European Journal of Orthodontics 23 (2001) 393–402
© 2001 European Orthodontic Society

The effect of zigzag elastics in the treatment of Class II division 1 malocclusion subjects with hypo- and hyperdivergent growth patterns. A pilot study

Aynur Aras, Alev Çinsar and Hakan Bulut
Department of Orthodontics, University of Ege, Turkey

SUMMARY The aim of this study was to investigate the effect of zigzag elastics in the treatment of Class II division 1 malocclusion subjects with hypo- or hyperdivergent growth patterns. Two groups were established, each consisting of 10 subjects classified as hypo- or hyperdivergent according to their pre-treatment SN–GoGn angle. The cephalometric radiographs taken before and after an elastic application period of approximately 4 months were used to generate 22 variables.

In both groups, there were no statistically significant differences in the vertical position of the lower molars, the SN–GoGn angle or the inclination of the lower incisors, whereas the sagittal skeletal relationship was improved as a result of an increase in the SNB angle and the mandibular length ($P < 0.01$). Upper incisor extrusion was statistically significant in both groups ($P < 0.05$). The downward rotation of the occlusal plane and the increase in overbite were found to be significant in the hypodivergent group ($P < 0.05$). Significant differences were observed between the groups in the extrusion of the upper incisor, the inclination of the occlusal plane, and the amount of overbite ($P < 0.05$). The results show that the zigzag elastic system is preferable, especially in hyperdivergent Class II division 1 subjects, as the use of such elastics does not cause an unfavourable effect on vertical jaw base relationship.

Introduction

In the treatment of Class II division 1 malocclusions, Class II elastics are used to correct the anteroposterior relationship of the dentition. Traditional Class II elastics stretching from a hook on the maxillary canine to the mandibular first molar not only exert a force sagittally, but also result in an extrusive effect on the attachment points. Such extrusive effects of Class II elastics on the upper central incisors in hypodivergent Class II division 1 patients and on the lower molars in hyperdivergent subjects are undesirable. Therefore, bite opening bends in the archwire mesial to the upper molar tubes or upper arches with increased curves of Spee has been a standard procedure to eliminate or minimize the vertical force components on anterior attachment points, especially in hypodivergent subjects. On the other hand, to enhance the anchorage of the mandibular molar teeth, Tweed (1966) placed tip-back bends in the mandibular arch. The bioprogressive technique also advocated torquing the roots of the mandibular first molar teeth into the more dense buccal cortical bone (Ricketts, 1979; Ricketts *et al.*, 1979).

It has been reported that attachment of Class II elastics to the lower second molars created a more horizontal vector of force (Thurow, 1970). To obtain this goal, Alexander (1986) suggested attaching the elastics from the distal wing of the upper lateral incisors to the lower second molars. In hyperdivergent subjects, Pearson (1997) recommended avoidance of elastic application to the lower second molars. He stated that if elastic engagement is absolutely necessary, short Class II elastics could be attached from the upper first molar to a Class II hook and then to the distal of the lower premolar (Figure 1). Likewise, Schudy (1992) applied the elastics from the upper first molar to the mesial of the upper canine, but ending at the distal of the lower canine.

In hypodivergent patients, Hocevar (1982a,b) used inter-maxillary 'check elastics', having one end over the posterior end of the maxillary arch wire, both strands under the end of the mandibular arch wire, and the other end up to the maxillary anterior teeth to reinforce bite opening bends, and extrude upper and lower molars. Philippe (1995) designed a system by which a vertical force was applied to the maxillary molars, rather than the incisors. In that system, Class II elastics were stretched from hooks placed on the anterior segment of an auxilliary archwire that extended between the maxillary first molars along the gingiva beneath the upper lip to the lower molars (Figure 2a). The same author employed elastics that were parallel to the occlusal plane and extended from the lower molar teeth to the hooks of an auxiliary archwire that bent downward in front of the upper molar tubes and ran along the mandibular arch, in hyperdivergent cases (Figure 2b).

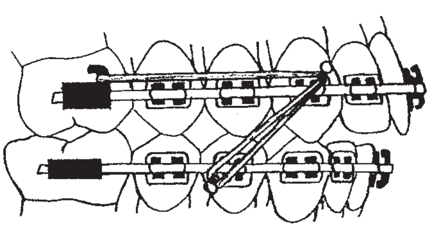


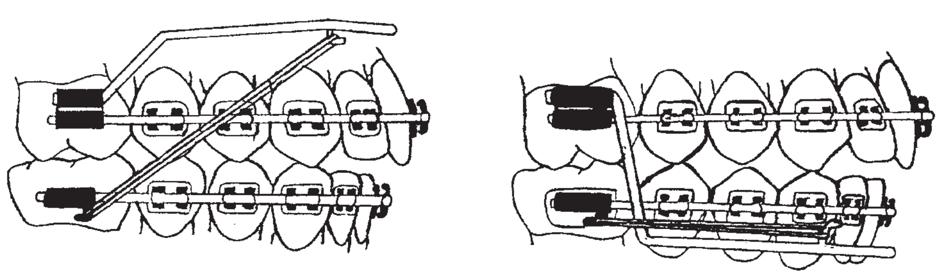
Figure 1 Diagrammatic illustration of elastic application according to Pearson.

Roth (1985) reported that one, two, or three short Class II elastics on each side may be applied from the mesial aspect of the lower first molar to the mesial of the upper second premolar, from the distal of the lower second premolar to the mesial of the upper first premolar, and from the distal of the lower first premolar to the upper canine. Thus, the anteroposterior relationship could be corrected without extrusion of the molars, or alteration of the inclination of the lower incisors or occlusal plane (Figure 3). Unfortunately, no statistical analysis studying the effectiveness of the above described methods of elastic attachment with regard to the vertical growth pattern in reducing the vertical side-effects of traditional Class II elastics, has previously been performed.

The aim of the present study, therefore, was to investigate the sagittal and vertical effects of zigzag elastics, a modified version of Roth's short Class II elastics, in the treatment of hypo- and hyperdivergent Class II division 1 subjects.

Subjects and methods

Twenty patients who exhibited skeletal and dental Class II division 1 malocclusions with either a hypo- or hyperdivergent growth patterns and treated to Class I molar relationship were included in this prospective study. These patients were divided into two groups of 10 subjects, with each group consisting of patients with hypo- and hyperdivergent growth patterns, established



a b

Figure 2 Diagrammatic illustration of elastic application in hypodivergent (a) and hyperdivergent patients (b) according to Philippe (1998).

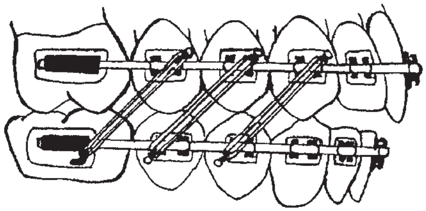


Figure 3 Diagrammatic illustration of elastic application according to Roth (1985).

according to their pre-treatment SN–GoGn angle (<26 degrees hypodivergent, >38 degrees hyperdivergent). The mean SN–GoGn angle was 24.1 degrees (SD = 1.03 degrees) for the hypodivergent group and 42.3 degrees (SD = 1.58 degrees) for the hyperdivergent group. In the hyperdivergent group, subjects were not included if the overbite was increased (<3 mm); half of the subjects had an anterior open bite. The other criterion for selection was non-extraction fixed appliance treatment. The ages of patients were approximately the same in each group. The mean chronological age was 12.75 years (SD = 1.18) for the hypodivergent group and 13.32 years (SD = 1.23) for the hyperdivergent group. The sex distribution of the patients for the hypodivergent group was five boys and five girls, and for the hyperdivergent group six boys and four girls. According to hand–wrist radiographs taken before elastic application, the subjects were in the developmental stages between epiphysial capping of the middle phalanx of the third finger and the epiphysial union of the proximal phalanx of the third finger (Grave and Brown, 1979). The groups were also similar with regard to the amount of overjet prior to elastic application (Table 1).

Table 1 Cephalometric records before and after elastic application.

Variables	Hypodivergent group				Hyperdivergent group			
	Before		After		Before		After	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Angular measurements								
SN–GoGn	25.35	1.33	25.60	1.22	41.95	2.39	42.30	2.03
SNA	80.25	2.51	80.15	2.48	79.60	3.18	79.45	3.49
SNB	73.50	2.04	75.95	2.25	73.80	2.51	75.90	2.06
ANB	6.65	1.76	4.30	1.53	5.80	1.49	3.55	1.25
Occ/SN	17.70	3.13	18.30	2.94	13.05	3.58	13.40	3.99
U1/PalP	113.00	3.54	100.75	2.91	112.80	2.83	101.80	2.09
U6/PalP	75.05	4.89	76.15	5.15	80.30	4.61	81.25	4.97
L1/ManP	89.10	3.08	90.30	2.77	95.30	2.40	96.10	2.59
L6/ManP	93.80	4.86	92.75	4.58	89.10	3.09	88.25	3.02
Linear measurements								
Ar–Gn	116.85	5.21	118.85	4.94	112.65	7.38	114.50	7.12
Vertical linear								
U1–PalP	30.90	3.13	32.05	3.14	29.80	2.81	30.30	2.62
U6–PalP	13.45	2.70	13.30	2.72	12.70	3.71	12.50	3.46
L1–ManP	38.00	2.79	38.60	2.98	43.20	1.40	43.50	1.96
L6–ManP	27.00	3.40	27.30	3.54	32.10	2.64	32.45	2.36
Overbite	1.20	0.67	2.05	0.53	1.85	0.47	2.20	0.44
Horizontal linear								
U1 crown–*Y* axis	71.50	6.31	71.35	6.19	69.90	5.87	69.70	5.76
U1 root–*Y* axis	66.20	5.53	66.75	5.14	65.05	5.12	65.30	5.05
U6–*Y* axis	20.65	2.30	20.50	2.79	19.50	1.99	19.30	1.81
L1 crown–S axis	9.65	2.85	9.75	3.08	5.40	2.26	5.55	2.31
L1 root–S axis	7.75	3.57	7.70	3.91	3.95	2.43	4.05	2.62
L6–S axis	29.55	3.41	28.40	3.26	32.20	2.23	31.20	2.05
Overjet	6.40	1.51	2.30	0.48	5.60	1.34	2.20	0.42

Pre-angulated and pretorqued 0.018-inch edgewise appliances 'Master Series-Roth system' (American Orthodontics, Sheboygan, W I, USA) were used in all patients. All were treated by the first and third authors. In levelling and aligning, the archwire sequence was 0.014-, 0.016-, and 0.016 × 0.022-inch rectangular nickel titanium wire. Before applying zigzag elastics, the correction of the deep bite in the hypodivergent patients was accomplished by 0.016 × 0.022-inch upper accentuated curve nickel titanium archwire only, or 0.016 × 0.022-inch upper accentuated curve and lower reverse curve nickel titanium archwires, together with cervical headgear. Very light Class III elastics were also employed, together with the cervical headgear to help control lower anterior tipping, if necessary. The open bite closure in the hyperdivergent patients was achieved by 0.016 × 0.022-inch stainless steel, step down maxillary arches, and high pull headgear avoiding inter-maxillary elastics.

During the last stage of treatment, zigzag elastics were applied together with 0.018 × 0.022-inch rectangular stainless steel archwires, without the use of extra-oral forces. Heavy 5/16-inch, 6 oz elastics were stretched from the mesial of the lower first molar to the mesial of the upper second premolar, then to the distal of the lower second premolar, up to the mesial of the upper first premolar, going down to the distal of the lower first premolar and ending on the mesial of the upper canine teeth (Figure 4). In the zigzag system, the force of the oblique elastic segments was approximately 200 g. The vertical elastic segments also possessed the same level of force. On premolar application points, a vertical component of the oblique elastic force was added to the force of the vertical elastic segment. Therefore, the approximate force level of the system at this point was 350 g. The patients were instructed to change the elastics, which fixed the mandible in a Class I molar relationship daily. Elastics were used until a stable Class I molar relationship was established. The elastic application time varied between a minimum of 2.5 months and a maximum of 7 months. The mean full-time elastic use was 3.89 months (SD = 1.07) for the hypodivergent group and for 4.18 months (SD = 1.32) for the hyperdivergent group.

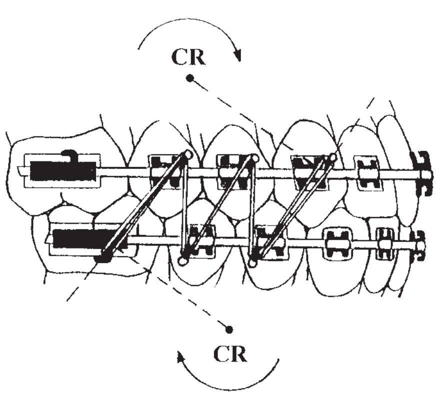


Figure 4 Diagrammatic illustration of zigzag elastic application and moments to the centres of resistance of the dentitions.

Cephalometric measurements

The cephalometric radiographs taken immediately before and after elastic application were traced and 23 landmarks were identified (Figure 5). Nine angular and 13 linear measurements were made to the nearest 0.5 mm and 0.5 degree on these radiographs (Figures 6 and 7). The horizontal linear measurements of the upper molars and incisors were determined according to the *Y* axis formed by dropping a line from the sella perpendicular to the SN line. The horizontal positional changes of the mandibular first molar, both linear and angular, were determined as described by Osborn *et al*. (1991). The anterior-superior angle formed by a line passing through the mesial cusp tip and the mesial root tip of the mandibular first molar, and intersecting with the mandibular plane, was used for measurement of the changes in angulation of these teeth. The horizontal linear movements of the mandibular first molars were measured between the two bisection points on the mandibular plane. These two bisection points were determined as follows: the most distal point on the distal surface of the first molar and the most posterior point on the mandibular symphysis formed the two reference points for the lines which intersected the mandibular plane at right angles. The points where these two lines met the mandibular plane formed the two bisection points. The anterior

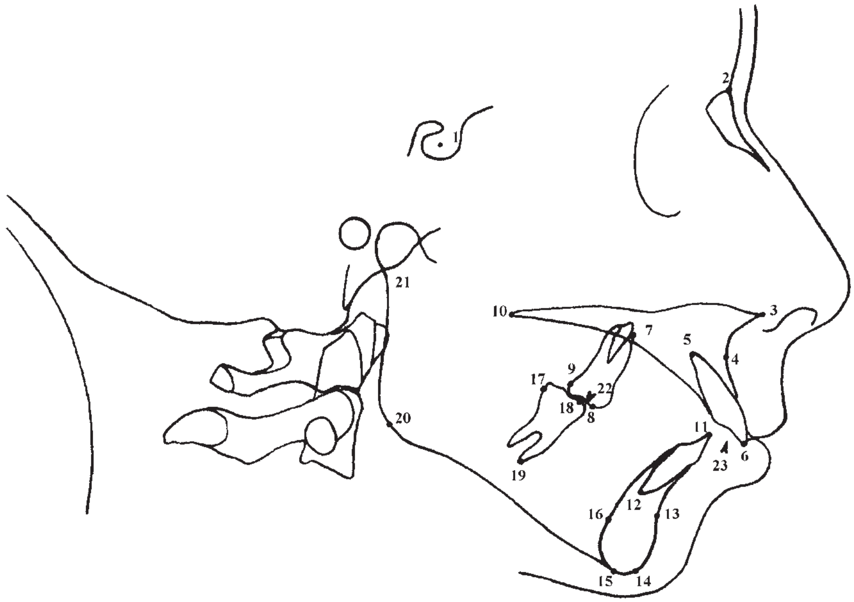


Figure 5 Landmarks used in the cephalometric analysis. (1) Sella; (2) nasion; (3) anterior nasal spine; (4) point A; (5) root apex of the maxillary central incisor; (6) tip of the crown of the maxillary central incisor; (7) mesial buccal root apex of the maxillary first molar; (8) tip of mesial buccal cusp of the maxillary first molar; (9) greatest distal contour of maxillary first molar; (10) posterior nasal spine; (11) tip of the crown of the mandibular central incisor; (12) root apex of the mandibular central incisor; (13) point B; (14) gnathion; (15) menton; (16) most posterior point on the mandibular symphysis; (17) greatest distal contour of mandibular first molar; (18) tip of mesial buccal cusp of the mandibular first molar; (19) mesial buccal root apex of the mandibular first molar; (20) gonion; (21) articulare; (22) midpoint of the line connecting 8 and 18; (23) midpoint of the line connecting 6 and 11.

line passing through the symphysis was termed as 'S axis' and the horizontal linear changes of the lower incisors were measured relative to the 'S axis' (Figure 7).

Statistical methods

For the different variables, the arithmetic mean and standard deviation (SD) were calculated. Since the number of patients was small, non-parametric statistical tests were applied. The Wilcoxon's test was used to evaluate the treatment changes within each group. To compare the changes observed in both groups, a Mann–Whitney *U*-test was performed.

For assessment of the combined method error in locating and measuring the changes of the different landmarks, 10 randomly selected cephalograms were retraced. The following formula was used for the method error calculation: $\sqrt{\Sigma d^2/2n}$, where d is the difference between two measurements of a pair and n is the number of double measurements. The method error did not exceed 0.35 mm and 0.76 degree for any of the variables investigated. It is known that the Dahlberg's method does not take into account the size of the error in relation to the magnitude of the variable itself. However, the errors of the magnitude in this study are regarded to be relatively low (Battagel, 1993).

Results

The cephalometric measurements in both groups before and after elastic application are shown in Table 1. The cephalometric changes and their

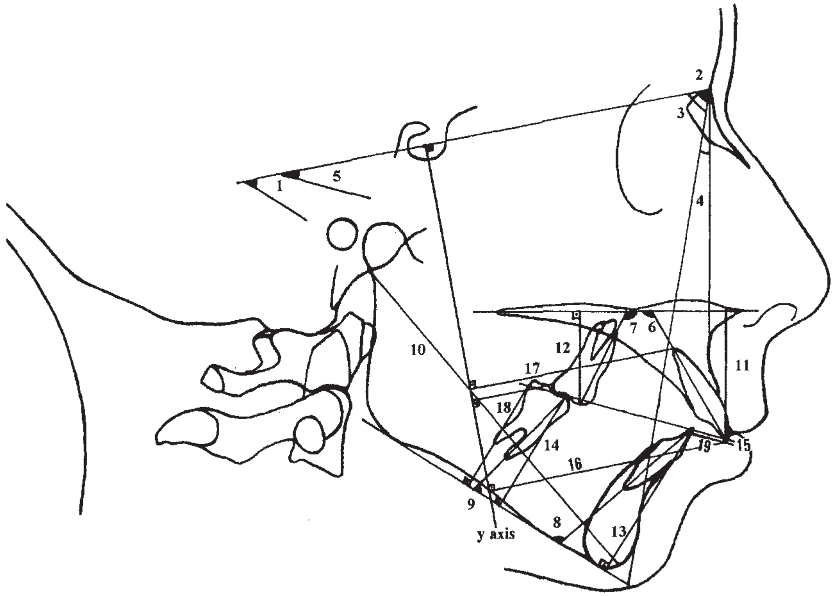


Figure 6 Angular cephalometric measurements: (1) SN–GoGn angle; (2) SNA angle; (3) SNB angle; (4) ANB angle; (5) occlusal plane to SN plane; (6) maxillary central incisor to palatal plane; (7) maxillary first molar to palatal plane; (8) mandibular central incisor to mandibular plane; (9) mandibular first molar to mandibular plane. Linear measurements: (10) mandibular length; (11) distance of maxillary central incisor to palatal plane; (12) distance of maxillary first molar to palatal plane; (13) distance of mandibular central incisor to mandibular plane; (14) distance of mandibular first molar to mandibular plane; (15) overbite; (16) distance of crown of maxillary central incisor to *Y* axis; (17) distance of root of maxillary central incisor to *Y* axis; (18) distance of maxillary first molar to *Y* axis; (19) overjet.

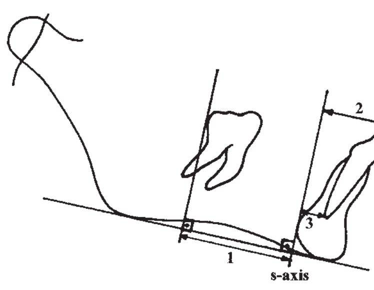


Figure 7 Linear horizontal measurements of mandibular first molar and incisors: (1) distance of mandibular first molar to S axis; (2) distance of crown of mandibular central incisor to S axis; (3) distance of root of mandibular central incisor to S axis.

significance within each group, and the inter-group differences for the changes are presented in Table 2.

In both groups, the vertical positions of the upper and lower molars and SN–GoGn angles were not statistically different, whereas upper incisor extrusion was statistically significant. There were no significant differences in the angulation, and horizontal distance of the upper and lower molars. In the hypodivergent group, the downward rotation of the occlusal plane and the increase in overbite were found to be statistically significant. Significant differences were observed between the groups in the extrusion of the upper incisor, the inclination of the occlusal plane, and the amount of overbite.

In both groups, the increase in SNB angle, the mandibular length, and the decrease in ANB angle, and accordingly the decrease in overjet were statistically significant, while no significant group differences were observed in these measurements.

Table 2 The mean changes within each group and comparisons between the groups.

Variables	Hypodivergent group			Hyperdivergent group			Group difference
	Mean change	SD	Wilcoxon test	Mean change	SD	Wilcoxon test	Mann–Whitney *U*-test
Angular measurements							
SN–GoGn	0.25	0.69	NS	0.35	0.66	NS	NS
SNA	–0.10	0.24	NS	–0.15	0.39	NS	NS
SNB	2.45	0.48	$P < 0.01$	2.10	0.85	$P < 0.01$	NS
ANB	–2.55	0.55	$P < 0.01$	–2.25	0.69	$P < 0.01$	NS
Occ/SN	0.60	0.68	$P < 0.05$	0.35	0.47	NS	$P < 0.05$
U1/PalP	–2.25	2.66	NS	–1.00	1.56	NS	NS
U6/PalP	1.10	2.02	NS	0.95	2.41	NS	NS
L1/ManP	1.20	1.81	NS	0.80	1.29	NS	NS
L6/ManP	–1.05	0.98	NS	–0.85	0.83	NS	NS
Linear measurements							
Ar–Gn	2.00	0.94	$P < 0.01$	1.85	1.05	$P < 0.01$	NS
Vertical linear							
U1–PalP	1.15	0.75	$P < 0.05$	0.50	0.47	$P < 0.05$	$P < 0.05$
U6–PalP	–0.15	0.24	NS	–0.20	0.32	NS	NS
L1–ManP	0.60	0.94	NS	0.30	1.83	NS	NS
L6–ManP	0.30	0.26	NS	0.35	0.31	NS	NS
Overbite	0.85	0.46	$P < 0.05$	0.35	0.41	NS	$P < 0.05$
Horizontal linear							
U1 crown–*Y* axis	–0.15	0.23	NS	–0.20	0.64	NS	NS
U1 root–*Y* axis	0.55	1.28	NS	0.25	1.07	NS	NS
U6–*Y* axis	–0.15	0.32	NS	–0.20	0.21	NS	NS
L1 crown–S axis	0.10	0.80	NS	0.15	0.61	NS	NS
L1 root–S axis	–0.05	0.51	NS	–0.10	0.79	NS	NS
L6–S axis	–1.15	1.20	NS	–1.00	0.96	NS	NS
Overjet	–4.10	1.73	$P < 0.01$	–3.40	1.26	$P < 0.01$	NS

Discussion

The zigzag elastic system did not cause significant extrusion of the mandibular molars or downward rotation of the mandible in either group. This observation is in agreement with the hypothesized mechanism for short Class II elastics by Roth (1985) who claimed that, even though short elastics give the impression of applying vertical force, they act almost like inter-maxillary fixation and, therefore, there is no vertical elevation effect on the mandibular molar teeth. The inter-maxillary fixation should be as strong as possible in order to achieve maximal intercuspation of the teeth, which is important in eliminating extrusive forces and moments resulting from elastics. In the current study to create stronger inter-maxillary fixation, instead of using individual multiple short Class II elastics, a single long zigzag elastic was applied to the same teeth.

The moments generated by the zigzag elastic system at the centre of the maxillary and mandibular arches are clockwise. The effect of the clockwise moments increase, moving anteriorly from the centre of resistance of the maxillary arch and posteriorly from the centre of resistance of the mandibular arch due to the increase in the distance from the centre of resistance to the line of force (the oblique elastic segments). These moments and vertical force components of elastics tend to extrude the lower molars and upper incisors (Figure 4).

The current study showed that a rigid upper arch and strong inter-maxillary fixation counteracted the extrusive tendency of the lower molars, but the fixation produced was not able to prevent extrusion of the upper incisors. This was probably due to the number of occlusal contacts in maximal intercuspation; that is, canine teeth have less occlusal contacts than molar and premolar teeth. When the hypodivergent group was compared with the hyperdivergent group, a significant difference existed between groups in extrusion of the upper incisors. It appears from these results that the maximal intercuspation of the teeth negates a considerable amount of the forces and moments that create the tendency for extrusion of the upper incisors; also the remaining moments that cause this extrusion are weak. Even though this was statistically significant, the minimal extrusion of the upper incisors in the hyperdivergent group supports this. Furthermore, in interpreting these results, the tendency to relapse of the upper incisors must be taken into account. Thus, the difference in extrusion of the upper incisors could be as a result of the following: i.e. weak extrusive moments and forces encourage a relapse tendency of the intruded maxillary incisors which occurred in the earlier stages of orthodontic treatment in the hypodivergent group.

The vertical force vectors of traditional Class II elastics extrude the upper incisors and the lower molar teeth, and lead to a downward rotation of the occlusal plane (Bien, 1951; Tovstein, 1955; Kanter, 1956; Zingeser, 1964; Tweed, 1966; Stoner and Lindquist, 1969; Thurow, 1970; Salzman, 1974; Ülgen, 1983; Proffit and Fields, 1986; Ellen *et al*., 1998). In addition, the horizontal force vectors cause retroclination of the maxillary anterior teeth, proclination of the mandibular anterior teeth, and displacement of the entire lower dental arch anteriorly (Bien, 1951; Kanter, 1956; Tweed, 1966; Thurow, 1970; Venezia, 1973; Salzman, 1974; Meikle, 1980; Dermaut and Beerden, 1981; Proffit and Fields, 1986; Yamaguchi and Nanda, 1991; Marsan, 1995; Ellen *et al*., 1998).

In the hypodivergent group, extrusion of the upper incisors resulted in a downward rotation of the occlusal plane and an increase in overbite. When the two groups were compared, the differences between the groups in the inclination of the occlusal plane and the increase in overbite were statistically significant. However, it should be borne in mind that all the side-effects found in the present study were less than those reported following the use of traditional Class II elastics (Ellen *et al*., 1998).

Theoretically, the horizontal force components were produced at each tooth to which the zigzag elastics were applied, and the clockwise moments tended to tip the upper teeth backward and the lower teeth forward.

It has been reported that if Class II elastics are used during the maximum growth and development period, then mandibular growth may be stimulated (McNamara, 1980; Edwards, 1983; Vallie, 1988). The present study demonstrated that a short-term application (approximately 4 months) of zigzag elastics resulted in an increased mandibular length and SNB angle, and accordingly an improved sagittal relationship between the apical bases (a reduced ANB angle) and a reduced overjet. The changes in these parameters were not found to be related to the pattern of vertical development.

With magnetic resonance imaging, after 6–12 weeks of Herbst treatment that fixes the mandible in an anterior position, condylar and glenoid fossa remodelling have been demonstrated (Ruf and Pancherz, 1998, 1999). Since zigzag elastics also secure the mandible into a Class I relationship, condylar growth can be stimulated and the glenoid fossa can be remodelled, which supports the orthopaedic results of zigzag elastics. However, rapid correction of a Class II division 1 malocclusion should be accompanied by a retention period that includes continued part-time use of elastics or a tooth positioner in order to permit continued neuromuscular adaptation that will lead to long-term stability.

Conclusions

The conclusions of this study can be summarized as follows:

1. The zigzag elastics that were used in the last stage of fixed appliance treatment of Class II malocclusions in growing patients were effective in the correction of the molar relationship, establishing a good intercuspation, as well as improving sagittal skeletal relationship.

2. A significant extrusive effect on lower molar teeth was not observed.
3. In both groups, the vertical position of the upper incisors showed a statistically significant increase, but this was greater in the hypodivergent group.
4. As there was no unfavourable effect on the vertical jaw base relationship, the zigzag elastic system is preferable especially in hyperdivergent subjects.

Acknowledgement

We wish to thank Professor Dr Yahya Tosun, for his help with this article.

Address for correspondence

Dr Aynur Aras
Ege University
Faculty of Dentistry
Department of Orthodontics
Bornova 35100
Izmir
Turkey

References

Alexander R G 1986 The Alexander discipline. Contemporary concepts and philosophies. Ormco Corporation, Glendora, California

Battagel J M 1993 A comparative assessment of cephalometric errors. European Journal of Orthodontics 15: 305–314

Bien S M 1951 Analysis of the components of force used to effect the distal movement of teeth. American Journal of Orthodontics 37: 514–520

Dermaut L R, Beerden L 1981 The effects of Class II elastic force on a dry skull measured by holographic interferometry. American Journal of Orthodontics 79: 296–304

Edwards J G 1983 Orthopedic effects with 'conventional fixed orthodontic appliances': a preliminary report. American Journal of Orthodontics 84: 275–291

Ellen E K, Schneider B J, Sellke T 1998 A comparative study of anchorage in Bioprogressive versus standard edgewise treatment in Class II correction with intermaxillary elastic force. American Journal of Orthodontics and Dentofacial Orthopedics 113: 430–436

Grave K C, Brown T 1979 Carpal radiographs in orthodontic treatment. American Journal of Orthodontics 75: 27–45

Hocevar R A 1982a Orthodontic force systems: technical refinements for increased efficiency. American Journal of Orthodontics 81: 1–11

Hocevar R A 1982b Orthodontic force systems: individualized treatment with open-minded 'Begg' technique. American Journal of Orthodontics 81: 277–291

Kanter F 1956 Mandibular anchorage and extra-oral force. American Journal of Orthodontics 42: 194–208

Marsan (Leblebicioğlu) G 1995 Angle Sınıf II, Bölüm1 ortodontik düzensizliklerin edgewise tedavi tekniği ile çekimsiz tedavisinde Sınıf II intermaksiller elastiklerin etkilerinin sefalometrik olarak incelenmesi. Doktora Tezi, İstanbul Üniversitesi, Turkey

McNamara J A Jr 1980 Functional determinants of craniofacial size and shape. European Journal of Orthodontics 2: 131–159

Meikle M C 1980 The dentomaxillary complex and overjet correction in Class II division 1 malocclusion: objectives of skeletal and alveolar remodeling. American Journal of Orthodontics 77: 184–197

Osborn W S, Nanda R S, Currier G F 1991 Mandibular arch perimeter changes with lip bumper treatment. American Journal of Orthodontics and Dentofacial Orthopedics 99: 527–532

Pearson L E 1997 Treatment of Class II backward rotating malocclusions. In: Nanda R (ed.), Biomechanics in clinical orthodontics. W B Saunders Company, Philadelphia, p. 288

Philippe J 1995 Mechanical analysis of Class II elastics. Journal of Clinical Orthodontics 29: 367–372

Proffit W R, Fields H W 1986 Contemporary orthodontics. C V Mosby Company, St Louis

Ricketts R M 1979 Features of the Bioprogressive therapy. Rocky Mountain Orthodontics, Denver

Ricketts R M, Bench R, Gugino C, Hilgers J, Schulhof R 1979 Bioprogressive therapy. Rocky Mountain Orthodontics, Denver

Roth R H 1985 Treatment mechanics for the straightwire appliance. In: Graber T M, Swain B F (eds) Orthodontics, current principles and techniques. C V Mosby Company, St Louis

Ruf S, Pancherz H 1998 Temporomandibular joint growth adaptation in Herbst treatment: a prospective magnetic resonance imaging and cephalometric radiographic study. European Journal of Orthodontics 20: 375–388

Ruf S, Pancherz H 1999 Temporomandibular joint remodeling in adolescents and young adults during Herbst treatment: a prospective longitudinal magnetic resonance imaging and cephalometric radiographic investigation. American Journal of Orthodontics and Dentofacial Orthopedics 115: 607–618

Salzman J A 1974 Orthodontics in daily practice. J B Lippincott Company, Philadelphia

Schudy F F 1992 JCO interviews on the vertical dimension. Journal of Clinical Orthodontics 26: 463–472

Stoner M M, Lindquist J T 1969 The edgewise appliance today. In: Graber T M (ed.), Current orthodontic concepts and techniques. W B Saunders Company, Philadelphia

Thurow R C 1970 An atlas of orthodontics principles. C V Mosby Company, St Louis

Tovstein B C 1955 Behavior of the occlusal plane and related structures in treatment of Class II malocclusions. Angle Orthodontist 25: 189–198

Tweed C 1966 Clinical orthodontics. C V Mosby Company, St Louis

Ülgen M 1983 Ortodontik tedavi prensipleri. Ankara Üniversitesi, Turkey

Vallie F W 1988 Crossroads: acceptance or rejection of functional jaw orthopedics. Letters to the editor. American Journal of Orthodontics and Dentofacial Orthopedics 94: 170–172

Venezia A J 1973 Pure Begg and edgewise arch treatments: comparison of results. American Journal of Orthodontics 43: 289–300

Yamaguchi K, Nanda R S 1991 The effects of extraction and nonextraction treatment on the mandibular position. American Journal of Orthodontics and Dentofacial Orthopedics 100: 443–452

Zingeser M 1964 Vertical response to Class II division 1 therapy. Angle Orthodontist 34: 58–64