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Long-term stability of dentoalveolar and skeletal changes after activator–headgear treatment

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SUMMARY The aim of this study was to analyze the long-term stability of combined activator–headgear treatment on skeletal and dental structures in Class II patients. The material comprised 26 subjects, 10 girls and 16 boys. All had a molar Class II relationship, overjet ≥6 mm, and overbite ≥5 mm. They were treated in one practice with combined activator and headgear appliances. Lateral cephalometric radiographs and dental study casts were taken before treatment (T0, mean age 11.9 years), at the end of activator–headgear treatment (T1, mean age 15.9 years), and 12–15 years out of retention (T2, mean age 28.6 years). Nineteen cephalometric and nine dental cast variables were evaluated using a paired sample *t*-test between T0–T1, T1–T2, and T0–T2.

At T1, the majority of the cephalometric measurements showed statistically significant changes. ANB was significantly reduced by 2.3 degrees due to a significant increase in SNB, but only small changes were observed in SNA. The interincisal angle increased as a result of significant retroclination of both maxillary and mandibular incisors. All patients achieved a Class I molar relationship and a significant reduction in overjet and overbite. At T2, the results showed only slight relapse from T1. However, the relapse did not compromise the significant improvement in almost all the cephalometric and dental variables. Combined activator–headgear treatment improved the skeletal and dental conditions and the results remained stable in the long term.

Introduction

Various removable and fixed functional appliances are used in the treatment of Class II division 1 malocclusions. Activators and modified activators with headgear are some of the oldest systems that are still frequently used (Andresen, 1936; Rakosi, 1997a,b; Proffit, 2000). A clinically evident improvement of Class II malocclusions is repeatedly demonstrated, but the nature of changes due to activator treatment has been controversial. Some investigators report mainly dentoalveolar (Jakobsson, 1967; Wieslander and Lagerström, 1979; Cura *et al.*, 1996), others mainly skeletal (Cozza *et al.*, 2004) changes, while some claim that the improvement of the sagittal occlusal relationship is due equally to skeletal and dental changes (Pancherz, 1984; Marşan, 2007). Regardless of the nature of the changes, the greatest challenge and major goal is to treat the malocclusion to correct function and aesthetics and to ensure that the treatment results remain stable.

While the short-term effects of Class II treatment have been widely investigated, long-term stability of skeletal and dental alterations has received less attention. It seems likely that relapse tendencies are inevitable, but their extent and clinical significance are variable (Herzberg, 1973; Wieslander and Lagerström, 1979; Fidler *et al.*, 1995; Janson *et al.*, 2004). Relapse of overbite and overjet, retroclination of the mandibular incisors, and worsening of the sagittal molar relationship are most often mentioned, but they do not seem to compromise an otherwise successful correction of a Class II division 1 malocclusion (Fidler *et al.*, 1995; Elms *et al.*, 1996).

Apart from one study that evaluated the stability of treatment results with only a headgear–activator 5 years post-retention (Lehman *et al.*, 1988), all other long-term investigations have evaluated Class II division 1 subjects treated with a combination of functional and/or headgear and fixed appliances. For a better understanding of the long-term benefits of any functional appliance, including the headgear–activator, it is important to have long observation periods and a treatment method limited to only one appliance. Therefore, the aim of this study was to investigate the long-term stability of the skeletal and dental changes in Class II division 1 patients treated only with a headgear–activator.

Subjects and methods

The subjects were 26 Class II malocclusion patients, 10 girls and 16 boys, with mean age of 11.9 years (±1.2). They were treated by a single orthodontist (ØT) in his private practice. The start records were collected in the period between 1983 and 1987. To be included in the study, the patients had to fulfil the following criteria: (1) treated only with a modified activator and Kloehn headgear; (2) have a Class II molar relationship; (3) an overjet of at least 6 mm and/or an overbite of at least 5 mm; and (4) to have full records at the end of treatment. Patients requiring fixed appliances (e.g. because of anterior crowding exceeding 4 mm, agenesis, or previous extractions) after the initial functional appliance treatment were excluded.

A complete file search of the practice included a total of 497 patients that had their start records collected during the 5 year period. Fifty cases were found to fulfil the inclusion criteria. Of those, 26 patients consented to participate. The other 24 patients had either moved abroad or to other parts of the country (nine patients), could not take time off work (six patients), or were not interested (two patients). One patient was pregnant and did not wish to undergo radiographic evaluation, and six patients could not be contacted.

Appliance design

The activator was a loose fitting appliance, where all the maxillary teeth as well as the mandibular incisors were covered by acrylic (Figure 1). The working bite was taken with the mandible set forward in an edge-to-edge relationship and bite raising of approximately 1 mm. For patients where the initial overjet was 9 mm or more, the working bite was taken behind an edge-to-edge relationship and a second activator was provided during treatment. Trimming was performed to guide eruption facets for the lower premolars and molars, and if necessary, to allow retroclination of proclined upper incisors. Bands were cemented on the upper first molars, and a Kloehn headgear with a cervical pull was adjusted. The adjustment included expansion of the inner bow by about 2 mm. The recommendations for use were 12–14 hours a day during active treatment. Active treatment was considered finished when the first molars were in Class I occlusion and the overjet and overbite were at least 4 mm or less. After active treatment, the bands were removed and the activator was used for retention. Five of the patients were provided with a new activator for retention. The retention phase consisted of approximately 2 years nightly use of the activator, first every night, then every second and third night until the activator was used approximately once a week. Treatment and retention lasted approximately 4 years (±1.1), while the post-retention period was 13.9 years (±1.6).

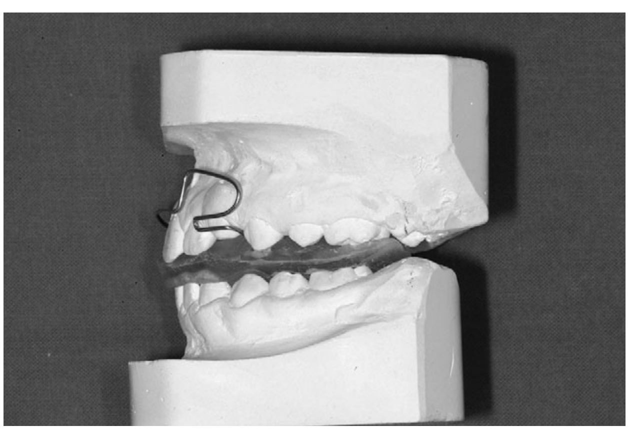

Figure 1 The activator appliance without the Kloehn headgear mounted on study casts.

Records, including lateral cephalograms and study casts, were taken at the start of treatment (T0), mean age 11.9 ± 1.2 years; after the end of active retention (T1), mean age 15.9 ± 1.1 years; and post-retention (T2), mean age 28.6 ± 1.6 years.

Cephalometric analysis

All the analyses were undertaken by one author (ML). The tracings were performed on acetate paper and then scanned on Adobe Photoshop. Corrections were made for linear enlargement, and the tracings were analyzed using FACAD® (Ilexis AB, Linköping, Sweden). Definitions relating to the angular and linear measurements are given below:

Angular measurements (in degrees);
ML/nsL, angle of the mandibular plane (go-gn) and nasion-sella line (s-n);
ML/NL, angle of the mandibular plane (go-gn) and nasal line (pm-sp);
ILs/Ili, posterior angle of the upper and lower incisor long axis;
ILi/ML, supero-posterior angle of the lower incisor long axis and mandibular plane (go-gn);
ILi/nB, supero-anterior angle of the lower incisor long axis and n-B;
ILs/nsL, infero-posterior angle of the upper incisor long axis and the nasion-sella line;
ILs/nA, supero-posterior angle of the upper incisor long axis and n-A.
Nasolabial angle, angle formed by a line drawn tangentially to the base of the nose and a line tangential to the upper lip.
Linear measurements (in millimetres);
Ii⊥Apg, distance from ii to A-pg;
Ii⊥nB, distance from ii to n-B;
Is⊥Apg, distance from is to A-pg;
Is⊥nA, distance from is to n-A;
PLi-EL, distance from PLi (prolabium inferior) to PRN-PG (Ricketts E line);
PLs-EL, distance from PLs (prolabium superior) to PRN-PG (Ricketts E line).

Study cast analysis

The molar relationship was measured as the distance between the mesiobuccal tip of the maxillary first molar and the buccal groove of the mandibular first molar, and the canine relationship as the distance from the cusp tip of the maxillary canine to the distal contact point of the mandibular canine. Overjet was measured as the distance parallel to the occlusal plane from the buccal surface of the most proclined upper incisor to the buccal surface on the corresponding lower incisor, and overbite as the distance from the incisal tip of the upper first right incisor to the incisal tip of the lower first right incisor.

Arch width. The intercanine distance was measured as the width between 33 and 43, from cusp tip to cusp tip. When the lower canines were unerupted, the distance was not measured. The maxillary intermolar distance was measured between the mesiopalatal cusps of 16 and 26 and the mandibular intermolar distance between the lingual fossae of 36 and 46. Space analysis gave the degree of space discrepancy. The total mesiodistal dimensions of the upper and lower six anterior teeth was calculated and subtracted from the arch length between the distal surfaces of the canines. All measurements were in millimetres.

Study error

Ten cephalograms and 20 study casts were randomly selected and re-measured after an interval of 3 months. The combined study error (SE) was calculated using the formula proposed by Dahlberg (1940):

$$SE = \sum d^2 / 2n,$$

where d is the difference between two registrations and n is the number of double registrations. The SE for measurements on study casts ranged from 0.6 to 1.5 mm with a mean of 0.9 mm and on the cephalograms from 0.7 to 2.8 degrees with a mean of 1.7 degrees for the angular and 0.6 mm (0.2–0.8) for the linear measurements.

Statistical analysis

The means and standard deviations were calculated for all the measured cephalometric and study models variables. A paired sample t-test was used to evaluate the mean changes between T0–T1, T1–T2, and T0–T2. A level of $P<0.05$ was considered to indicate a statistically significant difference.

Results

Cephalometric analysis

Treatment changes T0–T1. Nearly all craniofacial variables showed statistically significant changes, except for SNA. SNB and SNPg increased during treatment, while ANB decreased (Table 1, Figure 2a). A statistically significant decrease was observed for NSBa, the mandibular plane angle (ML/nsL), and the intermaxillary angle (ML/NL; Table 1, Figure 2b). The lower and upper incisors became more retroclined and retruded, which led to an increased interincisal angle. All these changes were statistically significant (Table 1, Figure 2c). The upper and lower lip became significantly retrusive, while the nasolabial angle became more obtuse, but this change was not significant (Table 1, Figure 2d,e).

Table 1 Treatment changes of selected cephalometric variables after active treatment (T0–T1), post-retention (T1–T2), and between pre-treatment and post-retention (T0–T2).

Variables	T0–T1		T1–T2		T0–T2	
	Mean	SD	Mean	SD	Mean	SD
SNA (°)	−0.3	1.3	0.5	1.4	0.2	1.5
SNA (°)	2.0**	1.6	1.0*	1.8	2.9	1.7
ANB (°)	−2.3**	1.7	−0.5	1.4	−2.6	1.4
SNPg (°)	2.1**	1.6	1.3*	1.7	3.4	1.8
ML/nsL (°)	−1.2*	2.1	−2.1**	2.5	−3.3	2.7
ML/NL (°)	−1.3*	2.1	−1.4*	2.4	−2.6	2.7
NSBa (°)	−1.1*	2.3	−1.7	2.6	−1.1	2.0
ILs/ILI (°)	6.4**	6.7	4.1*	6.8	10.5**	5.6
ILi/ML (°)	−2.7**	3.3	−1.3	4.0	−4.0**	4.5
ILi/nB (°)	−1.9*	2.6	−2.4*	4.1	−4.5**	4.1
Ii┴Apg (mm)	0.8*	1.5	−0.6*	1.2	−0.2	3.8
Ii┴nB (mm)	−0.2	1.1	−0.8*	1.2	−0.2	1.1
ILs/nsL (°)	−2.5	6.0	0.8	5.9	−3.3*	5.3
ILs/nA (°)	−2.2*	6.1	1.2	4.6	−3.4*	5.1
Is┴Apg (mm)	−2.5**	2.0	0.8	1.5	−3.4**	1.5
Is┴nA (mm)	−0.3	3.2	0.5	3.1	−0.7*	1.9
Nasolabial angle	2.5	9.8	−3.8*	5.6	−1.2	10.0
PLi-EL (mm)	−2.5**	1.9	−3.0**	1.8	−5.2**	2.3
PLs-EL (mm)	−3.5**	2.2	−27**	1.4	−6.4**	2.2

SD, standard deviation. *$P \leq 0.05$, **$P \leq 0.001$.

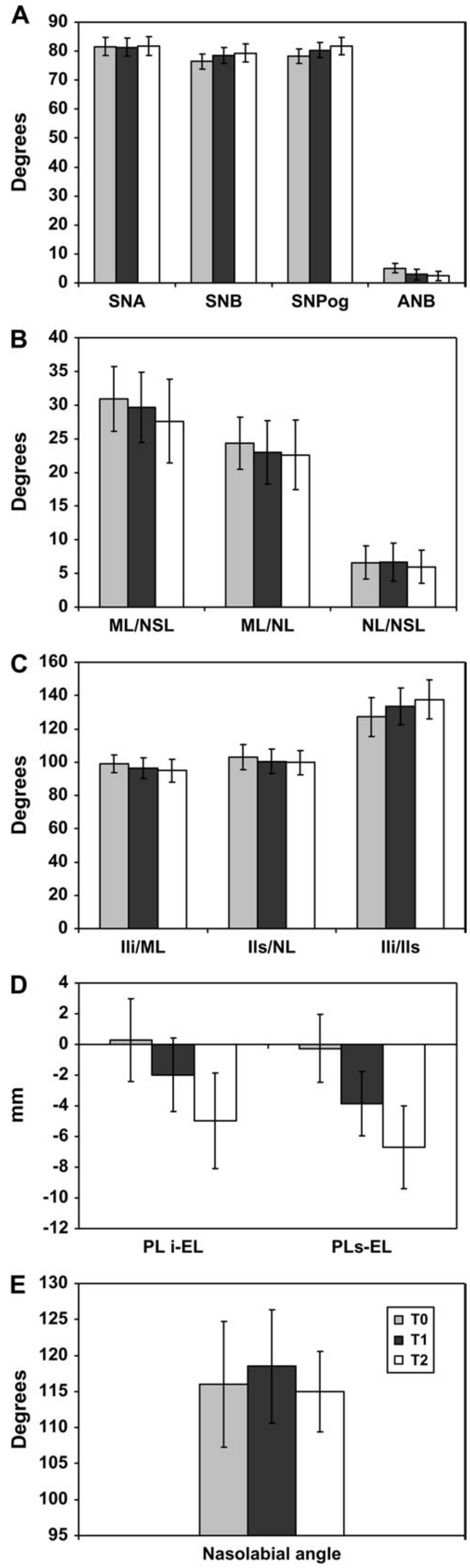

Figure 2 Mean values and standard deviations of mandibular and maxillary prognathism (A), mandibular (ML/nsL) and maxillary (NL/nsL) jaw inclination (B), incisor inclination (C), linear distance from lips to E line (D), and nasolabial angle (E) at treatment start (T0), treatment end (T1), and post-retention (T2).

Post-treatment changes T1–T2. SNB and SNPg continued to increase significantly after the end of retention. Despite this, there was a slight decrease in ANB, but the change was not significant (Table 1, Figure 2A). No significant changes were found for NSBa. During the post-treatment period, both ML/nsL and ML/NL decreased significantly (Table 1, Figure 2B).

The lower incisors became more retroclined and retruded (Table 1, Figure 2C). The distances from Ii to APg and Ii to NB were significantly reduced. The upper incisors showed a tendency for further retroclination. The distance from Is to APg was significantly reduced, resulting in more uprighted upper incisors. The interincisal angle continued to increase significantly after treatment, but with large individual variations (Table 1, Figure 2C).

Further significant retrusion of the lips was noticed, while the nasolabial angle significantly decreased (Table 1, Figure 2D,E).

Study cast analysis

Treatment changes T0–T1. Overjet and overbite were significantly reduced. The combined molar relationship on both sides significantly improved towards a Class I occlusion as did the canine relationship on both sides (Table 2, Figure 3A). The transverse dimensions showed an overall enlargement. The distance between the maxillary molars significantly increased during treatment. The mandibular intermolar distance also demonstrated a significant increase, but to a lesser extent. Intercanine distance decreased, but this was not significant (Table 2, Figure 3B). There was a slight, but significant increase in space in the upper anterior segment during treatment. The space conditions in the lower jaw remained almost the same, with a small tendency for reduction, but this was not significant (Table 2, Figure 3C).

Post-treatment changes T1–T2. Overjet remained stable, with only a slight, non-significant increase. Overbite, however, significantly increased. The molar relationship on both sides showed minor relapse and the canine relationship showed a tendency for further improvement. These changes were, however, not significant (Table 2, Figure 3A). The transverse dimensions reduced. Upper and lower intermolar width in both arches significantly decreased, as did intercanine distance (Table 2, Figure 3B).

A reduction in space occurred in both jaws. This was more pronounced in the lower anterior segment, and the changes were significant (Table 2, Figure 3C).

Discussion

The present investigation was based on a selected group of patients treated in a single practice, by an experienced orthodontist with only an activator–headgear appliance. Cephalometric and study cast analyses showed an overall

Table 2 Treatment changes (mm) of the variables measured on the study models post-treatment (T0–T1), post-retention (T1–T2), and between pre-treatment and post-retention (T0–T2).

Variables	T0–T1		T1–T2		T0–T2	
	Mean	SD	Mean	SD	Mean	SD
Overjet	−4.4**	1.7	0.1	1.7	−4.3**	1.7
Overbite	−2.3**	1.0	0.3*	0.7	−2.0**	1.2
Molar relationship	3.6**	1.2	−0.3	0.7	3.3**	1.2
Canine relationship	4.0**	1.1	0.1	0.8	−4.3**	1.1
16–26	2.2**	1.6	−0.8*	1.1	1.4**	1.4
33–43	0.04	0.8	−0.9*	1.1	−0.9**	1.1
36–46	1.0**	1.0	−0.5*	1.0	0.5	1.3
Space conditions upper anterior segment	0.7**	1.7	−0.4*	0.8	0.3	1.6
Space conditions lower anterior segment	−0.04	1.3	−1.6**	1.1	−1.6**	1.4

SD, standard deviation. *$P \leq 0.05$, **$P \leq 0.001$.

satisfactory treatment response. At T1, all patients achieved a Class I molar relationship and significant reduction of overjet and overbite. The treatment results showed slight relapse at T2, but it did not compromise the clinically significant improvement for almost all skeletal and dental variables.

The main focus of this investigation was long-term, post-retention stability and not the effectiveness of the appliance *per se*. However, assessment of the treatment changes was important. Firstly, the effectiveness of the activator–headgear appliance treatment had to be evaluated and secondly, the treatment results were necessary as a reference point for the study of stability or relapse during T2. In general, the observed skeletal and dental changes were in accordance with previous studies (Lehman *et al.*, 1988; Lagerström *et al.*, 1990; Altenburger and Ingervall, 1998; Bendeus *et al.*, 2002; Marşan, 2007). A significant reduction of the relative prognathism (ANB) was due to a significant increase in SNB and SNPg and an insignificant reduction of SNA. The inclination of the mandible decreased (ML/nsL) resulting in a decreased intermaxillary angle (ML/NL). Similar effects have been reported in almost all investigations that included activator, activator–headgear, and Herbst appliances (Wieslander, 1993; Altenburger and Ingervall, 1998; Bendeus *et al.*, 2002; Phan *et al.*, 2006). The time elapsed between T0 and T1 was 4 years and the mean age of the patients was approximately 16 years at T1. During this period, a substantial amount of growth had taken place, explaining changes such as augmentation of SNB by 2 degrees. Increases in SNA and SNB have also been shown in untreated Class II and Class I adolescents, with mandibular forward growth exceeding that of the maxilla (You *et al.*, 2001; Thilander *et al.*, 2005; Stahl *et al.*, 2008). Despite similar craniofacial growth in the two groups, no self-correction could be observed in the untreated Class II individuals (You *et al.*, 2001; Stahl *et al.*, 2008).

The interincisor angle significantly increased at T1, as both upper and lower incisors showed significant retroclination. Retroclination of the upper incisors is

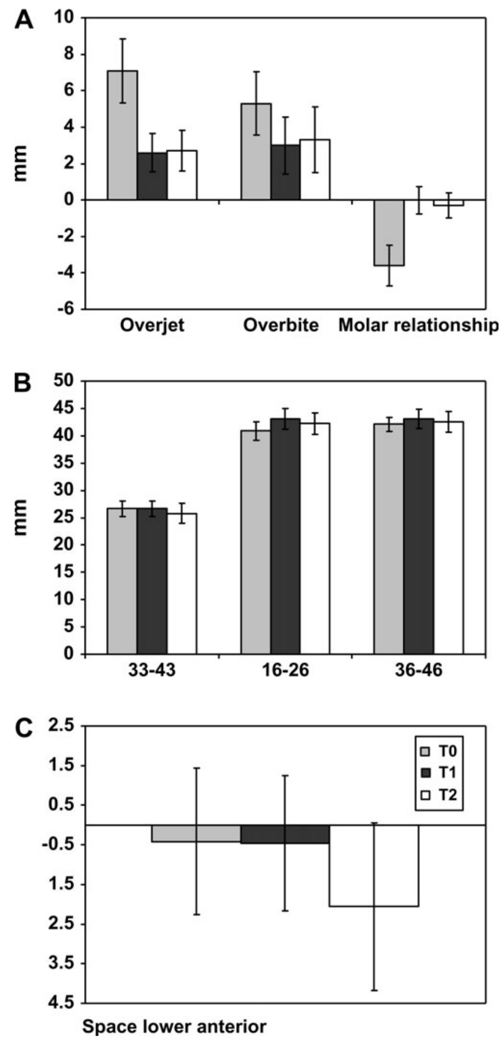

Figure 3 Mean values and standard deviations of dental overjet, overbite, and molar relationship (A), mandibular intercanine (33–43) and intermolar (36–46), and maxillary intermolar distance (16–26) (B), and available space in the lower anterior segment (C) at treatment start (T0), treatment end (T1), and post-retention (T2). Negative reading indicates a distal relationship.

commonly reported (Lehman *et al.*, 1988; Lagerström *et al.*, 1990; Altenburger and Ingervall, 1998; Bendeus *et al.*, 2002), but treatment changes in the inclination of the lower incisors are somewhat contradictory. Lehman *et al.* (1988) and Altenburger and Ingervall (1998) observed proclination during activator–headgear treatment, while Lagerström *et al.* (1990) and Bendeus *et al.* (2002) reported retroclination. The differences may have been due to appliance design, whether the incisors were capped with acrylic, trimming of the appliance, and patient compliance.

The treatment effects of functional appliances, whether skeletal or dental, are almost exclusively evaluated on lateral cephalograms. In this manner, the changes can only be assessed in the sagittal and vertical, but not in the transversal plane. On the other hand, precise identification of mesial and distal molar surfaces cannot be carried out bilaterally, although asymmetric, unilateral improvement can sometimes be observed. In order to overcome these shortcomings, plaster study models were included. Their analysis provided a reliable, bilateral evaluation of the sagittal changes in both canine and molar relationships, as well as overjet, overbite, transverse changes, and crowding. In agreement with previous findings, molar and canine relationship, as well as overjet and overbite significantly improved after treatment. In addition, a significant increase in intermolar distance was observed in both jaws, while the intercanine distance was stable. Retroclination of the lower incisors lead to minor, insignificant crowding in the lower anterior segment. Despite retroclination of the maxillary incisors, an increase in space conditions was observed. Possible distal movement of the teeth in the lateral segments may explain the overall gain in space and hence the increase in the incisor region. It is important to note that the transverse dimension and space measurements, although significant, were very small and considering the large measurement error should be interpreted with caution.

No matter how successful orthodontic treatment, if the results fail to remain stable, any favourable aesthetics and function will be compromised. Therefore, stability of treatment is of prime concern for patients and orthodontists alike. The results achieved during treatment in this study were stable and showed only small changes at T2. The overjet, overbite, and molar relationship relapsed, with overbite being the only variable showing a significant increase. However, all changes remained significant when compared with T0. The reduction in intermolar and mandibular intercanine distance was small, but significant, and so was the maxillary and mandibular anterior space, as crowding increased. Increased anterior crowding can be regarded as a result of the normal physiological processes of dental maturation and ageing as tooth alignment deterioration and mandibular intercanine distance reduction are also reported in individuals without previous orthodontic treatment (Humerfelt and Slagsvold, 1972; Bishara *et al.*, 1997; Bondevik, 1998, 2007). Furthermore, none of the patients were provided with bonded retainers.

A major factor contributing to the stability of treatment results is the growth pattern of the patients (Ormiston *et al.*, 2005). It has been reported that patients showing satisfactory response to activator–headgear treatment often display favourable growth (DeVincenzo, 1991; Elms *et al.*, 1996; Rakosi, 1997b; Janson *et al.*, 2004), while unfavourable growth can compromise even excellent treatment results (Herzberg, 1973). The majority of the patients in the present sample displayed further anterior mandibular growth as seen in the continued increase of SNB and SNPg. The mandibular and intermaxillary angles continued to decrease post-retention and these changes were significant. Overall, none of the skeletal variables showed relapse and continued to change in the same direction as during active treatment. The dental variables showed a slightly different pattern. The interincisal angle continued to increase after T1, mainly due to further uprighting of the mandibular incisors. The upper incisors, however, slightly proclined, but this change was not significant.

Studies on longitudinal growth changes in the adult craniofacial complex show that soft tissue changes in nose, lips, and chin occur as much after 25 years of age as between 18 and 25 years (Formby *et al.*, 1994). This supports the findings of the present study as the soft tissue variables showed greater changes than the skeletal ones. The lips became more retrusive and the nasiolabial angle significantly decreased post-retention. Such changes are most probably due to natural continued growth of the nose and chin, which has been shown to occur in both males and females (Nanda *et al.*, 1990).

Several other factors influencing the stability of orthodontically treated dentitions have been identified. Nanda *et al.* (1993) mentioned good occlusion and cuspal interdigitation, a constant intercanine width, and no proclination of the lower incisors as some of the most important factors for long-term stability. In this study, a satisfactory occlusion and intercuspation at the end of treatment was achieved; the intercanine distance was almost unchanged and the lower incisors showed slight retrusion. Despite this, the intercanine distance decreased and the lower incisors retruded even more after the end of retention, both changes being significant. Although these alterations did not compromise the good clinical result, it is questionable if the above-mentioned recommendations are sufficient to provide a stable post-treatment result.

Forces deriving from the surrounding orofacial tissues are also believed to promote stability of post-treatment results (Melrose and Millett, 1998). If dental changes are in harmony with the tongue and facial muscles, the result is more prone to be stable (Nanda *et al.*, 1993). Treatment with a functional appliance and a prolonged retention period as in the present study may have helped the soft tissues adapt to occlusal changes. The teeth were given sufficient time to adjust to the new position and function since the retention protocol included the same appliance as during treatment. Considering the good long-term outcome in these patients, it is probable that in addition to a favourable growth pattern, correct diagnosis, treatment, and retention protocol in motivated patients should be regarded as contributing factors to stable long-term treatment results.

Prediction of relapse and/or stability after orthodontic treatment seems to be difficult as the dentition constantly changes throughout life, with or without orthodontic treatment (Uhde *et al.*, 1983; Bishara *et al.*, 1997; Bondevik, 1998, 2007). Orthodontists need to differentiate post-treatment changes attributed to dental instability from those due to growth and ageing. Therefore, understanding of the physiological dental tissue alterations is important because of its influence on the occlusion after the end of orthodontic treatment and retention. Comparison of the study group with an untreated sample with the same malocclusion would have given useful information to differentiate these incidents. However, adults with an untreated Class II division 1 malocclusion are almost impossible to find. Besides these obvious limitations, it has to be emphasized that the main goal of this investigation was the long-term stability of combined activator and headgear treatment and not the effectiveness of the appliance versus growth. The only study that evaluated long-term changes of untreated adult patients with Class II division 1 malocclusion was published by Feldmann *et al.* (1999). Comparison of the skeletal changes with that investigation was not possible as no cephalograms were taken. Despite improvement of the sagittal and vertical occlusal variables from adolescence to adulthood, all individuals still presented features characteristic of Class II division 1 deep overbite patients. These findings are in contrast with the occlusal characteristics demonstrated in the present patient group, as all of them maintained the Class I sagittal and vertical occlusal traits. However, most of the untreated individuals developed mild dental crowding in both jaws (Feldmann *et al.*, 1999), which corresponds to the present findings and supports the natural developmental concept rather than instability or relapse.

Conclusions

The selected patient group treated with only a headgear–activator appliance and following a carefully planned retention protocol showed improved skeletal and dental conditions which remained stable 10–15 years post-retention. The post-retention changes in occlusion and dental alignment are in accordance with previously reported changes due to ageing in untreated patients. Nevertheless, taking into account the limitations deriving from the fact that no control group of untreated Class II adults was available, these results have to be interpreted with caution. Further research is needed to differentiate between changes due to natural ageing and those due to relapse after orthodontic treatment.

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