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Light maxillary expansion forces with the magnetic expansion device. A preliminary investigation

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SUMMARY An active maxillary magnetic expansion device (MED) was developed to be used clinically. The aim was to show the effects of light and continuous forces producing less traumatic stimulation of maxillary sutural growth than a conventional rapid maxillary expansion device.

In this study, two different types of appliances were used on six patients between 7 years 4 months and 16 years 2 months: the first type was bonded, the other one used bands. For better appreciation, four implants were placed on each patient: two apically between central and lateral incisors, and two between second premolars and molars. A standardized radiographic technique was used to take occlusal radiographs, and postero-anterior and lateral headplates. The results varied according to the age and the appliance used. The skeletal effect with the banded MED was between 16 and 77 per cent, and for the bonded MED 0 and 25 per cent in comparison to the overall expansion.

It seems that 250–500 g of continuous magnetic forces can produce dental and skeletal movements in a light force expansion concept, but further studies with larger samples are needed to make firm conclusions.

Introduction

Since Angell (1860) described the use of the maxillary expansion appliance in 1860, several investigators have used different types of maxillary expanders with different force levels and durations (Haas, 1961; Krebs, 1964; Reitan, 1964; Stockfisch, 1969; Hicks, 1978; Howe, 1982). They concluded that this application could have orthodontic and orthopaedic influences depending on age, growth potential, and sex of the patient, but individual changes (Krebs, 1958; Haas, 1961, 1965; Wertz, 1970; Hicks, 1978; Linder-Aronson and Lindgren, 1979; Timms, 1981; Mossaz-Joëlson and Mossaz, 1989) are unpredictable.

Skeletal effects, dental effects, and stability after rapid (RME), semi-rapid and slow expansion (SME), as well as after maxillary expansion with functional appliances and maxillary expansion combined with different surgical techniques, have been studied by several researchers. Nevertheless, palatal expansion is not yet fully understood and the different findings are contradictory (Chaconas and de Albay y Levy, 1977; Schwarz *et al.*, 1985; Warren *et al.*, 1987).

It is reported that, during rapid maxillary expansion, forces between 3 and 10 pounds are produced by single activation of jackscrew appliances, while multiple daily activations could result in cumulative loads of 20 pounds or more (Isaacson and Ingram, 1964; Zimring and Isaacson, 1965). It has been proved that the major resistance to maxillary expansion does not come from the mid-palatal suture, but from the other sutures of the maxilla (Isaacson and Ingram, 1964; Zimring and Isaacson, 1965; Bishara and Staley, 1987).

Under the influence of such heavy forces created by RME, root resorptions have been detected especially in anchor teeth which were extracted from humans and animals for subsequent histological examination (Dabbane, 1958; Rinderer, 1966; Starnbach *et al.*, 1966; Moss, 1968; Timms, 1968; Timms and Moss, 1971; Barber and Sims, 1981; Langford and Sims, 1982; Vardimon *et al.*, 1991). Thus, in adult patients, several authors suggest corticotomy with or without palatal osteotomy (Lines, 1975; Bell, 1976; Glassmann, 1984; Lehmann *et al.*, 1984; Alpern and Yurosko, 1987; Mossaz *et al.*, 1992) in order to avoid root resorption, to obtain skeletal effects and to ensure stability.

Actually, there is a tendency to use more continuous and less heavy forces (Mew, 1977; Mossaz-Joëlson and Mossaz, 1989). Semi-rapid and slow expansions are found to be more within biological boundaries (Rinderer, 1966; Barber and Sims, 1981; Vardimon *et al.*, 1991). Slow maxillary expanders such as the Quad-helix (Hicks, 1978) or Minne-expander (Mossaz-Joëlson and Mossaz, 1989) incorporate a force system varying from several ounces up to approximately 2 pounds. Krebs (1958) found that almost 50 per cent of the total reaction with the RME was skeletal and Hicks (1978) observed 16–50 per cent skeletal reaction with the SME.

Over the last 15 years, magnets and magnetic fields have been introduced to orthodontics (Blechman, 1985; Darendeliler and Joho, 1992; Gianelly *et al.*, 1988; Kawata *et al.*, 1987) and dentofacial orthopaedics (Darendeliler and Joho, 1993; Vardimon *et al*; 1987, 1989). Static and electromagnetic fields have been investigated and found to be effective on the rate and velocity of tooth movement and on bone healing (Darendeliler *et al.*, 1992; Stark and Sinclair, 1987). It is well known today that magnetic forces are able to produce orthodontic tooth movements (Darendeliler and Joho, 1992; Kawata *et al.*, 1987). In addition, they open an entirely new field in functional orthopaedic concepts, such as liberty of functioning and functional adaptation (Darendeliler and Joho, 1993). The transversal effects of repulsive magnets on the maxilla have been studied by Vardimon *et al.*, (1987) on animals and have been applied to patients in the Department of Orthodontics, University of Geneva.

This study examines the effects of light magnetic forces for maxillary expansion on patients of different ages. The aim was to observe the dental and skeletal responses to light and continuous forces in the presence of static magnetic fields and to examine if a less traumatic stimulation of maxillary sutural growth could be obtained.

Subjects and methods

An active maxillary magnetic expansion device, (MED), which applies forces between 250 and 500 g (0.55–1.1 pounds), was developed to be used on children and adolescents. Basically, in the MED, the conventional expansion screw was replaced by two repelling Samarium-Cobalt magnets (Sm_2Co_{17}). They measured 4 × 5 × 16 mm and were coated with vacuum-moulded plastic plus acrylic. The magnetic flux density induced was 1.6 Tesla (earth magnetic field, 0.05 milliTesla). The expansion force, produced between magnets, depends greatly on the distance between them: in the present study, the maximum force after coating was 500 g, the air gap being 0 mm and the magnets therefore being in full contact.

Two different types of MED appliance were used. A bonded MED (Fig. 1A) was placed in two patients while four patients received a banded MED (Fig. 1B). Pins and tubes had to be placed in the right and left acrylic parts of the appliance in order to guide the separation during treatment (Fig. 2). In the bonded type, two heavy wires shaped like open staples held the two acrylic parts together during the bonding procedure (Figs 2A and 3A) and were removed afterwards (Fig. 1A). In the banded

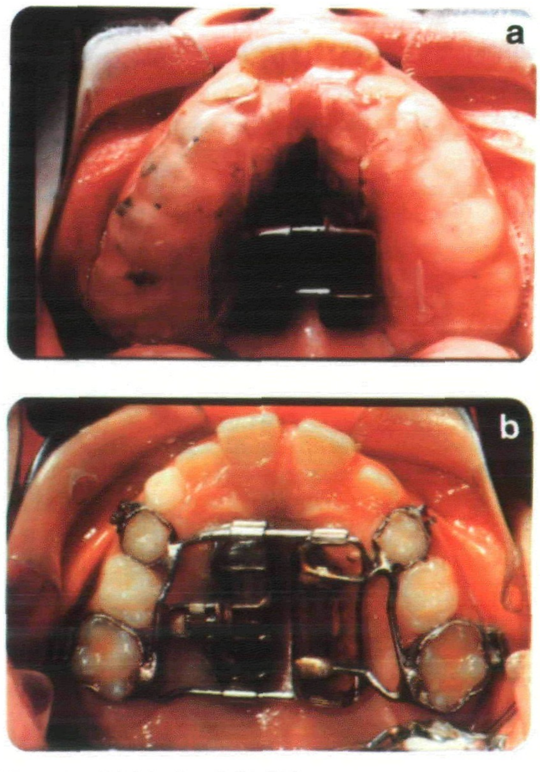

Figure 1 (A) The bonded MED. (B) The banded MED.

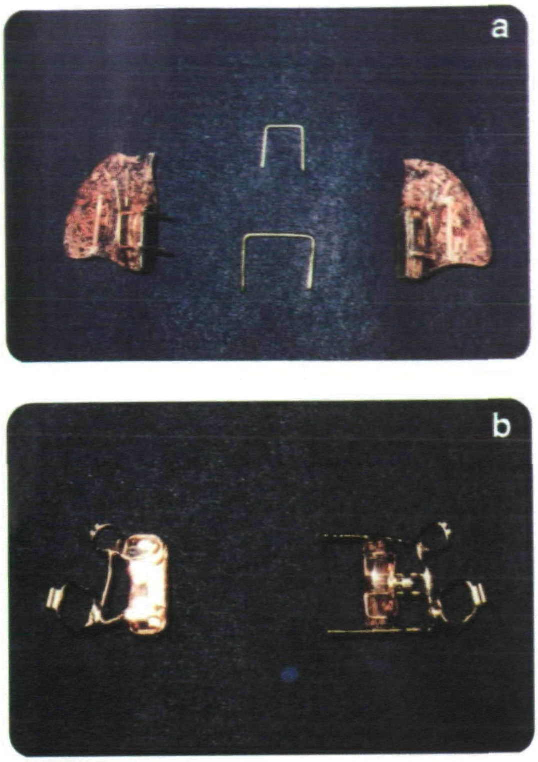

Figure 2 (A) The bonded MED before insertion. The 'U' form shaped heavy wires help to hold the acrylic parts together during bonding. (B) The banded MED before insertion. The expansion screw allows one of the magnets to move when activation is needed. A ligature holds the two parts together during cementing.

type, ligature wires were used to keep the two parts in contact during cementing of the appliance (Fig. 3B).

As the force decreases with the separation of the magnets, occasional activation is needed. In the banded type, the activation was made possible by an expansion screw which moved one of the magnets towards the other until the gap between them was closed again (Figs 1B, 2B, 3B and 3C). The screw was activated every 3 weeks. The repulsive force decreased from 500 g to approximately 250 g at the end of the third week (Fig. 4). This appliance is similar to a Minne-expander as far as the type of activation and the continuity of the force is concerned, but the force level with the Minne-expander is almost double (Mossaz-Joëlson and Mossaz, 1989).

In the bonded type, the appliance was activated once by adding smaller magnets on one

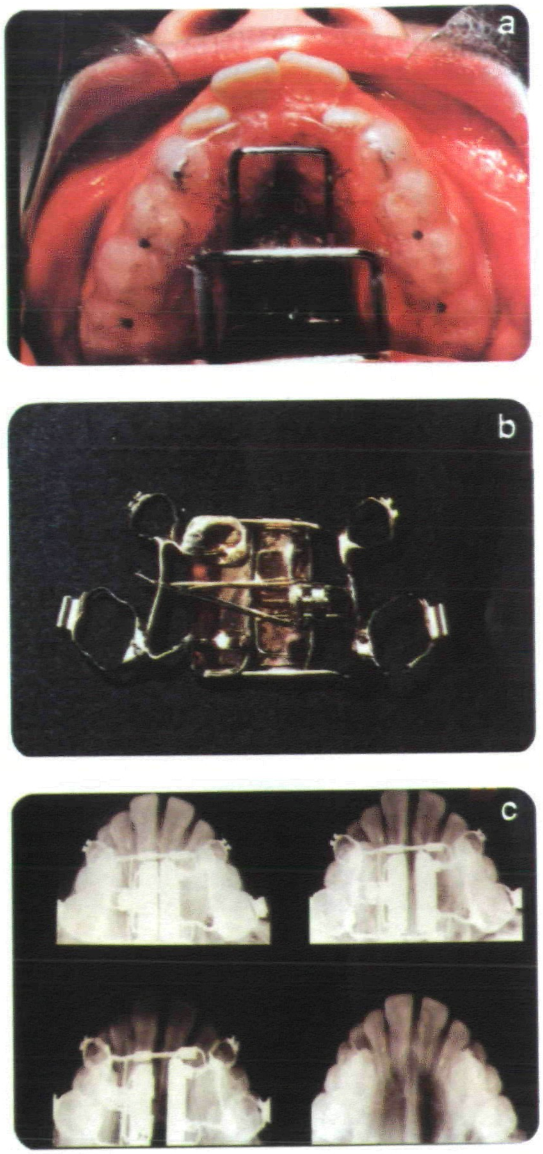

Figure 3 (A) The bonded MED in place. (B) The banded MED assembled before cementing. (C) The banded MED (case PL) Occlusal radiographs (a) day 1, (b) after 2 weeks, (c) at the end of the expansion period, and (d) at the end of the retention period.

side to fill the gap (Fig. 5C). The expansion was continued until 25 per cent overcorrection was obtained.

The MED was used on six patients aged between 7 years 4 months and 16 years 2 months. For a more accurate evaluation of the results, four implants were placed on each patient: one pair, right and left, apically between

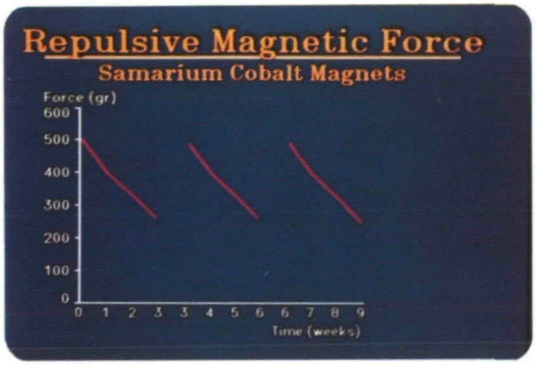

Figure 4 The repulsive force diagram of the banded MED.

upper central and lateral incisors, and another pair (Fig. 6), again on the right and left sides between upper second premolars and first molars. Occlusal radiographs, lateral and postero-anterior headplates, study models, and intra-oral photographs were taken on the day the appliance was placed, at the end of active treatment, after 6 months of retention and after a post-retention period which varied from 1 to 2½ years. Occlusal radiographs were taken with a standardization device (Fig. 7). A conventional maxillary retainer (Hawley appliance) was placed the day the MED was removed and worn for the 6 months of retention. The transverse distance between both canine points and both first molar central fossae on the study models, and the transverse distance between both anterior implants and both posterior implants on the occlusal and postero-anterior headplates were measured to evaluate the overall and skeletal expansion, and the relapse.

Results

Clinical findings

The results indicate that the dental expansion was successful in all six cases (Figs 8–10, Table 1). Both types of MED were well tolerated by the patients, but oral hygiene was much more of a problem with the bonded appliance. All patients showed speech problems at the beginning of treatment which disappeared within 2 weeks.

In one patient wearing the bonded type (FS), the posterior pin slipped out of its guiding tube

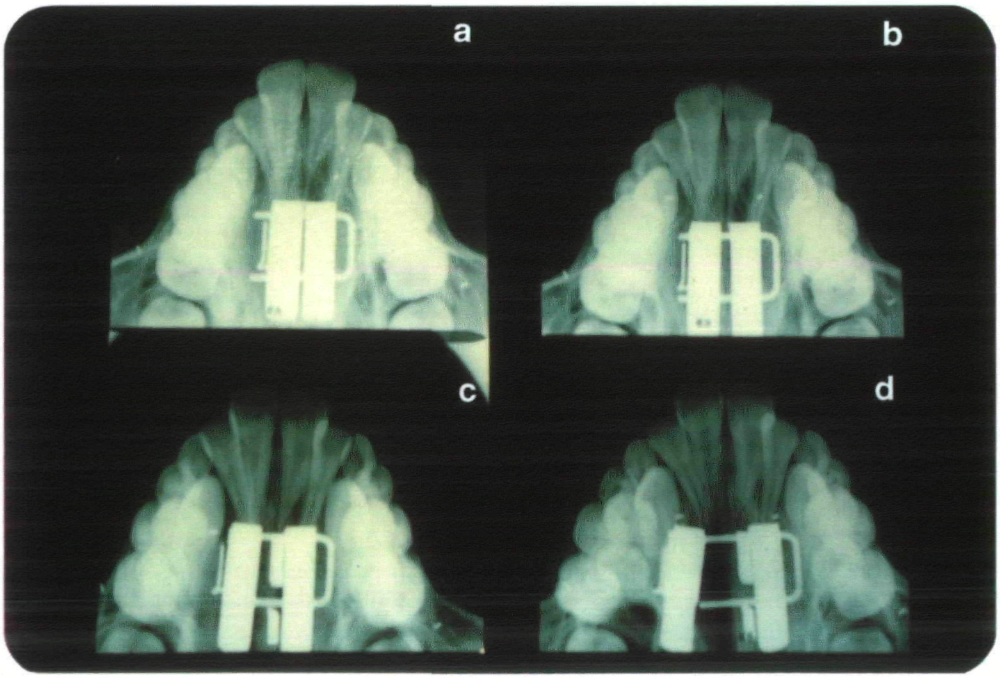

Figure 5 The bonded MED (case FS) occlusal radiographs. (A) Day 1. (B) After 2 weeks. (C) By adding two small magnets on one side the intermagnet distance is reduced, the repelling force is increased which corresponds to an activation of the appliance (after 6 weeks). (D) At the end of the expansion period (note that the posterior pin slipped out from its guiding tube).

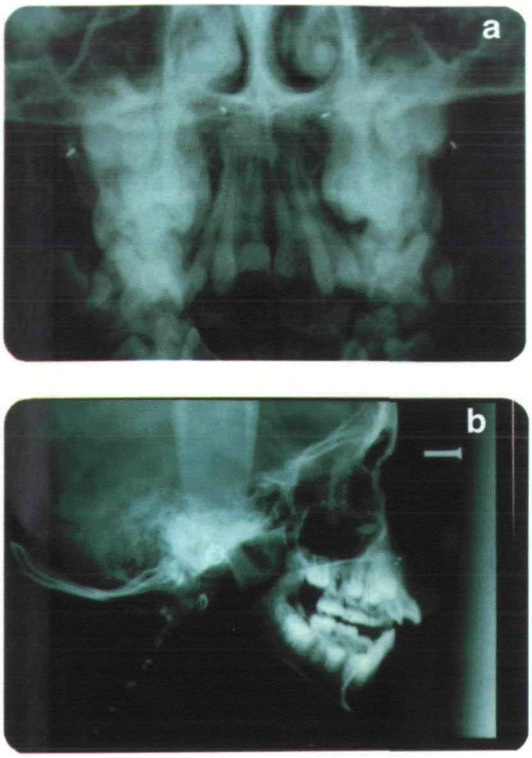

Figure 6 (A and B) Postero-anterior and lateral radiographs showing the implants one pair, apically between upper central and lateral incisors, the other pair, between upper second premolars and first molars.

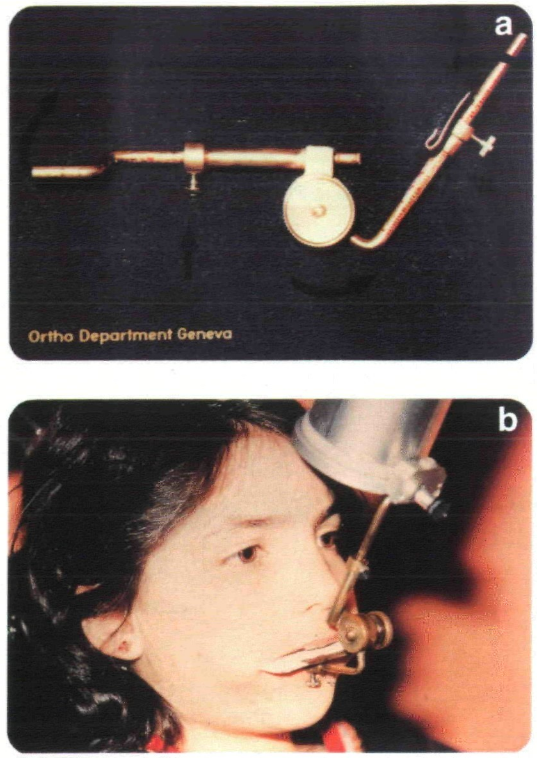

Figure 7 (A) Standardization device used for the occlusal radiographs. (B) *In situ*.

just before the last appointment and thus allowed more dental tipping (Fig. 5).

Removal of the bonded appliance took considerably more time than the banded one and the palatal mucosa was more erythematous and inflamed. The well-known midline diastema which is usually observed in conventional RME appliances was not observed in any of the six patients.

Cast analysis

The expansion gained and the post-retention changes in the anterior and posterior parts of the maxilla are described in Table 1. In all patients, the posterior width increased more

Table 1 Cast measurements (overall expansion).

			ANTERIOR		POSTERIOR	
Patient	Age	Treatment duration	Expansion	Post-retention width change	Expansion	Post-retention width change
RL*	7.4	6.5 months	6	+0.5	6.6	+0.8
PS	8.1	5.5 months	6.5	0	7.2	−1.7
PL	8.6	4.0 months	4.2	−1.2	7	−2.5
CM	9.8	8.0 months	2.2	+0.9	8.3	+1.3
FS*	10.2	5.5 months	4	+0.9	7.6	−1.6
DK	16.2	4.0 months	3.6	−1.5	7.0	−3.9

+: Increase in the transverse dimension
−: Decrease in the transverse dimension
*Patients with the bonded MED.

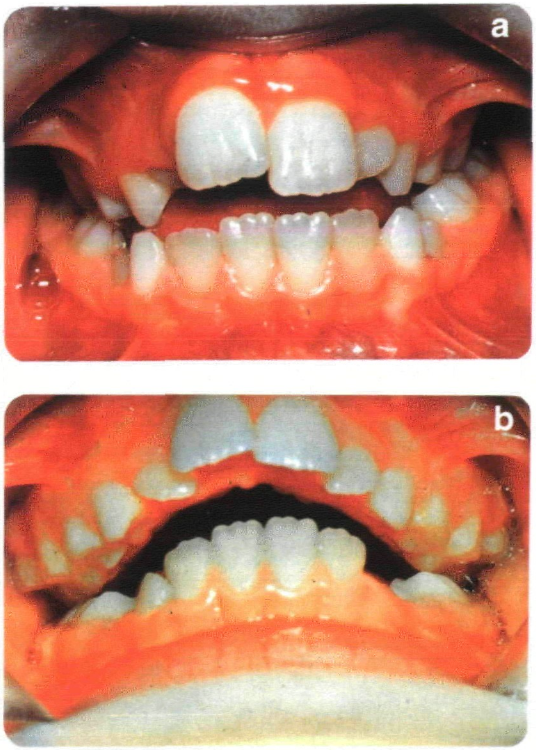

Figure 8 (A and B) Patient FS, age 10.2 years, before and after 22 weeks of appliance wear (the bonded MED).

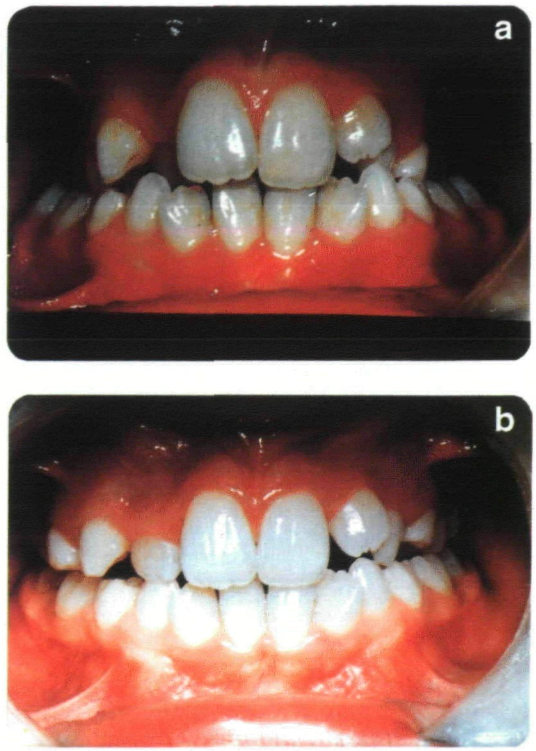

Figure 9 (A and B) Patient CM, age 9.8 years, before and after 32 weeks of appliance wear (the banded MED).

than the anterior width. In the 16-year-old patient, post-retention dental relapse was 56 per cent after 17 months. The 8-year 6-month old boy who did not follow the instructions of full-time wear of the retainer also showed a post-retention relapse of 36 per cent. The other four patients showed less or no relapse after a 12–18-month post-retention period.

Radiographic findings

Occlusal radiograph and P-A headplates

In the four patients between 7 years 4 months and 9 years 8 months, an opening of the mid-palatal suture was seen on the occlusal radiograph taken during the second week of expansion (Fig. 11). Anterior and posterior skeletal changes measured between the implants on the occlusal radiograph and P-A headplates were recorded three times and the mean values of the six measurements are reported in Table 2.

Almost no skeletal effects were detected in patients with bonded MED or in the 16-year-old patient (DK) with a banded MED. Skeletal versus overall expansion varied from 0 to 25 per cent in cases with bonded MED and from 16 to 77 per cent in cases with banded MED, the 16-year-old patient excepted (DK) (Table 3).

Skeletal width changes after 1–2 years post-retention showed almost no skeletal relapse (Table 2).

Angular changes of the upper first molars. In half of the cases, the expected buccal tipping of the first molars relapsed to a greater extent during retention and post-retention periods (Table 4). The amount of buccal tipping during expansion varied from 1.5 to 9.5 degrees except for one patient (FS), in which the tipping reached almost 20 degrees probably because the posterior pin had slipped out from its guiding tube.

Lateral cephalograms. Table 5 indicates the cephalometric values measured during and after treatment: no skeletal changes were observed, with the exception of a slight opening of the

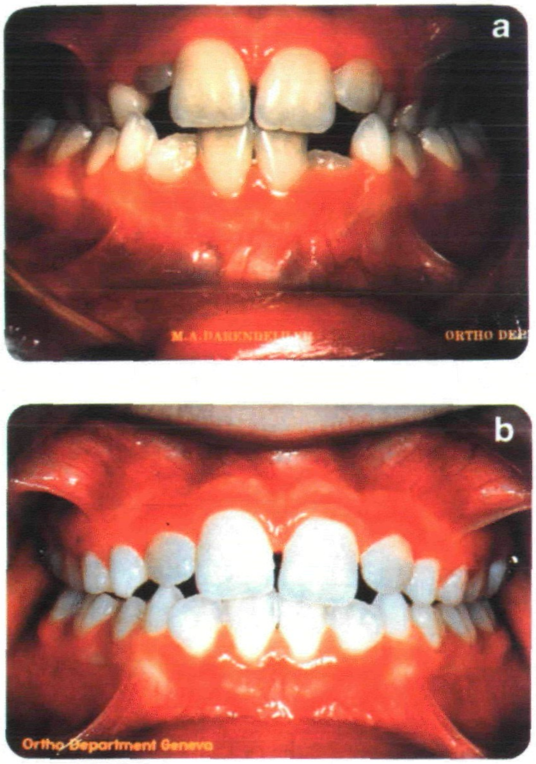

Figure 10 (A and B) Patient PS, age 8.1 years, before and after 22 weeks of appliance wear (the banded MED).

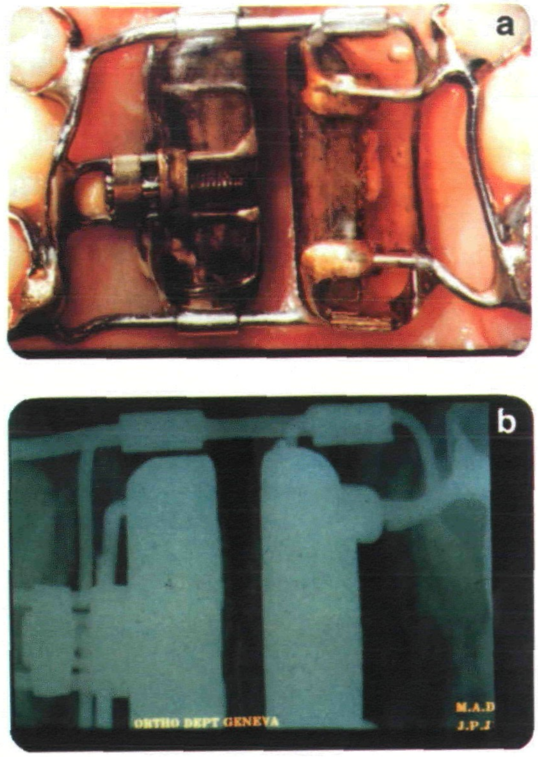

Figure 11 (A) A banded type of MED in place. (B) *Opening of the mid-palatal suture is evident in the second* week of expansion.

mandibular plane angle during expansion which closed again during retention.

Discussion

Clinical researchers have used various force levels to expand the maxilla and have focused on the amount of skeletal effect obtained. It has been reported that up to 20 pounds of force have been applied to the facial bones when using conventional RME appliances (Isaacson and Ingram, 1964; Zimring and Isaacson, 1965) and that approximately 50 per cent skeletal response has been obtained after 1–4 weeks (Timms, 1981). However, the optimal force

Table 2 Measurements between left and right implants (skeletal expansion).

			Anterior		Posterior	
Patient	Age	Treatment duration	Expansion	Post-retention width change	Expansion	Post-retention width change
RL*	7.4	6.5 months	0.7	+0.1	1.7	+0.5
PS	8.1	5.5 months	1.8	−0.6	3.0	+1.3
PL	8.6	4.0 months	0.7	+0.3	1.7	+0.1
CM	9.8	8.0 months	1.7	+0.2	4.1	+0.7
FS*	10.2	5.5 months	0.3	+0.4	0.7	+1.8
DK	16.2	4.0 months	0.2	+0.1	0.5	+0.6

+: Increase in the transverse dimension
−: Decrease in the transverse dimension
*Patients with the bonded MED.

Table 3 Percentage of skeletal changes.

		Anterior			Posterior		
Patient	Age	Skeletal (mm)	Overall (mm)	Skeletal (%)	Skeletal (mm)	Overall (mm)	Skeletal (%)
RL*	7.4	0.7	6.0	11.7	1.7	6.6	25.7
PS	8.1	1.8	6.5	27.6	3.0	7.2	41.6
PL	8.6	0.7	4.2	16.6	1.7	7.0	24.2
CM	9.8	1.7	2.2	77.2	4.1	8.3	49.3
FS*	10.2	0.3	4.0	7.5	0.7	7.6	9.2
DK	16.2	0.2	3.6	5.5	0.5	7.0	7.1

*Patients with the bonded MED.

Table 4 6/6 tipping (angulation between the upper molars and mid-sagittal plane measured on postero-anterior headfilms).

	Before treatment (°)		After treatment (°)		Tipping during expansion (°)		Post-retention period (°)		Tipping during post-retention (°)	
Patient	6/	/6	6/	/6	6/	/6	6/	/6	6/	/6
RL*	16	10.5	16	10.5	0	0	18	11	+2	+1
PS	12	11	19	12.5	+7	+1.5	13	12.5	−6	0
PL	16	12.5	23	18.5	+7	+6	16	15	−7	−3.5
CM	11	21	1	16.5	−10	−4.5	5	21.5	+4	+5
FS*	11	9	23	28.5	+12	+19.5	13	11.5	−10	−17
DK	19	18	28.5	22.5	+9.5	+4.5	21	21	−7.5	−1.5

*Patients with the bonded MED.

Table 5 Sagittal and vertical changes during treatment and post-retention period.

	SNA	SNB	ANB	ANS/PNS–MGo′	SN–ANS/PNS	SN–MGo′	Date
RL*	81	77.5	3.5	34.5	3	37.5	15.03.1990
	80	76	4	35	4	39	4.10.1990
	81	77	4	35	3.5	38.5	8.04.1992
PS	76.5	75	1.5	28	13	41	5.01.1990
	77	74	3	28.5	13	41.5	19.06.1990
	77	75	2	28	13	41	2.06.1992
PL	72.5	70.5	2	30.5	12	42.5	7.02.1989
	74	71.5	2.5	31.5	11	42.5	28.06.1989
	75	72	3	30.5	11	41.5	2.06.1992
CM	82.5	80.5	2.5	33	6	39	17.10.1989
	81	79	2	35.5	4.5	40	21.06.1990
	84	83	1	34	4.5	38.5	4.06.1992
FS*	79	70	9	44	6	50	11.04.1988
	78.5	71	7.5	41.5	8.5	50	15.09.1988
	79	72	7	40.5	9.5	50	4.04.1992
DK	75	74	1	25	13	38	21.11.1989
	75	74	1	24	14	38	1.03.1990
	75	74	1	25	13	38	7.03.1991

*Patients with the bonded MED.

levels for different ages have not yet been established. More recently, research results showed that slower maxillary expansion with the Minne-expander, applying forces up to 2 pounds, allowed 16–30 per cent skeletal expansion in 8–13 weeks in patients between 10 and 15 years old (Hicks, 1978), and 50 per cent skeletal response in patients between 8 and 12 years old (7–15 weeks) (Mossaz-Joëlson and Mossaz, 1989).

In the present study, using Light Maxillary Expansion Forces (LMEF) with the MED, generating forces between 250 and 500 g (banded MED), 16–77 per cent skeletal effect versus total expansion was obtained in patients between 8 years 1 month and 9 years 8 months (16–32 weeks). It is evident that, to obtain an orthopaedic expansion of the maxilla, the force must be sufficient to overcome the bio-elastic resistance of the periodontium, the alveolar bone and the sutural elements (Storey, 1955).

Orthopaedic effects on the maxillary complex are usually the result of a mechanical repositioning followed by an adaptive growth of the facial sutures depending on age and growth potential of the patient. In the sagittal plane, forward or backward growth modifications of the maxilla are observed by using forces between 400 and 2000 g (Cleall *et al.*, 1965; Storey, 1973). These forces influence the sutures of the naso-maxillary complex which are orientated in a similar, mostly sagittal, plane (Remmelink, 1988). Because these sutures are orientated in the sagittal plane and not in the vertical plane one would suppose that there is more resistance to the forces applied during transverse orthopaedic correction than during sagittal orthopaedic correction: this could be a reason in favour of the use of heavy forces to expand the maxilla. It is also well known that the major resistance to expansion is not the mid-palatal suture itself, but the other sutures of the maxilla (Bishara and Staley, 1987). The easiest technical way to apply transversal forces on the maxilla is the jackscrew and this is probably the reason for its large clinical use even though the forces applied are too heavy. Pathological effects such as root resorption, alveolar dehiscence and fenestration due to overpowered appliances have been reported by several authors (Rinderer, 1966; Barber and Sims, 1981; Vardimon *et al.*, 1991). In addition, mechanical separation at the mid-palatal suture can lead to an unfavourable healing response (Melsen, 1972). Melsen examined biopsy samples taken from the mid-palatal sutures of eight children aged between 8 and 13 years at various stages of RME and following expansion. She found numerous microfractures at sites of bony interdigitations in the older patients of that sample. Her findings clearly showed that lighter forces, for example those delivered by the Minne-expander, should be used. However, we still do not know if any pathological effect exists with the Minne-expander. Since an orthopaedic effect can be obtained with an expansion force of 250–500 g as shown in the present study, side effects of heavy expansion might be eliminated.

With regard to the different force levels, the duration of the expansion varies: approximately 1 month with RME (Krebs, 1958), 2–4 months with SME (Minne-expander) (Mossaz-Joëlson and Mossaz, 1989) and 4–8 months with LME (using MED).

Isaacson and Ingram (1964), and Zimring and Isaacson (1965) suggested that a more physiological expansion of the maxillary complex without the accumulation of a large residual load could be obtained using slower rates of expansion. Storey (1973) mentioned, following a study on rats and rabbits, that in animals subjected to slow maxillary expansion, sutural integrity was maintained and that the relapse potential was lower than in animals treated with RME. Ohshiama (1972) reported that there was less dental tipping with SME than with RME in monkeys. The rate of mid-palatal suture separation with slow expansion systems apparently leads to a more physiological response by the sutural elements than the disruptive nature of RME (Skieller, 1964). The enhanced maintenance of tissue integrity in slowly expanded sutural elements has been associated with greater stability and less relapse potential during reorganization of the maxillary complex (Skieller, 1964; Hicks, 1978; Timms, 1981; Bell, 1982).

With a slow expansion rate and light forces, the age and growth potential of the patient become more important. Mossaz-Joëlson and Mossaz (1989) found more skeletal effects (50 per cent) in patients aged 8–12 years than Hicks (1978) who used the same amount of force on patients aged 10–15 years and found 16–30 per cent skeletal effect. Thus, the LMEF, should be more effective if applied early.

Another aspect of the present study was the use of Static Magnetic Fields (SMF). Until now, very few histological findings concerning the effects of magnetic fields on facial bones, sutures and condyles have been published. Gerling *et al.* (1985) found an enlarged proliferative layer in guinea-pigs' condyles in the presence of pulsed electromagnetic fields (PEMF), but did not observe any increase in length of the mandible after a 10- and 30-day experimental period. In a previous study, on a sample of guinea-pigs, accelerated bone healing was found in the presence of SMF and PEMF after mandibular osteotomy. It is also mentioned that these magnetic fields could increase the rate of orthodontic tooth movement (Stark and Sinclair, 1987). Some authors (Cleall *et al.*, 1965; Stark and Sinclair, 1987; Darendeliler *et al.*, 1992) suppose that magnetic fields like electrical currents (Davidovitch *et al.*, 1980; Davidovitch, 1981) could change the membrane permeability and thus influence the exchange of cellular nucleotides, calcium uptake (Colaccicco and Pilla, 1983) and lead to a quicker appearance of osteoblasts and osteoclasts (Stark and Sinclair, 1987). It is not known if SMF have advantages or disadvantages in maxillary expansion and further histological evidence and clinical research is needed.

Conclusion

With such a large number of parameters and such a small sample, conclusions are only hypothetical, but it seems that 250–500 g of continuous magnetic force can produce dental and skeletal movements in a light force expansion concept. Further studies orientated towards the following three goals must be carried out:

1. The use of larger samples in order to study the efficiency of LMEF versus RME and SME, in particular versus the Minne-expander.
2. Histological research is needed to evaluate the effect of LME on root resorption and surrounding tissues.
3. The use of neodymium magnets which are more powerful than SmCo magnets. The same amount of force could be obtained with a smaller and thus less bulky MED.

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