European Journal of Orthodontics 30 (2008) 469–476
doi:10.1093/ejo/cjn045
Advance Access publication 12 September 2008

Dental arch changes following rapid maxillary expansion

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SUMMARY The purpose of this research was to evaluate changes in upper arch dimension and form following rapid maxillary expansion (RME) using a modified Haas appliance in the primary dentition. The sample comprised 49 children [17 males, 32 females, mean age 7 years 5 months, standard deviation (SD) 1 year 1 month] with a crossbite or maxillary crowding. Twenty patients had a normal SN–GoGn angle (7 males, 13 females, mean 33.25 degrees, SD 2.10), three were low angle (1 male, 2 females, mean 27.67 degrees, SD 2.31), and 22 were high angle (8 males, 14 females, mean 39.95 degrees, SD 3.15). The vertical dimensions of four patients could not be measured, due to the unavailability of radiographs. Expansion was undertaken to either correct a crossbite or treat maxillary crowding. The upper dental casts were analysed using a computerized system: before treatment (T1), at appliance removal (T2), and 2 years 4 months after appliance removal (T3).

Using bootstrap statistical analysis applied to distance ratio values [Euclidean distance matrix analysis (EDMA)], it was found that 48 patients showed a change in arch form. In 40.82 per cent (n = 20, group A), the arch form changed from T1 to T2, T1 to T3, and T2 to T3. In 32.65 per cent (n = 16, group B), it varied from T1 to T2 but relapsed at T3 to the form of T1. For 24.5 per cent (n = 12, group C), it changed from T1 to T2 but maintained the same form at T3. The favourable characteristics for obtaining expansion, identified by logistic regression analysis, were being male, of an immature stage of dental development (lateral incisor not fully erupted) and the presence of a lateral crossbite. Intercanine and intermolar widths, arch length, and the distance between the interincisive point and the line joining the canines (depth of the intercanine arch) at the different time points were analysed using a two-tailed t-test ($P < 0.05$). For the whole group, the increase in intercanine and intermolar width and in the depth of the intercanine arch was significant. Comparison between groups A, B, and C was undertaken using an analysis of variance, but there was no significant difference between the groups.

This modified type of Haas appliance was able to increase the transverse dimension of the maxillary dental arch in the mixed dentition. The most appropriate timing for treatment appears to be before the eruption of the permanent lateral incisors.

Introduction

Rapid maxillary expansion (RME) is a clinical technique largely employed in orthodontic treatment to manage maxillary transverse deficiencies (Kutin and Hawes, 1969; McNamara, 2000; Schiffman and Tuncay, 2001; Petrén *et al.*, 2003; Turpin, 2004). Many authors consider that widening of the midpalatal suture is a suitable method for treating maxillary arch size discrepancies (Haas, 1961, 1965, 1970, 1980; Wertz, 1970; Bishara and Staley, 1987; Ladner and Muhl, 1995; Spillane and McNamara, 1995; Sandikçioğlu and Hazar, 1997; McNamara, 2000; Giannelly, 2003; Sari *et al.*, 2003; Lima *et al.*, 2005).

The Haas appliance is one device designed to expand the palate. It is a tooth- and tissue-borne appliance attached to four teeth and to the palatal vault (Zimring and Isaacson, 1965; Haas, 1980). The screw produces orthopaedic expansion (Oliveira *et al.*, 2004) by the activation of the midline expansion screw on a daily basis. The technique is generally considered more appropriate in young patients because the sutures are not as interdigitated as in adults (Zimring and Isaacson, 1965; Melsen, 1975; Holberg and Rudzki-Janson, 2006). However, the negative effects of applying high forces to the anchor teeth include potential root resorption (Timms and Moss, 1971; Barber and Sims, 1981; Langford and Sims, 1982; Odenrick *et al*, 1991; Vardimon *et al.*, 1991, 1993) and exostoses and pulp stones (Timms and Moss, 1971). Due to these problems, Cozzani *et al.* (2003, 2007) evaluated the effectiveness of the Haas appliance when cemented on the primary canines and second molars and successfully achieved expansion of the upper first permanent molars.

The purpose of the present study was to evaluate the efficacy, in a group of young patients, of this modified Haas appliance in the primary dentition with respect to (1) changing the form and dimensions of the dental arch, (2) expansion stability at least 1 year out of retention, and (3) the most appropriate timing for treatment.

Subjects and method

Sample

The sample comprised 49 patients (Table 1), 32 females and 17 males (mean age 7 years 5 months, SD 1 year 1 month). The children were either in the first transitional period (van der Linden and Duterloo, 1983) with the first permanent upper molars erupted (36 patients, 14 males and 22 females) or in the intertransitional period (13 patients, 3 males and 10 females).

The vertical dimensions of 45 patients were assessed by measuring the SN–GoGn angle on lateral cephalograms taken before treatment (T1). The vertical dimension was considered to be normal if the angle measured between 30 and 36 degrees, low if the angle was less than 30 degrees, and high if the angle was more than 36 degrees. The normal angle group comprised 20 patients (7 males, 13 females; average angle 33.25 degrees, SD 2.10); the low angle group three patients (1 male, 2 females; average angle 27.67 degrees, SD 2.31), and the high angle group 22 patients (8 males, 14 females; average angle 39.95 degrees, SD 3.15). The vertical dimensions of four patients could not be measured, due to the unavailability of radiographs.

Patients required maxillary expansion for one of two reasons: in order to correct a crossbite (23 patients, 5 males and 18 females) or to treat maxillary crowding (26 patients, 12 males and 14 females).

Therapy

The patients were treated by three orthodontists, following the same protocol. A Hass appliance (Haas, 1980), modified such that it was attached to the maxillary second primary molars and primary canines, was inserted and activated once or twice per day (Figure 1). Each activation was 0.2 mm and the maximum expansion possible was 10 mm.

The patients were monitored weekly. Expansion was terminated in the crossbite group when the first molars were in normal occlusion and, in the crowded group, when there was sufficient space for the lateral incisors (on average 20 days). The appliance was stabilized and kept *in situ* as retention for at least 7 months (average 11 months, SD 4 months). No direct force or any retention was applied to the permanent teeth. After RME, no additional orthodontic treatment was carried out.

For each patient study, models were taken at T1, at appliance removal (T2), and at least 1 year after appliance removal (T3; average 2 years 4 months, SD 1 year 4 months).

Dental cast analysis

The maxillary dental arches were analysed according to a previously published computerized method (Mutinelli *et al.*, 2004). The models were scanned and the images enhanced using the software. The landmarks marked were: the interincisive point, the distal point of the right and left lateral incisor edge, the tip of the right and left canine, and the tips of the mesiobuccal cusps of the right and left first permanent molar (Figure 2). The same operator (SM) identified all landmarks, and the distances between the points were calculated automatically.

Table 1 Characteristics of the sample.

Group	*n*	Females	Males
Whole	49	32	17
Crossbite	23	18	5
Non-crossbite	26	14	12
Late dental age	13	10	3
Early dental age	36	22	14
High angle	22	14	8
Normal angle	20	13	7
Low angle	3	2	1
A (variability)	20	12	8
B (relapse)	16	12	4
C (stability)	12	8	4

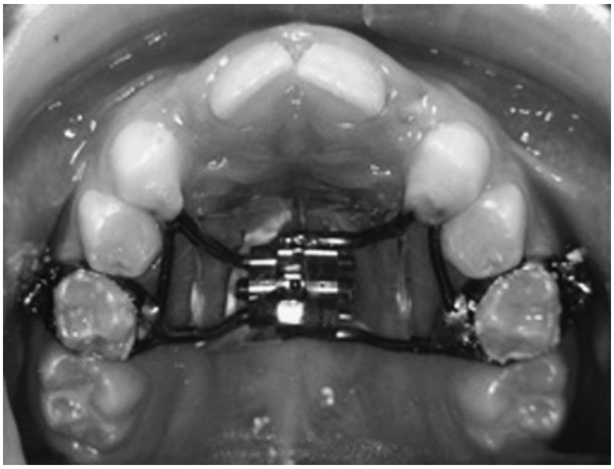

Figure 1 The Haas appliance anchored to the primary teeth (second molars and canines).

Method error

The method error was evaluated by comparing 189 measurements repeated twice by the same operator after an interval of 1 week using the method described by Dahlberg (1948). The difference was not significant ($P = 0.41$).

Data elaboration and statistical analysis

Evaluation of dental arch form change. The distances between the points were analysed using Euclidean distance matrix analysis (EDMA; Lele and Richtsmeier, 1991; Ferrario *et al.*, 1994; Cole and Richtsmeier, 1998) and the statistical bootstrapping technique (Efron and Tibshirani, 1993) in order to investigate the change in arch form

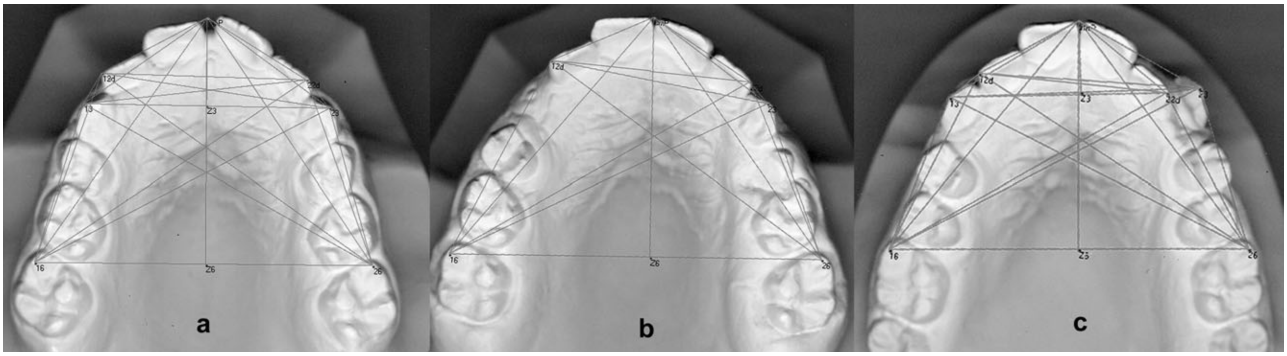

Figure 2 Dental cast analysis using the software (a) T1, before treatment, (b) T2, after removal of the Haas appliance, and (c) T3, at least 1 year after appliance removal with the identification of points: interincisive point, distal point of the right and left lateral incisor edge, tip of the right and left canine, and tip of the mesiobuccal cusp of the right and left first permanent molar.

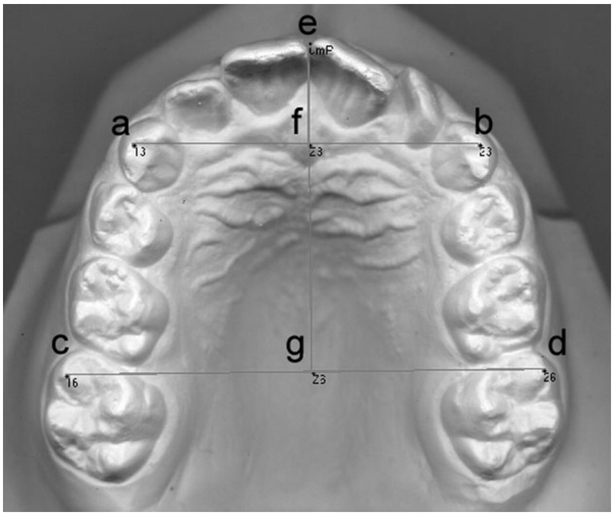

Figure 3 Intercanine (ab) and intermolar (cd) widths, intercanine arch depth (ef), and arch length (eg).

between the different time points: from T1 to T2 (expansion), from T2 to T3 (relapse), and from T1 to T3 (final expansion out of retention).

Using this method, it was first necessary to determine whether the average of the observations for a single patient was significantly different from 1. An observation is given by the ratio of a particular measurement at each of the different time points, T1, T2, and T3. Hence, for each measurement and each patient, three ratios were calculated: D_{T2}/D_{T1}, D_{T3}/D_{T1}, and D_{T3}/D_{T2} (EDMA). There were 21 observations for each patient (although in a small number of cases some of the measurements were missing, so that the observations were fewer than 21). A bootstrap analysis, which is a computer-based statistical method (Efron and Tibshirani, 1993), was run for each patient and for each of the three combinations of times: (T2/T1, T3/T1, and T3/T2). The confidence interval (CI, 95 per cent) of a predicted value was determined following duplication of the sample using 1000 iterations. Therefore, CIs were generated using the bootstrap method for the 21 measurements and the data studied to ascertain whether the value 1 was included in the interval: if the answer was positive, it was concluded that the distance was unchanged, otherwise the hypothesis that the distance was unchanged was rejected.

The patients were then divided into three groups based on the change in shape of the dental arch:

1. Group A (variability): the form changed from T1 to T2, from T2 to T3, and from T1 to T3.
2. Group B (relapse): the form changed from T1 to T2, from T2 to T3, but at T3 it was the same as at T1.
3. Group C (stability): the form changed from T1 to T2, from T1 to T3, but at T3 it was the same as at T2.

In order to further investigate the change in the arch form and establish why group C was more stable, logistic regression was undertaken with the following variables included: gender, presence or absence of a lateral crossbite, dental age (presence or absence of all four permanent incisors), and vertical dimension.

Evaluation of the transverse and sagittal dimensions. A two-tailed *t*-test ($P < 0.05$) was used to investigate intercanine and intermolar widths, arch length (distance between the interincisive point and intermolar width), and intercanine arch depth (distance between the interincisive point and the line joining the canines) measured at the different time points (Figure 3). For each group of measurements, the 95 per cent CI for the mean was calculated and groups A, B, and C were compared using an analysis of variance (ANOVA).

The analyses provided values for the whole sample and for the eight subsamples classified according to gender, presence or absence of a lateral crossbite, dental age, and vertical dimension at the start of treatment: (1) male group, (2) female group, (3) crossbite group, (4) non-crossbite group, (5) early dental age group, i.e. patients with lateral incisor eruption not yet complete (first transitional period), (6) late dental age group, i.e. patients with four permanent incisors (intertransitional period), (7) high angle group, and (8) normal angle group.

When analysing the vertical dimension groups, the low angle group was not considered because of the small number of subjects ($n = 3$).

Results

Arch form variation

The results of the analyses are shown in Table 1. One patient could not be classified because the arch form only changed from T2 to T3.

The coefficients for arch form stability after expansion, calculated using logistic regression, were dental age 2.3433 ($P < 0.001$), vertical dimension 0.0055 ($P = 0.94$), lateral crossbite –2.1287 ($P < 0.001$), and gender –0.1552 ($P = 0.0304$).

The coefficients showed that vertical dimension did not affect stability following upper arch expansion, whereas early dental age, a lateral crossbite, and male gender were statistically significant factors in obtaining stable expansion out of retention. The probabilities of relapse are shown in Table 2.

Arch width and length variation

Whole group.

Intercanine and intermolar width. The variations were significant ($P < 0.05$) from T1 to T2 (intercanine width 5.04 mm, SD 1.87; intermolar width 3.63 mm, SD 1.97) and from T1 to T3 (intercanine width 2.97 mm, SD 2.18; intermolar width 2.58 mm, SD 2.17). The measurements increased as a result of RME and then later relapsed (relapse of intercanine width 2.08 mm, SD 2.26; relapse of intermolar width 1.05 mm, SD 1.54); however, the final values, measured 2 years 4 months out of retention, remained significantly increased (Table 3).

Arch length and intercanine arch depth. Arch length increased significantly ($P < 0.05$) from T1 to T2 (1.03 mm, SD 1.33) and then decreased from T2 to T3 (0.58 mm, SD 1.19). Although the T3 value was greater than that at T1, there was no significant difference between the T1 and T3 measurements (increase from T1 to T3 of 0.44 mm, SD 1.45). Intercanine arch depth increased from T2 to T3 (T2 to T3 0.81 mm, SD 1.14; ns from T1 to T2 0.10 mm, SD 1.21; Table 3).

Intercanine and intermolar width in the subgroups

Crossbite and non-crossbite group. The only significant difference between the two groups was for intermolar width (Table 4) which was increased in the group with a lateral crossbite (crossbite group at T2 4.87 mm, SD 1.37 and non-crossbite group 2.56 mm, SD 1.81; T3: 3.85 mm, SD 1.57 and 1.37 mm, SD 2.01, respectively). However, the extent of the relapse was similar for the two groups (–1.02 mm, SD 1.40, versus –1.19 mm, SD 1.61).

Age/dental development. The group was divided into two subgroups with respect to the presence (late dental age) or absence (early dental age) of the permanent lateral incisors. The increase and relapse measured in the intercanine and intermolar widths were significant in both subsamples.

Comparing the two groups at T1, the intercanine width of the younger patients was significantly less (28.64 mm, SD 2.66) than for the older group (31.43 mm, SD 2.97). At T3, intercanine width showed a non-significant difference

Table 2 Probability of relapse of arch form after expansion in the subgroups of patients.

	Females with crossbite, $n = 18$ (%)	Females without crossbite, $n = 14$ (%)	Males with crossbite, $n = 5$ (%)	Males without crossbite, $n = 12$ (%)
Early dental age	9.35	50.00	9.35	46.30
Late dental age	55.49	91.24	91.24	89.98

Table 3 Differences in variation of intercanine and intermolar width and intercanine arch depth and arch length (mm) and 95 per cent confidence intervals (CIs) for the mean in the whole group before treatment (T1), after removal of the Haas appliance (T2), and at least 1 year after appliance removal (T3).

Distance	T2 − T1	95% CI	T3 − T2	95% CI	T3 − T1	95% CI
Intercanine width	5.04	4.42 to 5.66	−2.08	−2.71 to −1.44	2.97	2.31 to 3.62
Intermolar width	3.63	3.08 to 4.18	−1.05	−1.48 to −0.63	2.58	1.97 to 3.18
Intercanine depth	0.10*	−0.24 to +0.44	0.81	0.49 to 1.13	0.91	0.46 to 1.37
Arch length	1.03	0.65 to 1.40	−0.58	−0.92 to −0.24	0.44*	0.05 to 0.84

*$P > 0.05$.

Table 4 Differences in intercanine and intermolar width variation (mm) and 95 per cent confidence intervals (CIs) for the mean in the subgroups before treatment (T1), after removal of the Haas appliance (T2), and at least 1 year after appliance removal (T3)

Groups	*n*	T2 − T1	95% CI**	T3 − T2	95% CI**	T3 − T1	95% CI**
Crossbite	23						
Intercanine width		5.42	4.53 to 6.32	−2.15	−3.02 to −1.28	3.27	2.42 to 4.13
Intermolar width		4.87	4.31 to 5.43	−1.02	−1.59 to −0.45	3.85	3.21 to 4.50
Non-crossbite	26						
Intercanine width		4.71	3.85 to 5.57	−2.01	−2.94 to −1.08	2.69	1.72 to 3.67
Intermolar width		2.54	1.85 to 3.22	−1.09	−1.72 to −0.45	1.45	0.67 to 2.22
Early dental age	36						
Intercanine width		5.43	4.86 to 5.99	−1.96	−2.65 to −1.26	3.47	2.77 to 4.16
Intermolar width		3.54	2.95 to 4.13	−1.00	−1.50 to −0.50	2.54	1.83 to 3.25
Late dental age	13						
Intercanine width		3.98	2.32 to 5.65	−2.40	−3.85 to −0.96	1.58	0.28 to 2.88
Intermolar width		3.89	2.56 to 5.22	−1.21	−2.05 to −0.38	2.68	1.47 to 3.88
High angle	22						
Intercanine width		0.23*	−0.36 to 0.82	0.69	0.20 to 1.18	0.92	0.14 to 1.71
Intermolar width		1.30	0.71 to 1.89	−0.72	−1.28 to −0.17	0.57*	−0.12 to 1.27
Normal angle	20						
Intercanine width		4.43	3.38 to 5.48	−1.95	−3.01 to −0.90	2.47	1.28 to 3.67
Intermolar width		3.49	2.81 to 4.17	−1.18	−1.92 to −0.44	2.31	1.23 to 3.40
Males	17						
Intercanine width		4.88	3.66 to 6.10	2.09	1.01 to 3.17	2.79	1.49 to 4.09
Intermolar width		2.83	1.99 to 3.67	1.07	0.37 to 1.78	1.76	0.76 to 2.75
Females	32						
Intercanine width		5.13	4.42 to 5.84	2.07	1.28 to 2.86	3.06	2.32 to 3.79
Intermolar width		4.06	3.37 to 4.74	1.04	0.50 to 1.59	3.01	2.28 to 3.74
Group A	20						
Intercanine width		5.86	5.02 to 6.71	−2.29	−3.34 to −1.24	3.57	2.53 to 4.61
Intermolar width		3.99	2.98 to 5.00	−0.91	−1.70 to −0.13	3.08	2.06 to 4.10
Group B	16						
Intercanine width		5.01	4.17 to 5.86	−2.86	−3.98 to −1.74	2.15	1.25 to 3.06
Intermolar width		3.64	2.64 to 4.65	−1.46	−2.15 to −0.77	2.18	1.04 to 3.33
Group C	12						
Intercanine width		4.42	3.44 to 5.40	−0.88*	−1.71 to −0.04	3.54	2.41 to 4.67
Intermolar width		3.20	2.57 to 3.84	−0.77*	−1.45 to −0.08	2.44	1.51 to 3.36

*$P > 0.05$.

between the subgroups (32.11 mm, SD 2.55, and 33.10 mm, SD 1.58, respectively).

Therefore, the intercanine width expanded more before eruption of the permanent lateral incisors than after. At T3, the two groups relapsed in the same way although with a resultant greater net increase in arch width in the younger patients.

The increase in intercanine arch depth and arch length was significantly larger in the group expanded before eruption of the permanent lateral incisors.

High and normal angle group. Expansion at T2, and relapse at T3, of the intercanine and intermolar widths respectively in the high angle group were significant. Comparison of the same widths between the two subsamples was not significant.

Female and male groups. The increase (T2), and relapse (T3), of the intercanine and intermolar widths were significant. Comparison between males and females showed that the change in intercanine and intermolar widths was approximately the same in both groups.

Groups A, B, and C. The expansion, relapse, and net increase at T3 were significant in groups A and B. In group C, the changes were significant, but the relapse was not significant. Comparing the groups using ANOVA, the results were not significant.

Arch length and intercanine arch depth variation in the subgroups

Intercanine arch depth tended to increase slightly after expansion in all subgroups, with the exception of the older dental age group and group B, where there was a decrease in arch length and a non-significant change in intercanine arch depth (Table 5).

Discussion

In this study, expansion resulted in arch form changes in 98 per cent of the patients. Study model analysis showed that RME acted on the transverse dimension and did not affect the sagittal dimensions of the dental arch.

The intercanine and intermolar widths increased during expansion and a significant amount of this expansion was retained more than 2 years out of retention, confirming the

Table 5 Differences in intercanine depth and arch length variations (mm) and 95 per cent confidence intervals (CIs) for the mean in the subgroups before treatment (T1), after removal of the Haas appliance (T2), and at least 1 year after appliance removal (T3)

Groups	*n*	T2 − T1	95% CI**	T3 − T2	95% CI**	T3 − T1	95% CI**
Crossbite	23						
Intercanine depth		−0.11*	−0.57 to 0,34	0.71	0.43 to 1.00	0.60	0.17 to 1.03
Arch length		0.52*	−0.01 to +1.04	−0.41	−0.78 to −0.03	0.11*	−0.39 to + 0.61
Non-crossbite	26						
Intercanine depth		0.30*	−0.20 to +0.79	0.90	0.35 to 1.44	1.19	0.42 to 1.96
Arch length		1.48	1.01 to 1.95	−0.74	−1.29 to −0.19	0.74	0.14 to 1.33
Early dental age	36						
Intercanine depth		0.33*	−0.07 to 0.72	1.05	0.77 to 1.34	1.38	0.93 to 1.83
Arch length		1.37	1.00 to 1.73	−0.52	−0.90 to −0.14	0.85	0.42 to 1.27
Late dental age	13						
Intercanine depth		−0.51*	−1.08 to +0.06	0.14*	−0.67 to +0.96	−0.37*	−1.27 to +0.53
Arch length		0.09*	−0.70 to +0.88	−0.75*	−1.49 to −0.02	−0.67*	−1.28 to −0.05
High angle	22						
Intercanine depth		5.76	4.99 to 6.54	−1.97	−2.95 to −0.99	3.79	2.97 to 4.61
Arch length		3.70	2.80 to 4.59	−1.06	−1.66 to −0.45	2.64	1.82 to 3.46
Normal angle	20						
Intercanine depth		0.16*	−0.32 to 0.64	1.05	0.53 to 1.56	1.21	0.63 to 1.78
Arch length		1.01	0.51 to 1.51	−0.40*	−0.94 to 0.13	0.61	0.10 to 1.12
Males	17						
Intercanine depth		0.30*	−0.23 to +0.82	0.68	0.13 to 1.22	0.97	0.42 to 1.53
Arch length		1.41	0.81 to 2.01	−0.77	−1.43 to −0.11	0.64*	0.04 to 1.25
Females	32						
Intercanine depth		0.00*	−0.44 to +0.44	0.88	0.48 to 1.28	0.88	0.24 to 1.53
Arch length		0.82	0.36 to 1.29	−0.48	−0.87 to −0.09	0.34*	−0.18 to +0.86
Group A	20						
Intercanine depth		0.07*	−0.50 to +0.63	0.87	0.59 to 1.15	0.94	0.39 to 1.49
Arch length		1.12	0.59 to 1.64	−0.29*	−0.65 to +0.08	0.83	0.32 to 1.34
Group B	16						
Intercanine depth		−0.22*	−0.86 to +0.42	0.52*	−0.31 to +1.35	0.30*	−0.73 to +1.33
Arch length		0.52*	−0.14 to + 1.17	−1.08	−1.73 to −0.43	−0.57*	−1.31 to +0.18
Group C	12						
Intercanine depth		0.50*	0.00 to 1.00	1.17	0.73 to 1.62	1.68	0.94 to 2.41
Arch length		1.45	0.63 to 2.26	−0.26*	−1.03 to +0.52	1.19	0.62 to 1.76

*$P > 0.05$.

efficacy of the Haas appliance when anchored to the primary canines and primary molars. The effectiveness of the Haas appliance has been demonstrated by others, but with the device anchored to the permanent teeth (Ladner and Muhl, 1995; Moussa *et al.*, 1995; Spillane and McNamara, 1995; Sandikçioğlu and Hazar, 1997; Sari *et al.*, 2003; Oliveira *et al.*, 2004; Lima *et al.*, 2005). Cozza *et al.* (2001) successfully used an expander banded to the second primary molars, but it was a butterfly type without an acrylic palatal button.

The expansion of the intercanine width was greater than that in the intermolar area: e.g. in group C, at T2, the intercanine width expanded 1.4 times more than the intermolar width. This could be explained by the triangular opening of the palatal suture due to the position of the centre of resistance of the maxilla with respect to the screw position (Wertz, 1970; da Silva Filho *et al.*, 1995; Lee *et al.*, 1997; Moore, 1997; Vardimon *et al.*, 1998; Braun *et al.*, 1999; Davidovitch *et al.*, 2005).

The dental arch showed a tendency for intercanine arch depth to increase after expansion. Analysis of the change in intercanine arch depth with respect to dental age at T3 showed that the group expanded before the eruption of the permanent lateral incisors had a significant increase from T2 to T3, whereas the older group (with erupted permanent lateral incisors) did not show any change in intercanine arch depth.

Growth linked to dental eruption has been suggested as a predictive factor for the success of arch expansion. Sillman (1964), Moorrees *et al.* (1969), and van der Linden and Duterloo (1983) explained the change as a result of buccal proclination of the permanent incisors with respect to the primary teeth.

After computation of the variation in arch form with EDMA and bootstrapping, the patients were classified into three subsamples. Group C showed little relapse between the three observational points and was therefore considered to be ‘stable’. Using logistic regression, three pre-treatment characteristics appear to be important factors to obtain stable expansion: the presence of a posterior crossbite, dental age, and being male.

Spillane and McNamara (1995) did not find any relationship between expansion and age or between expansion and a posterior crossbite. However, they used an acrylic bonded expander, and the methods of evaluation were different from the present study.

The first predictive characteristic for stability was a posterior crossbite. The intermolar width increased more in the crossbite group, but relapse was equal for both subsamples. The initial width in the crossbite group was significantly less than that in the group with a normal transverse relationship. After expansion, this difference was no longer apparent. This behaviour was similar to that observed in the variation of the intercanine width found in the two different dental age groups.

The second predictive characteristic for stability was dental age. Subjects in the early dental age group showed an increase in intercanine arch depth. In group C (stable), this increase compensated for the reduction in arch length in the region of the primary molars and first permanent molar. Therefore, at T3 arch length was unchanged. Some authors have explained this reduction in length of the molar area as being a consequence of space closure between the primary molars (Sillman, 1964; Moorrees *et al.*, 1969; van der Linden and Duterloo, 1983). Evaluation of the intercanine width in the younger (first transitional period) and older (intertransitional period) patients before expansion showed a significantly lower value in the first group. After expansion there was no significant difference: the increase in the younger children was greater but the relapse was the same in both groups. Dental age did not affect expansion of the intermolar distance.

It is also important to consider how much of the increase in intercanine width is due to growth and how much to RME. The increase in intercanine width during growth has been analysed by many authors. Sillman (1964), Knott (1972), and Bishara *et al.* (1997) noted an increase in the intercanine width until 13 years. Moorrees *et al.* (1969) and van der Linden and Duterloo (1983) reported a significant increase in intercanine width during the eruption of the permanent incisors and a further small increase as the permanent canines erupt. Sinclair and Little (1983) found a significant decrease from the mixed dentition stage into early adulthood; however, the mixed dentition stage in that research corresponded with both the intertransitional and the second transitional periods.

Therefore, it is possible that upper intercanine width increases between the intertransitional and second transitional periods. Consequently, there may be additional space created by growth, as well as by early treatment with RME. However, Schiffman and Tuncay (2001), in a meta-analysis, found no data to support the hypothesis that space can be gained in the dental arch in addition to the increase produced by normal growth, even if the maxilla has been expanded. Comparing the results of the two studies, the short-term post-expansion intermolar data were similar: 75 per cent in the meta-analysis (Schiffman and Tuncay, 2001) and 71 per cent in the present investigation. However, in the meta-analysis the average age of the patients was older than that in the present study and the effect of expansion was evaluated only by the change in intermolar width. Therefore, the increase found in the present investigation in younger patients may be due to the appliance producing earlier growth in the intercanine area.

In contrast to the work by Spillane and McNamara (1995) and Lima *et al.* (2005), there was a significant difference ($P < 0.05$) in stability between males and females in the present study.

Conclusions

Expansion of the maxilla using a Haas appliance anchored to the primary teeth resulted in a significant increase in transverse width. The most stable result was in younger patients (first transitional period) with a lateral crossbite. Therefore, when presented with the choice of treating early or postponing expansion, it may be better to commence therapy before eruption of the permanent lateral incisors. In addition, at this dental age it is possible to band the second primary molars, without involving the permanent dentition and this consequently avoids the risk of damage to these teeth. Moreover, with favourable growth the intercanine arch width may increase until eruption of the permanent canines, resulting in a widening of the anterior part of the arch.

Further, long-term studies are necessary to evaluate the 'real' amount of intercanine growth after expansion and to confirm the greater stability of the results obtained in younger patients.

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