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Magnetic attachment for denture type appliance in pediatric patients

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Abstract Several types of denture attachments are used in pediatric dentistry, however, it is difficult to obtain optimal retention using conventional clasps in young patients, because of the shape variations of primary and erupting permanent teeth. We tested application of a magnetic attachment for space maintenance with an orthodontic appliance in pediatric patients. Using a mixed dentition model, we examined the attraction force of denture materials with a magnetic attachment under several conditions, including type of anchor tooth, keeper angle for tooth axis, and direction of retraction. The optimal keeper angle for the primary first, second, and permanent first molars of the maxilla and primary first and second molars of the mandible was 10°, whereas 20° is best for the permanent first molars of the mandible. In the maxilla, a denture containing primary first and second molars as anchor teeth had relatively high retention compared to the same with permanent first molars. In clinical cases, dentures with magnetic attachments showed greater attraction force than those with Adams clasps in the maxilla, while in the mandible, retention was not significantly different between the two. These results suggest that a magnetic attachment may be useful for denture appliances in pediatric patients.

Key words
Denture type appliance,
Magnetic attachment,
Retention force

Introduction

Several kinds of permanent magnets have been used in dentistry since the early 1950s.[1)], with application as denture retainers also attempted. Alnico, ferrite, and platinum-cobalt magnets were most often used, however, their size was generally greater than 1 cm and the use was largely restricted because of bulk. In late 1970s, the rare earth-cobalt magnets were developed[1–4)], after which the samarium-cobalt (Sm-Co) magnets were shown to have excellent magnetic properties with a higher magnetic force and a smaller size. Thereafter, the magnetic force necessary for dental applications was obtained with very small Sm-Co magnets[5)], however, the materials were found to corrode in an oral environment.

Dental materials generally require high corrosion resistance and must be innocuous to oral tissue. To prevent corrosion of the exposed surface of Sm-Co magnets, the surface is covered with stainless steel or titanium foil, and close the circuit, as the magnetic force of a closed circuit is stronger than one that of open[4,6–7)], the magnet is enclosed in a sandwich of ferromagnetic materials covering the magnet, which are made from highly pure chrome stainless steel. This type of magnet is able to provide strong magnetic force and corrosion in an oral environment and recently its use as a magnetic attachment, have been studied for retention of partial dentures clinically, especially in adults.

Denture-type space maintainers and orthodontic appliances are most frequently used in pediatric dentistry for occlusal guidance, with Adams, ball, simple, and other types of clasps, used for retention. However, it is often difficult to use a certain anchor tooth, because of shedding and the anatomical form of primary teeth as well as erupting permanent teeth[8)].

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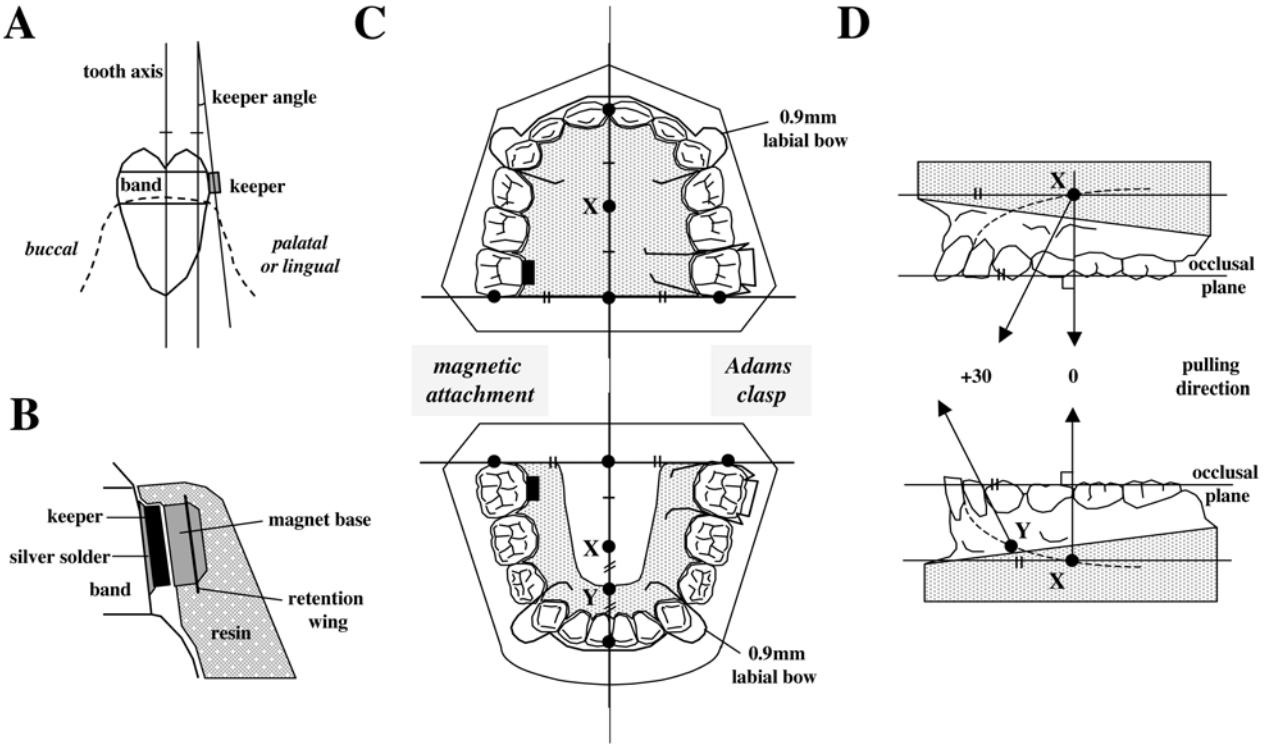

Fig. 1 Location of keeper on anchor teeth, design of denture models, and pulling direction of denture in the experiments. (A) Keepers were fixed on the palatal or lingual side. (B) High magnification of the keeper and magnetic base. (C) Dentures with and without magnetic attachments were designed. Maxillary and mandibular dentures both had a 0.9 mm diameter labial bow. (D) The pulling directions to the occlusal plane were + 30° and 0°.

Further, with conventional retention components, a decline of retention power often occurs as a result of breaking and metal fatigue during transformation[4].

The retention force of an individual magnetic attachment is approximately 400 to 600 gf and the long-term stability of attraction force provided by a magnetic attachment has been established[4,9,10]. Further, such denture and retentive devices that feature a simpler construction may allow easier cleaning, as well as be more difficult to break and transform[4,7,9]. As a result, the maintenance of denture appliances fitted with a magnet is thought to be much easier than conventional appliances fitted with clasps. In addition, those with magnetic attachments have another advantage of automatic self-seating by magnetic force[4,6]. However, there is no known report regarding the application of magnetic attachments in pediatric dentistry.

We tested magnetic attachments as retentive components in denture-type space maintainers and orthodontic appliances for application in a model of mixed dentition as well as in clinical cases. The effect of retention by magnetic dentures according to the angle of the keeper, number of magnetic attachments, type of anchor teeth employed, and direction of traction were examined using a dental study model of mixed dentition. We also compared denture retention between Adams clasps and magnetic attachments in clinical cases.

Materials and methods

Preparation of experimental model

An epoxy model of mixed dentition (Nissin Dental Products Inc., Kyoto, Japan) was used to compare the holding force of a denture appliance fitted with magnets to that with Adams clasps. Impressions for the mixed dentition model were taken by using silicon impression paste (EXAFINE® PUTTY TYPE and REGULAR TYPE, GC Corp., Tokyo, Japan), after which denture-type space maintainers fitted with a magnetic retention appliance (Magfit™ EX400W, GC Corp.), or Adams clasps were prepared. The magnetic attachment used was Sm-Co magnet sandwiched in stainless steel, and was placed as shown in Figure 1. The maxillary and mandibular

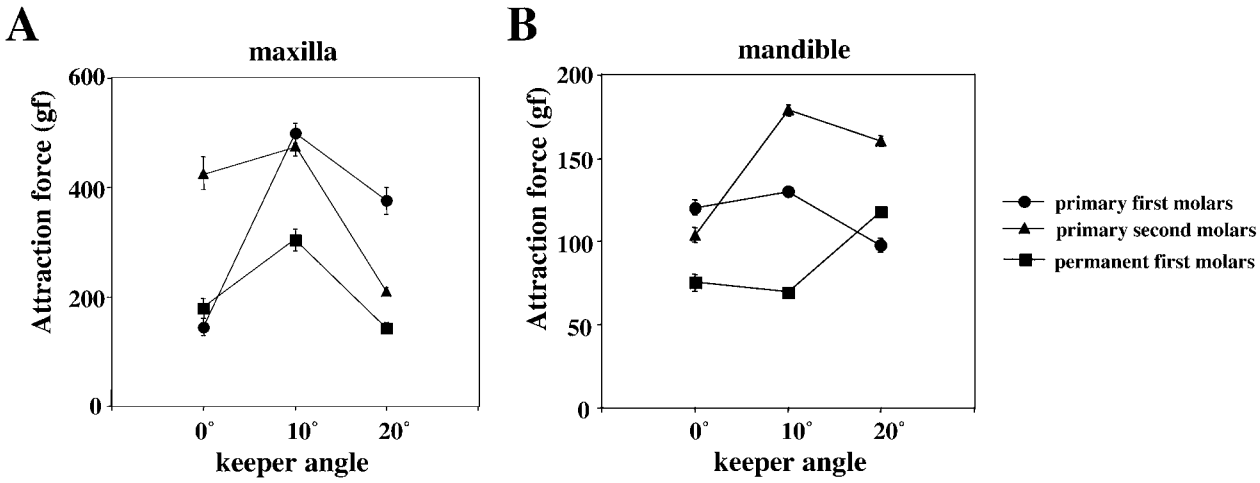

Fig. 2 Effect on attraction force according to angle of keeper to anchor tooth axis. Attraction force of maxillary (A) and mandibular (B) dentures. Retention results of dentures anchored with the primary first molars (closed circle), primary second molars (closed triangle) and permanent first molars (closed square) are shown. Data are expressed as mean ± S.D. of 10 different measurements.

primary first and second molars and permanent first molar were used as anchor teeth, and the keepers for magnetic attachment to the tooth axes were set at 10°, 20°, and 30° angles. The keeper was fixed in each retention tooth by chemically cured acrylic resin (Unifast, GC Corp.). Adams clasps were made of Supura wire 0.8 mm in diameter (Nippon Shiken Dental Co. Ltd., Tokyo, Japan) and placed into the denture as shown in Figure 1. All dentures had a labial bow (0.9 mm diameter Supura wire: Nippon Shiken Dental Co. Ltd.).

Measurement of attraction force

To examine the retention force of the magnetic denture, an OHBA tension gage (OHBA INSTRUMENT WORKS LTD., Tokyo, Japan) was used. A ligature wire (0.25 mm diameter: TOMY, Tokyo, Japan) was fixed at the center of the denture (Fig. 1: point X), and connected to the probe of the tension gauge as shown in Figure 1D, and then each denture appliance was tested 10 times. Data are expressed as mean ± S.D. Statistical analysis used in the study were analysis of variance (ANOVA) and Fisher's PLSD, and calculations were performed with Stat View software (Abacus Concepts Inc., Berkeley, CA, USA).

Clinical experiments

Before clinical experiments, informed consent was obtained from the children and/or their parents. In order to compare the retention ability of the magnetic attachment to conventional Adams clasps in clinical cases, we applied both types with dentures, 1 of each type for each patient, for space maintenance and occlusal guidance. For preparation of the magnetic denture, bands were placed on the maxillary and mandibular permanent first molars or primary second molars, and then an impression was taken with alginate impression paste (SANKIN KOGYO K.K., Tokyo, Japan) for a working model. Magnetic keepers were fixed with silver solder on the bands at 10° for the primary first and second molars and upper permanent first molars, and at 20° for the lower permanent first molars, and then the magnetic attachments were placed in a denture using chemical cure resin (Orthocrystal: Nissin Dental Products Inc.). Retention was measured with an OHBA tension gage as in the experimental model described above, except for cases with a mandibular denture, in which the appliance was pulled from point Y (Fig. 1D), because of the presence of the tongue. Retention force was examined 10 times in each clinical case. A total of 15 cases were examined (10 with upper dentures, 5 with lower dentures). Statistical analysis was performed using a paired Student's *t*-test.

Results

Effect of keeper angle on retention force

A magnetic attachment was placed on each keeper, which was fixed on the tooth. In pediatric dentistry,

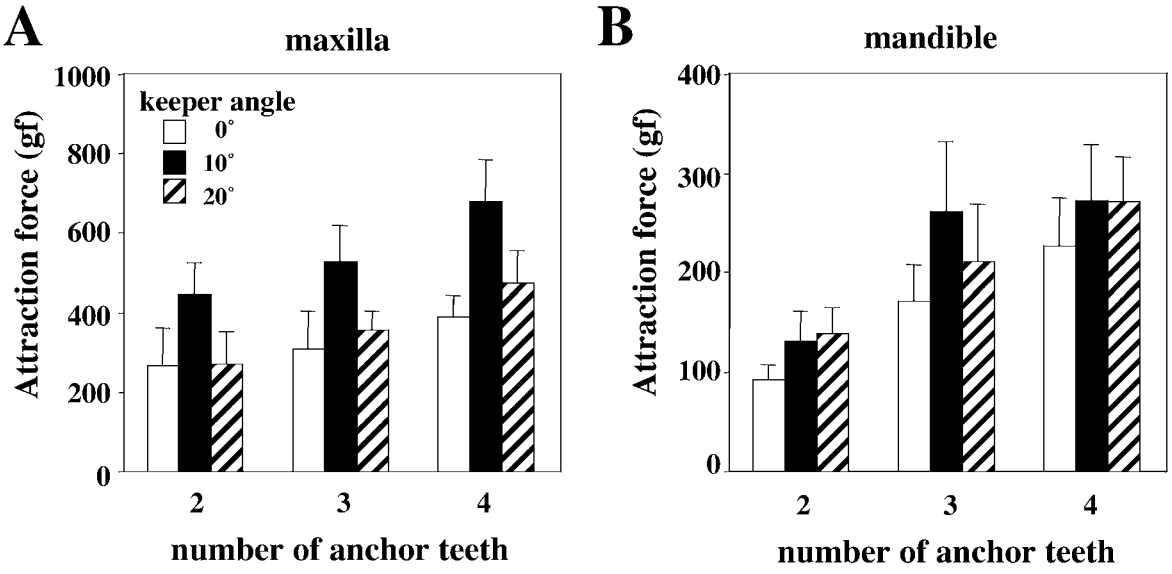

Fig. 3 Effect on attraction force according to number of anchor teeth. Attraction force of maxillary (A) and mandibular (B) dentures. Keepers were fixed on the palatal or lingual side of the teeth at 0° (open bar), 10° (closed bar) and 20° (oblique bar). Data are expressed as mean ± S.D. of 10 different measurements.

anchor teeth usually have a normal crown, which sometimes has dental caries, however, the anchor teeth in adults have often lost their crown. Therefore, keepers might be fixed on the buccal or palatal/lingual side of the tooth in pediatric dentistry. In such a situation, retention by the magnetic attachment can not be fully obtained, because the holding force is strong in the vertical direction and weak in the lateral[11,12]. To examine the attraction force of a denture with a magnetic attachment, keepers were fixed at 3 different angles, 0°, 10°, and 20° to the tooth axes, on the palatal/lingual side of either the primary first molars, primary second molars, or permanent first molars in a mixed dentition model (Fig. 1A).

In the maxilla, a 10° keeper angle showed the strongest attraction force when anchored to the primary first molars (500.5 ± 17.7 gf), followed by the primary second molars (477.5 ± 18.6 gf) and permanent first molars (304.5 ± 20.6 gf) (Fig. 2A). On the other hand, in the mandible, 10° was the strongest with the primary second molars (178.0 ± 3.5 gf) followed by the primary first molars (130.0 ± 0.0 gf), while 20° was strongest with the permanent first molars (125.0 ± 0.0 gf) (Fig. 2B).

Effect of number of anchor teeth on attraction force

To determine the effect of the number of anchor teeth on retention in the pediatric dentures, magnetic keepers were fixed on 2, 3, or 4 maxillary or mandibular molars in mixed dentition models. We found that a magnetic attachment to only 1 side of the denture did not provide enough force to retain the denture, and detachment from the alveolar fundus easily occurred (data not shown), suggesting that 2 magnetic attachments, one on each side of the arch, should be employed.

An increase in the number of anchor teeth led to excessive attraction force in both the maxilla and mandible (Fig. 3A and 3B). Moreover, the maxillary denture showed approximately 2 times higher retention force as compared to the mandibular denture under nearly all of the experimental conditions, regarding number of teeth and keeper angles (Fig. 3 and Table 1).

In both the maxilla and mandible, a significantly higher attraction force was obtained with the 10° keeper angle as compared with other angles, except for under conditions of 2 and 4 anchor teeth with a 20° keeper angle in the mandible. We also analyzed the effect of kind of tooth for anchoring on retention force in clinical applications. In the maxilla, when the anchor teeth were the primary first and second molars, a relatively high amount of attraction force was seen as compared with the permanent first molars (Table 1). However, in the mandible, similar results were not observed.

Table 1 Attraction force in mixed dentition model

Number of tooth	Anchor teeth	Maxilla			Mandible			(keeper angle)
		0°	10°	20°	0°	10°	20°	
2	6|6	179.5±18.3	304.5±20.6	143.0±11.4	82.5±4.9	77.0±2.6	125.0±0.0	(gf)
	E|E	426.5±30.2	477.5±18.6	209.5±7.6	103.0±4.8	178.0±3.5	159.5±2.8	
	D|D	145.5±15.5	500.5±17.7	376.5±24.0	120.5±4.4	130.0±0.0	98.0±4.2	
	6|E	336.0±20.1	422.5±17.5	258.5±11.8	88.5±2.4	128.0±3.5	155.5±5.5	
	6|D	249.5±10.1	545.0±15.8	319.0±9.7	84.0±4.6	126.0±2.1	174.5±6.0	
	E|D	252.5±18.5	431.5±14.4	331.0±12.9	80.0±0.0	149.0±3.2	119.5±6.0	
3	6E|6	354.0±39.7	369.5±10.4	316.5±7.5	102.0±4.2	125.5±2.8	114.0±2.1	
	6D|6	215.0±29.3	415.5±10.7	377.5±18.5	213.5±8.2	259.0±1.2	161.0±2.1	
	ED|6	257.5±19.3	477.5±18.0	427.5±7.9	173.5±3.4	328.5±1.6	322.5±2.6	
	6E|E	498.0±66.4	509.0±15.2	325.0±0.0	121.0±5.7	172.0±7.1	167.0±1.2	
	6D|E	394.5±37.8	585.0±20.7	305.0±10.5	160.0±0.0	308.5±7.8	223.5±2.4	
	ED|E	346.0±14.5	577.5±22.1	325.0±0.0	174.5±1.6	274.5±6.0	198.0±9.2	
	6E|D	247.0±8.2	651.5±22.0	309.0±12.0	210.0±1.1	327.0±7.1	228.0±2.6	
	6D|D	257.0±11.4	579.5±9.0	397.5±21.9	199.0±5.7	330.0±4.7	257.0±4.8	
	ED|D	196.5±8.2	597.5±22.8	418.5±26.9	185.5±6.4	240.0±7.8	236.0±3.9	
4	6D|E6	382.0±41.7	613.5±12.0	370.5±10.1	253.5±5.8	302.0±1.0	231.0±3.2	
	6D|DE	383.0±10.3	836.0±12.4	505.0±10.5	270.5±1.1	225.0±3.3	313.5±1.1	
	6D|D6	325.0±16.7	710.0±31.6	495.5±9.6	203.5±1.1	322.5±4.9	273.5±4.1	
	6E|E6	460.0±35.8	508.5±10.3	387.0±10.6	137.5±1.0	173.0±4.2	203.0±4.8	
	6E|DE	432.5±29.0	697.5±22.0	462.0±11.8	274.5±2.8	324.0±1.0	330.0±0.0	
	ED|DE	362.5±17.7	718.0±37.9	617.5±12.1	223.5±9.4	293.5±8.8	281.0±5.2	

Table 2 Attraction force of pediatric denture in clinical cases

Jaw	Case No.	Sex	Age	Anchor teeth	Purpose of application	Attraction force (gf)		$P<0.01$
						Adams clasp	Magnetic attachment	
Maxilla	1	M	9Y5M	permanent first molars	orthodontics	268.5±24.6	401.0±44.1	*
	2	F	8Y10M	permanent first molars	space maintenance	274.5±24.1	324.0±42.7	*
	3	F	5Y10M	primary second molars	retention	175.5±25.9	241.5±28.8	*
	4	F	7Y2M	primary second molars	orthodontics	392.0±41.4	483.5±44.5	*
	5	M	9Y8M	permanent first molars	orthodontics	118.0±4.8	365.0±60.3	*
	6	M	12Y1M	primary second molars	orthodontics	216.0±11.3	353.5±20.0	*
	7	M	12Y0M	permanent first molars	retention	345.0±25.8	446.0±26.2	*
	8	M	7Y2M	primary second molars	retention	314.0±32.1	489.5±44.9	*
	9	M	7Y2M	primary second molars	orthodontics	172.5±34.3	282.5±37.4	*
	10	M	8Y11M	permanent first molars	orthodontics	307.5±23.7	582.5±20.6	*
Mandible	11	F	6Y6M	permanent first molars	space maintenance	87.5±15.5	127.0±2.6	*
	12	M	12Y1M	primary second molars	retention	329.5±9.0	189.5±15.7	
	13	M	7Y2M	primary second molars	retention	429.0±27.8	373.5±44.4	
	14	M	6Y7M	primary second molars	retention	159.0±9.7	348.0±4.2	*
	15	M	5Y7M	primary second molars	retention	312.0±12.7	424.0±14.9	*

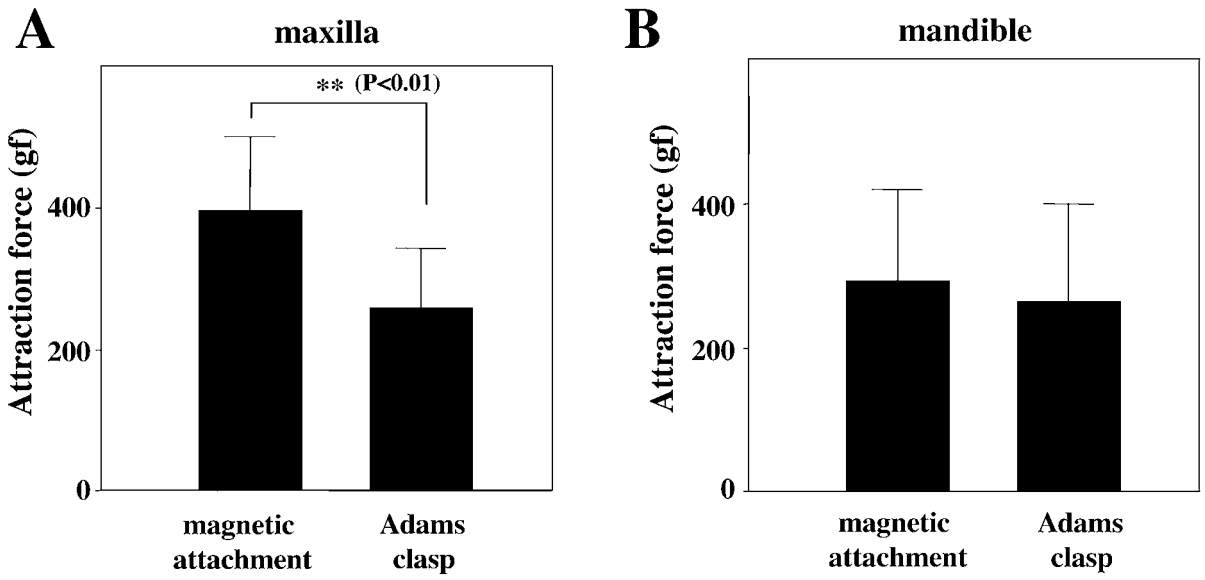

Fig. 4 Comparison of attraction force between magnetic attachments and Adams clasps in clinical cases. Dentures were applied in the maxilla (A) and mandibular (B), and attraction force was measured as described in Materials and Methods.

Retention force of magnetic denture in clinical cases

In the mixed dentition model, a 10° keeper angle with the primary first and second molars and maxillary permanent first molar and a 20° keeper angle with the mandibular permanent first molars showed higher retention results than other angle and tooth combinations. According to our results in the study model experiments, we used the 10° keeper angle for all magnetic dentures, except for 20° in cases that used the mandibular permanent first molars, for space maintenance and orthodontic treatment in clinical cases. A total of 15 cases were analyzed in the present study, of which 10 used maxilla and 5 mandibular dentures (Table 2). The number of anchor teeth was 2 in all cases. The attraction force of the magnetic dentures for the maxilla (396.9 ± 104.6 gf) was significantly higher than those that used an Adams clasp (258.4 ± 86.3 gf) (Fig. 4A). However, in the mandible, attraction force of the magnetic dentures (292.4 ± 127.4 gf) was not significantly different from those with the Adams clasp (263.4 ± 137.8 gf) (Fig. 4B). Almost all cases that utilized magnetic dentures showed a higher attraction force than those that used the Adams clasp, except for 2 mandible dentures, though those 2 cases did not demonstrate an easy detachment during retention following orthodontic treatment. All cases showed adequate attraction force, and no problems were encountered during space maintenance and orthodontic treatment. Photographs of dentures from case No. 10 and 14, with and without magnetic attachments, which showed a high level of retention as compared to those fitted with Adams clasps, are shown in Figure 5.

Discussion

An infinite variety of appliances are commonly used in pediatric dentistry for space maintenance and orthodontic treatment, though several features are essential for a good design. Foremost among them is a means to retain the appliance so that force applied to the tooth will not dislodge it. Adams clasps are often prescribed and are highly retentive in pediatric dentistry applications, however, they can be difficult to adjust and may interfere with occlusion[8]. A reduction of attraction force has also been observed in wire type anchorages. Further, an additional amount of retention and stability is known to be gained from palatal acrylic maxillary appliances as compared to conventional appliances.

Magnetic retention has been used for partial dentures in adults[2,3], with the keepers usually fixed to a de-crowned or root-filled tooth. In this procedure, the magnet, is fixed into the over-denture base, so that it grips the keeper element in the root

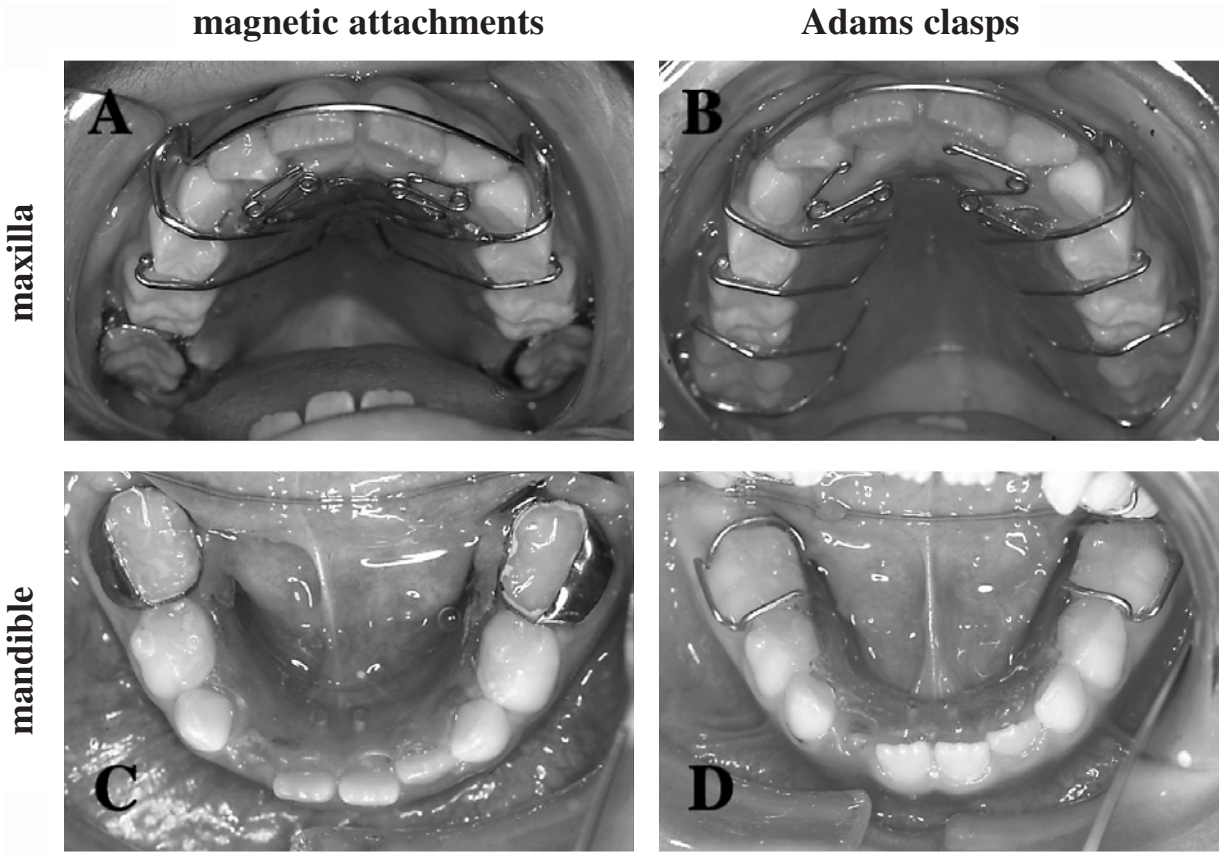

Fig. 5 Photographs of clinical cases. (A) and (B) are of the maxilla in case No. 10, and (C) and (D) are of the mandible in case No. 14 as also shown in Table 2. (A) and (C) are dentures with magnetic attachments, and (B) and (D) employed Adams clasps.

magnetically with a force of approximately 400 gf per attachment[13]. However, in pediatric dentistry, magnetic denture retention elements, used as keepers are not placed on root faces for a variety of reasons. For example, in primary teeth, post-type sustainment is difficult to apply, because of the absorption of the root, while anchor teeth are usually crowned, not fully erupted, or replaced by a successive permanent tooth. Further, in a clinical situation, retention of a pediatric denture for space maintenance and orthodontic treatment is difficult to fully obtain using conventional clasps[8], because of shedding and the anatomical form of primary teeth, as well as erupting permanent teeth.

For the present study, we used magnetic attachments with pediatric dentures, with the keepers placed on the lingual/palatal side of teeth using orthodontic bands. This was a disadvantage for obtaining maximum retention with the magnets, as magnetic retention is much stronger vertically than laterally[11,12]. However, the retention of the magnetic denture was significantly high in the maxilla and nearly the same in the mandible as compared with conventional clasps in the present clinical cases. We obtained 300 to 500 gf of attraction force in the maxilla and 80–180 gf in the mandible using 2 magnets in mixed dentition models. These amounts of retention were lower than previously reported in adult partial dentures, as 500 to 1000 gf of retention has been reported necessary in adults[14]. However, in present clinical cases, we did not experience any difficulties in the retention of pediatric dentures.

In pediatric patients, the denture appliance is smaller as compared to those of adults, whereas the number of teeth that be used as anchors are many. As a result, a high attraction force, such as needed for adult dentures, may not be necessary in pediatrics. In fact, case No. 5 (118.0 ± 4.8 gf in the maxilla) and case No. 11 (87.5 ± 15.5 gf in the mandible) showed the lowest retention with Adams clasps in our experiments (Table 2). However, dislocation from the alveolar fundus was not observed in

clinical experiments, as the retention provided by the magnetic attachments was higher than that with Adams clasps. We concluded that a magnetic denture had an advantage in retention compared with Adams clasps. Further, the minimum attraction force needed for a pediatric denture depends on the type of treatment, as that for orthodontic treatment may require a higher level of retention than that used for space maintainer or retention after orthodontic treatment.

In our experiments with a mixed dentition model, dentures anchored with the primary first and second molars in the maxilla showed relatively high retention. It seemed that an anchor tooth close to the pulling point may provide strong retention, which is important for the selection of an anchor tooth.

Keeper angle is also important for denture retention, as 10° of angle in the primary first, and second molars and maxillary permanent first molars, with 20° in the mandibular permanent first molars, showed the highest retention in a mixed dentition model. A similar tendency was observed in clinical cases. The tooth axis of the permanent first molar slopes to the buccal side in the maxilla and to the lingual in the mandibular. This suggests that a large keeper angle in the pulling direction is necessary for high retention, because the retention power of a magnet is higher vertically than laterally[11,12]. However, we could not clarify why 20° of keeper angle in the primary first and second molars showed less retention than 10°, though it may been related to friction caused by the magnet base sliding on the keeper, the retention ability of the acrylic resin, or labial bow. These factors are now under investigation in our laboratory.

In general, the advantages seen with magnetic dentures include following.

1) The retention is always present, and is reliable and dynamic.
2) The degree of retention can be set to permit optimum function, maintaining ease of insertion and removal of the denture.
3) The torquing forces placed on the abutment teeth are limited to the magnetic force around the tooth and are not considered to be damaging to periodontal tissues.
4) The design and manufacture of the appliance is relatively simple in comparison to other similar precision attachment dentures, with a reduced cost.
5) The magnetic units can be easily removed and replaced if necessary.
6) Improved appearance, oral hygiene, and periodontal health are apparent, as there are no inaccessible regions to impair cleaning[1].

Pediatric dentures with magnetic attachments also showed the following advantages in our experiments. The children could easily insert the denture into appropriate region with automatically self-seating[4], and preferred the feeling of the magnetic force as compared with conventional mechanical attachments. Especially in the maxilla, retention force was not affected by the decrease of denture area and this decrease may be serve to reduce discomfort. However, the decrease of denture area as compared to those with conventional clasps may cause a reduction of retention.

There are also some disadvantages with magnetic dentures. For magnetic resonance imaging (MRI) analysis, magnetic keepers may disturb the MRI field and give artificial images[15]. However, the frequency of MRI analysis in children is low compared to adults who require prosthetic treatment, especially in cases of a partial denture. Further, this type of magnetic attachment is much more expensive than wire type clasps and may be dependent on the frequency of usage.

A lower attraction force than that provide by Adams clasps was seen in only 2 cases. In those, the anchor teeth were inclined to the lingual side, thus, the anchoring teeth may not have been able to maintain an optimal keeper, as retention of the denture is affected by the angle of the keeper[11,12]. If the tooth is inclined or rotated, the keeper must be placed carefully. In some cases, magnets in a maxillary denture became detached, because of interference by occlusion. In that instance, the keeper should be placed on the palatal surface close to the gingival side.

In conclusion, dentures with magnetic attachments showed several advantages in pediatric patients, and were found to be useful for orthodontic treatment and space maintenance that could not be otherwise by conventional attachments.

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