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Treatment changes in Class I and mild Class II malocclusions using the *en masse* removable appliance

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SUMMARY The aim of this retrospective study was to examine the dental changes which occurred during buccal segment retraction in 39 subjects considered suitable for treatment with headgear to the maxillary dentition. Initially, a removable *en masse* appliance was fitted to distalize the buccal segments. Once the molar relationship was corrected, fixed appliances were placed for upper arch consolidation and/or alignment. Only five subjects required lower appliance therapy.

Twenty-nine individuals had upper second molars extracted as an adjunct to treatment: in the remaining 10 patients these teeth were left *in situ*. Corresponding lower second molars were extracted in 19 children, whilst 20 pairs of teeth were not removed. Measurements were made at the start of treatment, the completion of buccal segment retraction, and when active treatment was complete.

After the first stage, molars and premolars had been retracted nearly 4 mm, whilst the canines showed 2 mm spontaneous distal drift. The inter-molar width had increased by 4 mm and arch perimeter by 5 mm. There was a 5 per cent reduction in crowding. Spontaneous changes were also seen in the lower arch, despite the absence of any therapy. Crowding was slightly improved and inter-molar width increased, apparently as a response to the expansion in the opposing jaw. At the end of treatment, upper arch retraction and expansion were reduced as the teeth were integrated with the lower dentition: the canines required less than 1 mm further retraction. In the lower arch, the expansion of the molars was essentially stable.

The extraction of upper second molars did not appear to influence the outcome of treatment. Although slightly more movement appeared to occur in the extraction group, few measurements showed statistical significance.

Introduction

Facial appearance is an important aspect of orthodontic treatment planning. Thus, patients with relatively mild malocclusions are increasingly being treated on a non-extraction basis, relying on headgear to create space for anterior tooth alignment. When there is inadequate space for all 32 teeth and third molars are developing, the loss of upper second molars may be considered (Morris, 1960; McCallin, 1961; Morse and Webb, 1973). Such a regime may be extended to include the loss of lower second molars as well, and this is especially helpful when the need for lower arch therapy is minimal (Morse and Webb, 1973; Richardson and Mills, 1990).

Extra-oral traction may be applied direct to upper molar bands and the arch bonded only after molar correction has been accomplished. Where the upper buccal segments are aligned, however, an upper removable *en masse* appliance has much to recommend it (Orton *et al.*, 1996a,b). In the United Kingdom, the distal movement of buccal segments with removable appliance systems is a well recognized technique (Morris, 1960; McCallin, 1961; Morse and Webb, 1973; Howard, 1982). The basic appliance design has changed little over the years, with modifications being directed towards a more flexible, individualized design and a detachable extra-oral bow (Orton *et al.*, 1996a). Other techniques, describing the distalization of the entire upper arch with headgear to a removable appliance (Tenenbaum and Gabriel, 1973; Bernstein *et al.*, 1977), do not seem to enjoy such widespread use.

Despite early enthusiasm for the retraction of buccal segments as a unit, there is little published data on the clinical effects of these appliances (Howard, 1982; Orton *et al.*, 1996a,b). Where data have been analysed, these normally relate to the effect of the extra-oral apparatus on the teeth and craniofacial skeleton: that is they are cephalometric investigations (Bernstein *et al.*, 1977; Mills *et al.*, 1978; Howard, 1982).

Less attention has been paid to changes within the dental arch and for examination of the occlusion, for which a model measuring routine is required. Several systems for recording arch dimensions have been documented. The Reflex metrograph (Takada *et al.*, 1983; Richmond, 1987; Jones, 1991), travelling microscope (Bhatia and Harrison, 1987) and Reflex microscope (Drage *et al.*, 1991) all allow direct recording of model data into a computer.

Arch dimensions may be calculated quickly and easily, and a number of computer-based systems for the estimation of crowding have been described. Crowding may be defined as the sum of the individual tooth widths minus the arch perimeter. Whilst the former is relatively easy to record, the latter is less reproducible. Rudge (1982) and Rudge *et al.* (1983) demonstrated a computer program in which arch perimeter was recorded using a tracing stylus in 'on line' mode. Sampson (1981) explored conic sections, Richmond (1987) chose a mathematically-defined parabolic curve, whilst both fourth order polynomial and mixed elliptical/parabolic configurations were analysed by Ferrario *et al.* (1994).

Analysis of individual models is thus routine, but the measurement of inter-arch relationships has only recently been reported (Orton *et al.*, 1996b). A Reflex microscope was adapted to allow the analysis of both paired and single study casts. Using a customized computer program, crowding was calculated directly from the overlaps between adjacent teeth, thus avoiding the need to determine arch perimeter. This technique was found to be both valid (Battagel, 1996) and reproducible (Battagel *et al.*, 1996).

Table 1 Ages of the sample (n = 39: 14 males and 25 females).

	Mean	SD	Range
Age at start of treatment (years)	13.7	1.6	11.1–18.3
Age at end of buccal segment retraction (years)	14.5	1.6	11.7–19.6
Age at completion of treatment (years)	15.7	1.6	12.8–20.2
Duration of buccal segment retraction (years)	0.9	0.3	0.4–1.6
Total duration of treatment (years)	2.0	0.5	1.0–3.5

In the investigation by Orton *et al.* (1996b), only the initial retraction phase of treatment was described, with no details of the group at the completion of appliance therapy. The aim of the present study, therefore, was to examine more completely the changes which occurred during buccal segment retraction with headgear to an *en masse* appliance. Children were examined both at the completion of the retraction phase and at the end of all active treatment.

Subjects

Thirty-nine children (14 males and 25 females) participated in the study (Table 1). Their mean age at the beginning of treatment was 13.7 years. Fifteen children presented with crowded Class I malocclusions, 21 with Class II division 1 incisor relationships, and three with Class II division 2 malocclusions. Their skeletal patterns were Class I or mild Class II, and the lower arches were either aligned or showed minimal crowding. All were considered suitable for treatment with an initial phase in which the upper buccal segments were retracted *en masse* with headgear applied to an upper removable appliance. During this stage, the upper canines were freed from contact with the acrylic to allow for spontaneous movement. Once a Class I molar relationship (or better) had been achieved, treatment was completed with fixed appliances to retract and/or align the

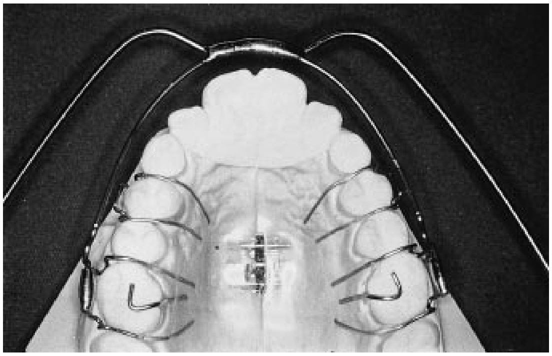

Figure 1 Standard design of the *en masse* appliance used to retract the buccal segments. Adams' clasps are placed on first molars and first premolars with occlusal rests on 6|6. A midline screw is used for expansion. Unless bite opening is required, the plate is saddled anteriorly. Extra-oral traction is applied via a detachable facebow fitting into tubes on 6|6.

upper labial segment, and detail the occlusion. Where necessary, lower fixed appliances were also prescribed.

In 29 children upper second molars were removed and in 10 these teeth remained *in situ*. The matching lower molars were extracted in 18 individuals, whilst in 21 patients they were retained. The decision as to whether or not to extract was a clinical one, depending on the degree of distal movement required, the amount of crowding in the lower jaw, the length of the arches and the presence and position of the corresponding third molars.

Records were selected retrospectively. All treatment plans were devised by the same orthodontist and all individuals who had successfully completed treatment, and for whom records were available, were included in the investigation.

Appliance design

Appliance prescription followed a standardized pattern (Figure 1). Unless there were indications to the contrary, the appliance was designed with Adams' clasps on first molars and first premolars and a midline screw for arch expansion. The exact clasping pattern was varied according to the dictates of the malocclusion. Where no expansion of upper first premolars was needed, double clasps were placed on 65| and |56: if the canines were aligned and relatively little distalization was required, the anterior clasps were positioned on the canine teeth. Occlusal rests on the first molars prevented the posterior margin of the appliance from sinking into the palatal tissues. Unless bite opening was required, the acrylic was saddled anteriorly. Headgear tubes were soldered to the bridges of the first molar clasps and a removable facebow was provided. An Interlandi headgear and safety strap completed the extra-oral component.

Methods

Model measuring technique

Study casts taken at the beginning of treatment (T1), at the end of buccal segment retraction (T2), and at the completion of treatment (T3) were evaluated. Using a specially designed jig, casts were clamped to the recording table of the Reflex microscope (Figure 2a,b).

To record the inter-arch relationships, upper and lower models were examined together. The casts were placed in occlusion with each attached to its respective half of the jig (Figure 2b). A threaded screw allowed for various sizes of model and the double beaks of the clamp ensured that the models did not move. Where the incisor relationship was being measured, models were placed as shown in Figure 2b: to record the buccal segments, models were clamped on their sides so that the posterior teeth could be clearly seen. The lower model was fixed, whilst the upper model, although firmly attached to the table, could be moved away from the lower enough to visualize the lower teeth. The stepping motor responsible for this translation also recorded the degree of separation between upper and lower casts, permitting the antero-posterior relationship between upper and lower teeth to be calculated. The following points were recorded: the tips of the cusps of the first molars, first premolars and canines, the mesio-incisal corner of the upper right central incisor, and a point on the tip of the corresponding lower tooth immediately below this.

For recording intra-arch measurements, upper and lower models were positioned on their

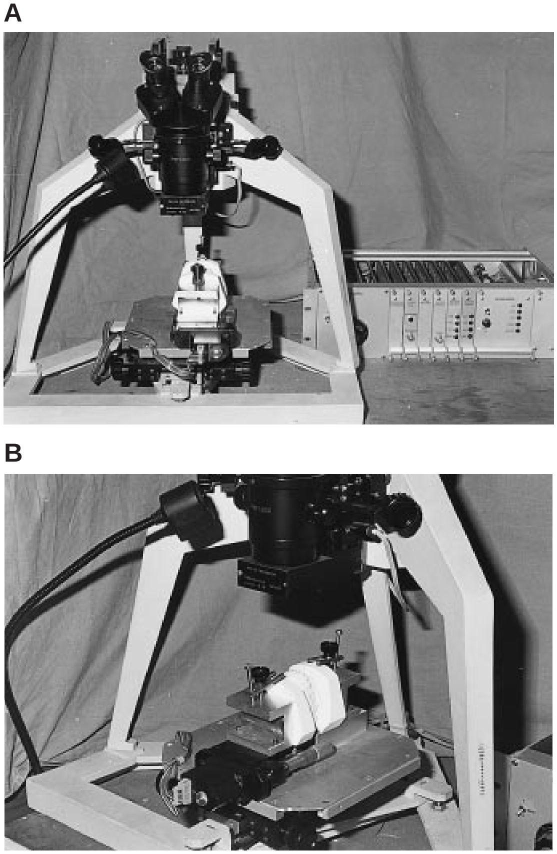

Figure 2 (A) The Reflex microscope and recording jig, with upper and lower models clamped in position. To the right is the control box for the stepping motor, which regulates and measures the amount of separation of the casts. (B) Close-up view of the models on the table of the Reflex microscope. The models are clamped in the jig upside-down. The table is split: the lower model is secured to the fixed upper portion of the jig and the upper cast attached to the moveable, lower section.

respective bases. The tips of the canines and of the mesiobuccal cusps of the first molars were registered, together with the mesial and distal contact points of each tooth. All points were recorded twice with an accuracy of 0.1 mm and a mean value taken. The microscope was interfaced with an IBM compatible PC, allowing calculation of the molar, premolar, and canine relationships together with the overbite and overjet. Inter-molar and inter-canine widths and arch length were similarly determined. Using a custom designed program module, the degree of crowding and arch perimeter were evaluated (Battagel, 1996). Definitions of these measurements are given in Table 2.

Statistical analysis

Data were analysed using SPSS PC+. Because there were no significant differences between measurements for male and female subjects, data for the sexes were pooled.

Descriptive statistics were calculated for the whole group at each stage: T1, T2 and T3. The changes at the end of buccal segment retraction (T2 – T1) and at the completion of active treatment (T3 – T1) were also determined and their statistical significance assessed using paired *t*-tests (Table 3).

The effect of upper second molar extraction was then examined. Grouping the subjects into extraction (n = 29) and non-extraction (n = 10) subsets, the upper arch changes which occurred during buccal segment retraction and over the entire treatment period were compared (Table 4).

Error of the method

To determine the intra-observer error, 20 sets of models were re-recorded by the same observer at least 2 weeks after the original recording session. The error between duplicate determinations was assessed using Dahlberg's (1940) method and the coefficient of reliability and systematic error at the 10 per cent level were also determined as recommended by Houston (1983) (Table 5).

Dahlberg errors ranged from 0.15 for upper inter-canine width to 0.9 mm for lower arch crowding. The coefficient of reliability exceeded 95 per cent for all measurements except for crowding in the upper and lower labial segments. Systematic errors were found in several measurements and these were most marked in the assessment of lower arch crowding. In general, where systematic errors occurred, the values in the second recordings were lower than those in the original data.

Results

These are presented in Tables 3 and 4. Table 3 describes the measurements recorded at each

Table 2 Definitions of the measurements recorded.

Measurement	Definition
Molar relationship	The antero-posterior distance between the tips of the disto-buccal cusps of the upper (left and right) and lower first molars. In a Class I molar relationship, this value will be approximately 2–3 mm. Values more negative than this indicate a Class II relationship.
Premolar relationship	The antero-posterior distance between the tips of the cusps of the upper and lower (left and right) first premolars. In a Class I molar relationship, this value will approximate 3 mm. Values more negative than this indicate a Class II relationship.
Canine relationship	The antero-posterior distance between the tips of the cusps of the upper and lower (left and right) canines.
Overjet	The antero-posterior distance between the labial surface of the most prominent upper incisor and the lower tooth directly below this point.
Overbite	The vertical distance between the tips of the upper and lower incisors as described above.
Intercanine width	The distance between the tips of the cusps of the upper or lower canines.
Intermolar width	The distance between the tips of the mesiobuccal cusps of the upper or lower first molars.
Arch length	The perpendicular distance between the tip of the most prominent incisor and a line drawn between the mesial contact points of the first molars.
Arch perimeter	The sum of the widths of all teeth in that arch minus the amount of overlap recorded between pairs of adjacent teeth. Where spacing was present, tooth overlap was registered as negative: in crowded arches, the overlap was positive.
Crowding	The sum of the overlaps between pairs of adjacent teeth. Where spacing was present, tooth overlap was registered as negative: in crowded arches, the overlap was positive.
Labial segment crowding	The sum of the overlaps between pairs of adjacent teeth between the right and left canines.

If a tooth was partially erupted or unerupted, the width of its antimere was substituted. If both teeth were absent from the arch, a standard value was employed, based on tables given by Moyers *et al.* (1976) and modified for each patient according to the size of the other teeth present.

Table 3 Measurements (in mm) recorded at the beginning of treatment (T1), at the end of buccal segment retraction (T2), and at the completion of treatment (T3), changes between T1 and T2, T1 and T3, and the significance of these (n = 39).

Measurement	Start of treatment (T1)	Completion of buccal segment retraction (T2)	Completion of treatment (T3)	Differences: (T2 – T1) and their significance	Differences: (T3 – T1) and their significance
Left molar relationship	0.1 ± 2.2	3.9 ± 1.9	2.9 ± 1.5	3.8 ± 2.1***	2.8 ± 2.1***
Right molar relationship	–1.2 ± 2.0	2.6 ± 1.8	1.8 ± 1.7	3.8 ± 2.0***	3.0 ± 2.2***
Left premolar relationship	0.6 ± 2.3	4.3 ± 1.8	3.2 ± 1.2	3.7 ± 2.1***	2.6 ± 2.0***
Right premolar relationship	–1.2 ± 1.9	2.6 ± 1.8	2.1 ± 1.3	3.7 ± 1.9***	3.2 ± 2.2***
Left canine relationship	–1.1 ± 2.1	1.0 ± 1.9	1.3 ± 1.7	2.1 ± 2.1***	2.4 ± 1.8***
Right canine relationship	–2.4 ± 2.4	–0.5 ± 1.5	0.5 ± 1.8	1.9 ± 1.4***	2.9 ± 2.0***
Overjet	5.8 ± 2.1	4.7 ± 1.7	3.2 ± 1.1	–0.9 ± 1.3**	–2.6 ± 1.6***
Overbite	4.1 ± 1.8	3.6 ± 1.5	3.2 ± 1.2	–0.5 ± 0.9*	–0.9 ± 1.2*
Upper intercanine width	33.5 ± 2.5	35.3 ± 2.8	34.1 ± 1.9	1.0 ± 2.9***	0.6 ± 1.3**
Upper intermolar width	49.6 ± 3.1	53.6 ± 3.1	52.6 ± 2.7	4.1 ± 1.4***	3.1 ± 2.0***
Upper arch length	37.7 ± 3.0	39.7 ± 3.1	37.4 ± 2.3	2.0 ± 1.3***	–0.2 ± 2.4
Upper arch perimeter	96.1 ± 6.0	101.4 ± 6.1	98.0 ± 5.0	5.2 ± 2.7***	1.9 ± 3.8**
Upper arch crowding (6/6)	1.2 ± 3.5	–4.6 ± 2.8	–1.0 ± 1.6	–5.8 ± 2.8***	–2.2 ± 3.7***
Upper labial segment crowding (3/3)	1.6 ± 2.4	–0.8 ± 2.2	-0.2 ± 1.0	–2.5 ± 1.1***	–1.8 ± 2.1*
Lower intercanine width	26.0 ± 1.9	26.6 ± 2.0	26.1 ± 1.8	0.6 ± 0.6***	0.1 ± 0.8
Lower intermolar width	44.1 ± 2.7	45.4 ± 2.6	45.3 ± 2.6	1.4 ± 1.0***	1.2 ± 1.4***
Lower arch length	33.5 ± 2.2	33.3 ± 2.4	33.1 ± 2.4	–0.1 ± 1.1	–0.4 ± 1.6
Lower arch perimeter	88.0 ± 4.4	88.7 ± 4.7	87.8 ± 5.0	0.6 ± 1.7*	–0.2 ± 2.5
Lower arch crowding (6/6)	1.1 ± 2.6	0.2 ± 1.8	0.7 ± 1.5	–0.9 ± 1.7***	–0.4 ± 2.3*
Lower labial segment crowding (3/3)	1.1 ± 1.3	0.6 ± 1.2	0.8 ± 1.1	–0.6 ± 0.9***	–0.3 ± 1.1*

Significance: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 4 The effect of upper second molar extraction on treatment. Comparison between the changes which occurred during buccal segment retraction (T2 – T1) and during the entire treatment (T3 – T1) and the significance of these. All measurements are given in millimetres.

Measurement	Upper second molars extracted (*n* = 29)		Upper second molars not extracted (*n* = 10)		Difference (extraction minus non-extraction groups)	
	T2 – T1	T3 – T1	T2 – T1	T3 – T1	T2 – T1	T3 – T1
Left molar relationship	3.9 ± 2.3	2.8 ± 2.2	3.5 ± 1.6	2.6 ± 1.9	0.4	0.3
Right molar relationship	4.1 ± 2.0	3.1 ± 2.3	2.7 ± 2.0	2.7 ± 2.2	1.4	0.4
Left premolar relationship	4.0 ± 2.1	3.0 ± 2.0	2.9 ± 1.9	1.5 ± 1.7	1.0	1.5*
Right premolar relationship	4.2 ± 1.7	3.6 ± 2.2	2.4 ± 1.9	2.3 ± 2.0	1.9*	1.4
Left canine relationship	2.2 ± 1.3	2.6 ± 1.8	2.0 ± 1.2	1.7 ± 1.7	0.2	0.9
Right canine relationship	2.0 ± 1.4	3.1 ± 2.3	1.6 ± 1.6	2.2 ± 1.9	0.5	0.9
Overjet	–0.7 ± 1.4	–1.2 ± 1.7	–0.4 ± 0.9	–1.2 ± 1.6	0.2	0.0
Overbite	–0.2 ± 1.0	–0.4 ± 1.2	–0.4 ± 0.7	–0.7 ± 1.4	0.1	–0.4
Upper intercanine width	1.8 ± 0.9	0.7 ± 1.4	1.7 ± 0.6	0.4 ± 0.7	0.2	0.3
Upper intermolar width	4.1 ± 1.6	3.3 ± 2.2	3.8 ± 0.9	2.3 ± 0.9	0.3	1.0*
Upper arch length	2.3 ± 1.3	–0.2 ± 2.7	1.4 ± 1.1	–0.3 ± 1.4	0.8	–0.2
Upper arch perimeter	5.7 ± 2.9	2.0 ± 4.2	3.8 ± 1.8	1.3 ± 2.0	1.9*	0.7
Upper arch crowding (6/6)	–6.3 ± 2.9	–2.4 ± 4.1	–4.3 ± 1.9	–1.5 ± 2.3	1.9*	0.9
Upper labial segment crowding (3/3)	–2.7 ± 1.1	–2.0 ± 2.4	–2.2 ± 0.6	–1.5 ± 1.4	0.5	0.4

Significance: *$P < 0.05$.

Table 5 Error of the method.

Measurement	Dahlberg's calculation (mm)	Houston's coefficient of reliability (per cent)	Systematic error: *t*-test at 10 per cent level and its significance
Left molar relationship	0.28	99.1	2.284*
Right molar relationship	0.40	98.5	2.218*
Left premolar relationship	0.28	98.7	2.243*
Right premolar relationship	0.32	98.7	1.590 NS
Left canine relationship	0.25	98.4	0.975 NS
Right canine relationship	0.28	99.7	0.179 NS
Overjet	0.24	98.8	0.155 NS
Overbite	0.29	96.4	0.389 NS
Upper intercanine width	0.15	99.7	0.179 NS
Upper intermolar width	0.16	99.8	2.888*
Upper arch length	0.28	99.6	3.869*
Upper arch perimeter	0.39	99.7	1.724 NS
Upper arch crowding (6/6)	0.01	96.2	2.663*
Upper labial segment crowding (3/3)	0.02	94.4	2.207*
Lower intercanine width	0.15	99.7	1.898 NS
Lower intermolar width	0.17	99.7	1.206 NS
Lower arch length	0.15	99.9	0.015 NS
Lower arch perimeter	0.40	99.6	2.745*
Lower arch crowding (6/6)	0.91	95.2	7.763*
Lower labial segment crowding (3/3)	0.62	91.5	7.979*

Significance: *$P > 0.1$.

phase of treatment: start of treatment (T1) in column 1, completion of buccal segment retraction (T2) in column 2 and the end of treatment (T3) in column 3. Columns 4 and 5 describe the differences during buccal segment retraction and for the total treatment time, respectively. Buccal segment relationships are described in millimetres, recorded as the distance between the cusp tips of pairs of upper and lower teeth.

In the molar region a measurement of zero would indicate a half-unit Class II or end-to-end relationship. Negative values indicate a molar position which is more Class II than this, whilst a value of 2–3 mm equates with a Class I molar arrangement.

Buccal segment retraction (T2–T1) (Tables 1 and 3)

On average, this phase of treatment lasted approximately 11 months (Table 1). The changes recorded during this period are shown in Table 3, column 4.

The occlusion. Molars and premolars were retracted approximately 3.7 mm, that is, a little more than half a unit on each side. The upper canines were not included in the appliance and were deliberately left to drift during the retraction phase. Their 2 mm movement was therefore less than that of the molars and premolars. All these differences were highly statistically significant.

In this mixed Class I and Class II sample, alterations in overbite and overjet were not always required. The small mean reduction in overjet of 0.9 mm is a spontaneous change, whilst the 0.5 mm overbite reduction represents the use of an anterior bite plane in those subjects in which overbite reduction was an aim of treatment.

The upper arch. All measurements showed highly significant differences. Inter-canine width increased by 1 mm, inter-molar width increased by 4 mm, whilst arch length and arch perimeter increased by 2 and 5 mm, respectively. Crowding reduced by approximately 6 mm overall and 2.5 mm in the labial segment.

The lower arch. Despite the absence of any treatment, spontaneous changes were apparent. Both the inter-canine and inter-molar widths increased, mirroring the alterations in the upper jaw. Intercanine width improved by 0.6 mm, half of the increase seen in the upper arch, whilst in the molar region 1.4 mm expansion (one-third of that recorded in the upper arch) was seen. Both were highly statistically significant.

By contrast, lower arch length and perimeter altered very little. Mean arch length remained unchanged, but arch perimeter increased slightly because of the expansion already described. These mean changes hide a wide range of individual variation: approximately half of the group had received lower second molar extractions and the other half had not. On average, crowding improved slightly, but again, this mean figure did not take into account the extraction pattern in the lower arch.

The entire treatment period (T3–T1) (Table 3, column 5)

The occlusion. During this 13-month interval, fixed appliances were employed to retract and align the upper labial segment, and detail the occlusion. Many of the dental changes seen during the retraction phase were reversed so that total treatment effects were smaller than at the completion of distal movement. In the buccal segments retraction had reduced by 0.5–1 mm, suggesting some over-correction during the initial stage. Net retraction remained at approximately half a unit and was still highly significant.

During the second stage the canines were incorporated into the fixed appliance and finally aligned. Only 1 mm further retraction was required. Both overbite and overjet reduced as a Class I occlusion became established.

The upper arch. At the completion of treatment, arch expansion had reduced by one-third when compared with its position at T2. For the canines this was because buccally placed teeth had been moved palatally; for the molars this was due to the correction of arch form together with some mesial movement of the teeth themselves.

Mean arch length at T3 was essentially the same as at T1. Arch perimeter also reduced during the T3–T2 interval, mirroring the reductions in arch length and width.

At the end of treatment, very mild spacing was apparent in the arch as a whole. The spacing present after buccal segment retraction had been consolidated and the crowding apparent at T1 eliminated. All alterations remained statistically significant except for upper arch length, but the levels of significance tended to be reduced.

The lower arch. Of the five significantly improved lower arch variables at T2, only the increase in inter-molar width remained highly significant at the completion of therapy. Small improvements in the degree of crowding also persisted.

The effect of upper second molar extractions (Table 4)

Small differences in favour of the second molar extraction group were seen for nearly all measurements, but because of the unbalanced sizes of the two groups, these alterations were rarely statistically significant. These differences had disappeared by the completion of treatment as the arches were finally aligned.

Discussion

Active changes in the upper arch

The upper buccal segments were retracted approximately half a unit. Since the original malocclusions were relatively mild, half a unit of molar retraction was adequate to achieve correction in most cases. The movement recorded at the end of the distalization phase suggested that clinicians had over-retracted the buccal segments at this stage, rather than obtaining the correct molar position and then maintaining it.

The amount of distal movement reported here is smaller than the full unit reported by Orton *et al.* (1996b) and the 3–6 mm movement described by Bernstein *et al.* (1977). It does however, accord with the ranges reported for molar distalization alone (Melsen, 1978; Hubbard *et al.*, 1994). Although both Orton *et al.* (1996a) and Bernstein *et al.* (1977) used removable appliances, their studies are not directly comparable: the latter authors were hoping to achieve orthopaedic, as well as orthodontic change and, therefore, applied extremely heavy forces for up to 23 hours per day. The study by Orton *et al.* (1996a,b) described the *en masse* technique, but only reported the results of the buccal segment retraction phase.

At the completion of treatment the upper inter-molar width had increased by 3 mm. This was approximately 75 per cent of the enlargement reported by Gibbs and Hunt (1992) following Fränkel appliance therapy, but similar to the post-treatment expansion noted by Ghafari *et al.* (1994) using headgear to upper molars. Other headgear studies have noted smaller increases (Mills *et al.*, 1978; Bishara *et al.*, 1994).

The failure of mean arch length to differ between the initial and final measurements may be explained by the heterogenous nature of the sample: those crowded Class I and Class II division 2 occlusions in which arch length did increase were balanced by an equal number of Class II division 1 subjects who presented with spacing and for whom arch length was subsequently reduced. The increase in arch perimeter accords with the augmentation of inter-molar width.

Changes in canine position

During buccal segment retraction, the canines underwent spontaneous alignment, thus minimizing their active retraction with its attendant anchorage requirements. Canines showed 2-mm distal drift and only needed a further 1 mm retraction to bring them into alignment. These changes were accompanied by modest increases in the inter-canine width, commensurate with the teeth occupying a broader part of the arch. These are smaller than might be expected because of the mixed sample: in subjects with buccally-placed canines the inter-canine distance would be reduced as the teeth moved into occlusion, diluting the expansion required in those cases where the canines were moved distally around the arch.

Behaviour of the lower arch

Significant increases in arch width were observed during treatment, especially in the molar region. This was also reported by Orton *et al.* (1996b) and during isolated upper molar retraction (Mills *et al.*, 1978; Ghafari *et al.*, 1994). The amount of expansion gained was significant, equating with that achieved during Fränkel appliance therapy (Gibbs and Hunt, 1992) and lip bumper treatment (Werner *et al.*, 1994; Grossen and Ingervall, 1995). This tooth movement mirrored the larger alteration in width occurring in the upper arch and was significantly different from the normal growth changes which would be expected during this period (Moyers *et al.*, 1976). The alterations in lower arch dimensions were facilitated by the appliance design which tended to hold the teeth out of occlusion.

It would appear that this change represented a bucco-lingual uprighting of the molars, as the modifications to arch length and perimeter were negligible, negating any increase in the antero-posterior direction. Interestingly, unlike most of the interim improvements reported in the lower arch, the increase in inter-molar width remained at the end of treatment. It was not affected by procedures to align the upper arch.

Some small changes in other lower arch dimensions were also apparent at the completion of buccal segment retraction, but all were reversed during upper arch consolidation. As approximately half the subjects had lower second molars removed, any potentially beneficial changes in the extraction subgroup (as described by Richardson and Mills, 1990) would be balanced by normal growth in the non-extraction element. The five subjects who wore lower fixed appliances during the period of upper arch alignment would further complicate the issue. The differences between the extraction and non-extraction groups will be explored further in a subsequent investigation. The alterations in arch length and perimeter seem to be compatible with normal growth (Humerfelt and Slagsvold, 1972; Moyers *et al.*, 1976; Sinclair and Little, 1985).

The effect of upper second molar extractions

From examination of Table 4, it appears that the extraction of upper second molars had little beneficial effect on treatment. On closer evaluation, although statistical differences between the two groups were rare and relatively weak, there was a trend towards greater improvements during both phases of treatment in the second molar extraction group. The loss of upper second molars did not reduce the time taken to complete treatment.

These were not unexpected findings. In general, the decision to remove second molars was a clinical one: these teeth were extracted if third molars were present, of normal size, and in favourable positions. Otherwise, second molars were retained. The subjects in the two groups were not matched in any way: comparatively few retained second molars and the number of patients in this sub-group was too small for adequate statistical analysis. Furthermore, the patients were not matched for severity of malocclusion, age, or compliance with their extra-oral traction. A further study, designed specifically to examine the effects of second molar extraction might elucidate this question.

Conclusions

1. Retraction of buccal segments with an *en masse* appliance achieves similar results to the more conventional technique using headgear to upper molar bands.
2. Because space is gained mesial to the first premolars, spontaneous canine drift occurs and active retraction is minimized.
3. As the upper arch is expanded and retracted, spontaneous, sympathetic movements occur in the lower arch. These changes tend to be reversed during the second phase of treatment: however, inter-molar expansion remains relatively stable.
4. Upper second molar loss does not seem to affect the outcome, but the study design was not ideal to test this properly.

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