0·72), while the smallest method error was in U5-RP measurement (0·29; Table 1). Tables 2 and 3



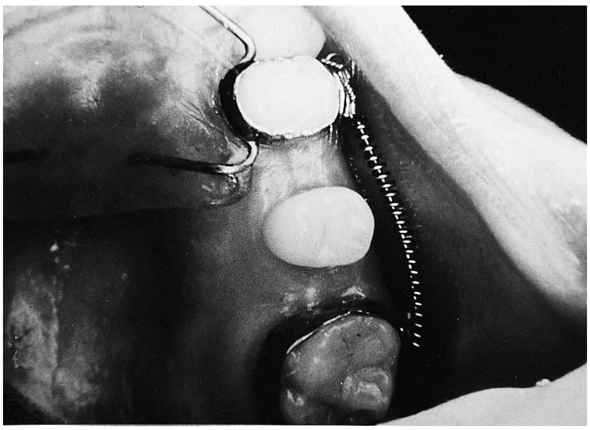


FIG. 3. Intra-oral view of magnet (A) and Ni-Ti open-coil spring (B) applications.

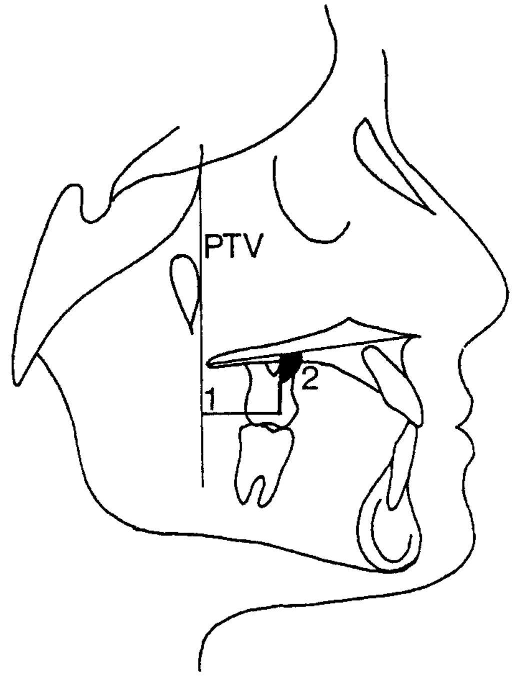


FIG. 4. Cephalometric measurements used in the study: (1) U6-PTV, (2) U6 ANS-PNS.

TABLE 1 *Method error values of parameters*

	Magnet	Coil spring
U6-PTV	0·40	0·57
U6-ANS PNS	0·71	0·72
U6-RP	0·37	0·48
U6-ML	0·68	0·43
U5-RP	0·29	0·37

TABLE 2 *Means and standard deviations both before and after molar distalizaton in the magnet group*

		Before		After		Wilcoxon
Magnet	*n*	*x*	S.D.	*x*	S.D.	*P*
U6-PTV (mm)	15	24·4	7·6	22·2	7·4	***
U6-ANS PNS (degree)	15	105	9	112·6	9	***
U6-RP (mm)	15	17·6	4·4	19·7	5·2	**
U6-ML (degree)	15	53	7·3	63·1	7·2	***
U5-RP (mm)	15	8·5	4·2	8·5	4·2	—

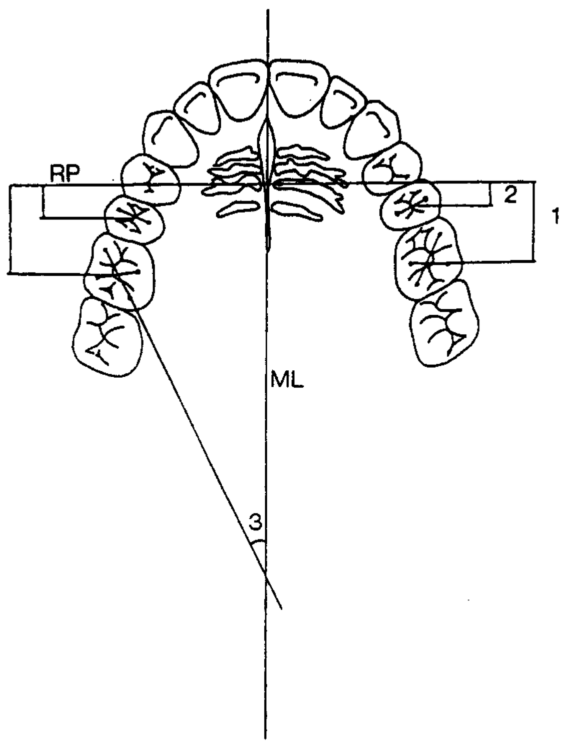


FIG. 5. Measurements used in the model analysis. (1) U6-RP, (2) U5-RP, (3) U6-ML. ML: midline drawn along the median palatal suture. RP: reference plane constructed by drawing a perpendicular to the ML passing through the marked rugae.

show the mean values both before and after the distalization procedure with each technique.

According to the measurements made on the lateral cephalograms, compared to the pretreatment position, upper first molars on the magnet side moved distally on average by 2·1 mm ($P < 0{\cdot}001$; Table 2). The average amount of distal tipping of their crowns was 7·6 degrees ($P < 0{\cdot}001$). Measurements made on the model photocopies showed that the upper molars were distalized for 2·1 mm ($P < 0.01$) and rotated distopalatally for 9·9 degrees ($P < 0{\cdot}001$) (Table 4).

On the nickel-titanium coil spring side, the upper first molars moved distally by an average distance of 3·8 mm ($P < 0{\cdot}001$) and their crowns were distally tipped by 9·9 degrees ($P < 0{\cdot}001$) as measured on the lateral cephalograms. Model photocopy measurements showed that the distalization amount of the upper first molars was 4·2 mm ($P < 0{\cdot}001$), and the amount of distopalatal rotation was 8·6 degrees ($P < 0{\cdot}001$) (Table 4).

When molar distalization with magnets and nickel-titanium open coil springs were compared on lateral cephalograms, the amount of distal movement achieved with the coil springs was found to be 1·6 mm more than that gained with the magnets. The difference was found to be statistically significant ($P < 0{\cdot}001$). However, when the amounts of distal crown tip were compared, the difference was not significant. The comparison made according to model photocopy measurements revealed that the amount of molar distalization with nickel-titanium coil springs was 1·5 mm more than that with magnets, which was statistically significant ($P < 0{\cdot}001$). The difference in distopalatal rotation was not significant (Tables 1 and 2).

Movement of the upper second premolars was also evaluated. Measurements made on model photocopies showed that on the magnet side, second premolars were distalized by an average of 0·05 mm, which was not statistically significant. On the nickel titanium coil spring side, upper second premolars were moved distally for an average of 0·8 mm, which was statistically significant ($P < 0{\cdot}05$). However, when the two procedures were compared from the point of second premolar distalization, the difference was not found to be significant (Table 4).

TABLE 3 *Means and standard deviations both before and after molar distilization in the coil spring group*

		Before		After		Wilcoxon
Coil spring	*n*	*x*	S.D.	*x*	S.D.	*P*
U6-PTV (mm)	15	23·5	6·7	19·7	6·9	***
U6-ANS PNS (degree)	15	103	7·8	112·9	7·8	***
U6-RP (mm)	15	17	4·9	21·2	5·4	**
U6-ML (degree)	15	60·2	6·4	68·8	7·3	***
U5-RP (mm)	15	8·4	3·8	9·2	4·5	*

TABLE 4 *Comparison of magnet and coil spring groups*

		Magnet		Coil spring		MW-U test
	n	*x*	S.D.	*x*	S.D.	*P*
U6-PTV (mm)	15	2·1	0·1	3·8	1·1	***
U6-ANS PNS (degree)	15	7·6	3·7	9·9	4·9	***
U6-RP (mm)	15	2·7	0·7	4·2	0·9	**
U6-ML (degree)	15	9·9	7·3	8·6	4·3	***
U5-RP (mm)	15	0·05	0·8	0·8	1·4	—

Discussion

To achieve as much standardization of the cases as possible, particular attention was paid to selecting individuals with reasonably similar dental and skeletal features. Additionally, comparison of the effects of both techniques on the same patient reduced the likeliness of any misleading result that might otherwise arise due to age difference.

Skeletal Class I or II cases, with Class II molar relationships and well aligned lower dental arches were included in the study (Bondemark and Kurol, 1992). Anchorage was maintained with a modified Nance appliance which employed upper first premolars as an anchorage unit although some investigators have used second premolars as anchorage units instead (Bondemark and Kurol, 1992; Erdoğan and Ciğer, 1990). In the present study first premolars were used for three reasons. First, to find out if the upper second premolars moved distally along with the first molars in the course of treatment, as suggested by Gianelly *et al.* (1989), secondly because the second premolars were not yet fully erupted and may have been disrupted by being used as anchorage units, and thirdly, because the distance between the mesial end of the molar tube and the distal wing of the second premolar bracket would have been very short.

In the construction of the anchorage appliance, Gianelly *et al.* (1991) suggested the use of a bite plane to eliminate any posterior occlusal interferences. However, in the present study, a bite plane was not employed in order not to cause any molar extrusion other than that expected as a result of molar distalization (Jones and White, 1992).

To ensure measurement validity, a reference plane which would be relatively unaffected by growth changes was needed. For this reason, the reference plane was constructed by joining the most anterior point on the mesial convexity of the pterygomaxillary fissure and the point of intersection of the sphenoidal plane with the greater wing of the sphenoid bone.

The most prominent rugae close to the midline was marked on the study model in order to construct a reference plane on the model photocopy. A mesially directed force was expected to act upon the anchorage appliance in reaction to the force which was pushing the molars distally. Since the marked rugae could move mesially due to this reactive force, model analysis would not show the actual molar distalization. However, as the same reference point was used in comparison of the two procedures, movement of the rugae would not influence our findings. In three cases, slight inflammation of the palatal mucosa was observed under the acrylic button of modified Nance appliance at the end of the treatment period. The signs of this inflammation disappeared two or three days after removal of the appliance. Similarly, Bondemark and Kurol (1992) reported a finding of slight inflammation in two out of 10 cases, with a mention of quick reversal of the condition once the appliance was removed. As the inflammatory changes were only minimal, with no real impact on palatal morphology, and palatal rugaes were considered reliable as reference points.

It was found that with magnetic force, the upper first molars were distalized an average of 2·1 mm ($P < 0{\cdot}001$) as measured on the lateral cephalogram and 2·7 mm ($P < 0{\cdot}01$) as measured on the model photocopies. Distal tipping of the molars was on average, 7·6 degrees ($P < 0{\cdot}001$) while the amount of distopalatal rotation was 9·9 degrees ($P < 0{\cdot}001$). All of these results were in accordance with the findings of Gianelly *et al*. (1988 and 1989), Erdoğan and Ciğer (1990), and Itoh *et al.* (1991). However, they contrasted with the findings of Bondemark and Kurol (1992) in that these investigators found the rotation of the molar to be distobuccal.

Using nickel-titanium open coil springs, an average of 3·8 mm ($P < 0{\cdot}001$) of molar distalization took place as measured on the lateral cephalograms. Model measurements showed the amount of molar distalization to be 4·2 mm ($P < 0{\cdot}001$). The amount of distal tipping was on average, 9·8 degrees ($P < 0{\cdot}001$) while there was a distopalatal rotation of 8·6 degrees ($P < 0{\cdot}001$). Although these findings were also supported by previous studies, work by Gianelly *et al.* (1988, 1989), and Jones and White (1992) merely referred to the presence of molar tipping without measurement.

Former studies on intra-oral molar distalization procedures have usually been performed as a trial of one technique on one case (Itoh *et al.* 1991; Bondemark and Kurol, 1992; Gianelly *et al.* 1991). In the present study, two different techniques were tested on the same patient. Molar distalization produced by nickel titanium open coil spring was, on average, 1·6 mm ($P < 0{\cdot}001$) more than that produced by magnetic force, as measured on the lateral cephalograms. According to the measurements made on model photocopies, the difference was 1·4 mm ($P < 0{\cdot}001$). No difference was found as regards distal crown tipping or distopalatal rotation between the two procedures ($P < 0{\cdot}05$). These findings were in accordance with the results of a similar study by Bondemark *et al.* (1993), although in that study, magnets and springs were activated only once every 4 weeks. This may have been to the disadvantage of the magnets since, as claimed by Gianelly *et al.* (1988) when the distance between the magnets was 0 mm, the force generated was 225 grams, but when the distance increased to 1 mm, the force value decreased to 75 g. Itoh *et al.* (1991) reported that force decreased by 50–70 per cent for every 0·5–1 mm of tooth movement.

On the coil spring side, the free distal movement of the second premolars was 0·7 mm more than for the magnet side. However, this was statistically not significant. The difference between the two techniques from the point of second premolar distalization was not significant.

Conclusions

Although nickel-titanium open coil springs were found to be a more effective means of molar distalization, both procedures were clinically acceptable. The disadvantages of the magnets were their cost, bulky appearance and requirement for weekly activation. Further investigations are necessary to find out if tooth movement achieved with magnets is histologically different from that obtained by conventional mechanics.

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