

Class II Non-Extraction Patients Treated with the Forsus Fatigue Resistant Device Versus Intermaxillary Elastics

Graham Jones^a; Peter H. Buschang^b; Ki Beom Kim^c; Donald R. Oliver^d

ABSTRACT

Objective: To evaluate the Forsus Fatigue Resistant Device (FRD) as a compliance-free alternative to Class II elastics.

Materials and Methods: A sample of 34 (14 female, 20 male) consecutively treated nonextraction FRD patients (12.6 years of age) were matched with a sample of 34 (14 female, 20 male) consecutively treated nonextraction Class II elastics patients (12.2 years of age) based on four pretreatment variables (ANB, L1-GoMe, SN-GoMe, and treatment duration). Pretreatment and post-treatment cephalometric radiographs were traced and analyzed using the pitchfork analysis and a vertical cephalometric analysis. *t*-Tests were used to evaluate group differences. Group differences were evaluated using *t*-tests.

Results: No statistically significant differences were found in the treatment changes between the groups. There was a general trend for mesial movement of the maxilla, mandible, and dentition during treatment for both groups. The mandibular skeletal advancement and dental movements were greater than those in the maxilla, which accounted for the Class II correction. Lower incisor proclination was evident in both groups. Vertically, the maxillary and mandibular molars erupted during treatment in both groups, while lower incisors proclined. With the exception of lower molar mesial movements and total molar correction, which were significantly ($P < .05$) greater in the Forsus group, there were no statistically significant group differences in the treatment changes.

Conclusions: The Forsus FRD is an acceptable substitute for Class II elastics for noncompliant patients.

KEY WORDS: Cephalometrics; Forsus; Intermaxillary elastics; Pitchfork analysis; Treatment outcomes

INTRODUCTION

Class II malocclusion presents a major and common challenge to orthodontists. Based on overjet greater than 4 mm, the National Health and Nutrition Examination Survey (NHANES III) data indicate an 11% prevalence of Class II malocclusion in the US popu-

lation.¹ Numerous orthodontic techniques and appliances have been introduced to treat Class II malocclusions, including intra-arch and interarch appliances, extra-oral appliances, selective extraction patterns, and surgical repositioning of the jaws.

Intermaxillary elastics are a typical interarch method used for Class II correction. The effects of Class II elastics include mesial movements of the mandibular molars, movements and tipping of the mandibular incisors, distal movements and tipping of the maxillary incisors, extrusion of the mandibular molars and maxillary incisors, and clockwise rotation of the mandibular and the occlusal planes.²⁻⁷ However, intermaxillary elastics rely heavily on patient compliance for their effectiveness, and compliance in orthodontics is variable and difficult to predict.⁸ Poor cooperation can lead to poor treatment results and increased treatment time.^{9,10}

A number of compliance-free interarch appliances have been developed. Fixed interarch appliances typ-

^a Private Practice, Monroe, Wash.

^b Professor, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex.

^c Assistant Professor, Department of Orthodontics, Saint Louis University, St. Louis, Mo.

^d Assistant Professor, Department of Orthodontics, Saint Louis University, St. Louis, Mo.

Corresponding author: Dr Peter Buschang, Baylor College of Dentistry, Department of Orthodontics, 3302 Gaston Ave, Dallas, TX 75246

(e-mail: phbuschang@bcd.tamhsc.edu)

Accepted: May 2007. Submitted: March 2007.

© 2008 by The EH Angle Education and Research Foundation, Inc.

ically demonstrate mesial movement of the mandibular molars, tipping of the mandibular incisors, and variable effects associated with mandibular growth.^{11–20} Only one study has compared the effects of Class II correction obtained with elastics and fixed interarch (Herbst) appliances.⁴ While molar corrections were similar, anterior lower facial height and the mandibular plane angle increased more in the elastics group than in the Herbst group. The skeletal improvement was 10% in the elastics group, compared with 66% in the Herbst group.

More studies are needed comparing the effects of Class II elastics with the effects of compliance-free appliances, which may be necessary to achieve successful treatment. The skeletal and dental changes produced by interarch appliances may be substantially different from those produced with Class II elastics. Potential differences between appliance systems must be identified and understood, so that an appropriate decision can be made when deciding on treatment alternatives.

The present study was designed to evaluate the effects of the Forsus Fatigue Resistant Device (FRD) (3M Unitek Corp, Monrovia, Calif). The FRD is a three-piece, semirigid telescoping system incorporating a superelastic nickel-titanium coil spring that can be assembled chair-side in a relatively short amount of time. It is compatible with complete fixed orthodontic appliances and can be incorporated into preexisting appliances. The FRD attaches at the maxillary first molar and onto the mandibular archwire, distal to either the canine or first premolar bracket. As the coil is compressed, opposing forces are transmitted to the sites of attachment. Our purpose was to determine the skeletal and dental effects produced during Class II correction with the Forsus FRD and to compare these effects with those produced during Class II correction with elastics.

MATERIALS AND METHODS

Sample

A pretreatment sample (T1) of 98 consecutively treated patients (41 Forsus FRD and 57 Class II elastics) was selected from the offices of two private practice orthodontists (74 records from practice A and 24 records from practice B). The criteria for patient selection were:

- Pretreatment occlusion of at least end-on Class II malocclusion;
- Treatment completed without any permanent teeth extracted (excluding third molars);
- Class I posttreatment occlusion;
- Starting age between of 9.0 years and 17.0 years;

Table 1. Sizes and Average Ages at the Start of Treatment of the Forsus and Elastics Groups

Group	Male Patients, N	Female Patients, N	Average Start Age, Years
Class II elastics	20	14	12.2
Forsus	20	14	12.6

— Good quality pretreatment and posttreatment cephalometric radiographs.

Patients were rejected if any appliances other than Forsus FRD or Class II elastics (prescribed to be worn full-time, ie, 24 hours/day) were used to correct the Class II malocclusion. Class II elastics were chosen as the comparison group because interarch elastics represent a typical compliance-reliant method of Class II correction.

Most previous reports of fixed interarch appliances measured changes at the time of appliance removal, rather than at the end of comprehensive treatment. The present study was designed to measure and describe the posttreatment differences. Except for the method of Class II correction employed, the treatments of both groups were similar, consisting of full, fixed orthodontic appliances. By limiting the sample to two practitioners performing both treatments, variation in treatment technique was minimized. Class II elastics were initially prescribed in the treatment of the patients in the Forsus sample and may have been worn after Forsus removal in order to maintain the occlusal relationship. As such, the patients in the Forsus sample should be considered Forsus FRD/Class II elastics patients.

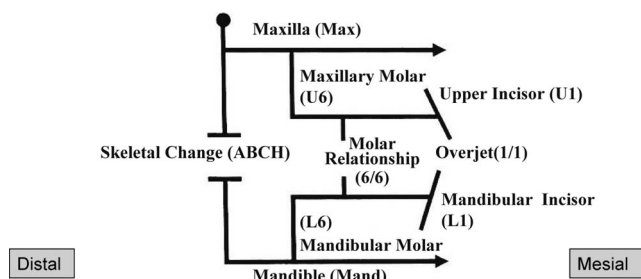
A dispersion analysis based on ANB, L1-GoMe, and SN-GoMe angles, as well as treatment duration, was performed in order to ensure comparability across samples. Outlying subjects were removed to match the samples based on starting skeletal relationships. The final sample consisted of 34 subjects per group (Table 1). The posttreatment (T2) records were processed after the outlying subjects had been removed.

Data Collection

The pretreatment and posttreatment cephalometric radiographs were hand-traced on acetate paper, and 15 landmarks were identified (Table 2). In order to describe the sagittal treatment changes that occurred, the radiographs were analyzed using the pitchfork analysis (PFA).²¹ The PFA accounts for and summarizes sagittal mandibular and maxillary molar movements, sagittal maxillary and mandibular advancement relative to the cranial base, and the combination of all of these movements in correcting the molar relationship (Figure 1). Distal maxillary skeletal and dental

Table 2. Summary of Cephalometric Landmarks and Definitions

Landmark	Abbreviation	Definition
A point	A	The deepest point on the premaxilla below ANS
Anterior nasal spine	ANS	The tip of the anterior nasal spine
SE point	SE	The intersection of the averaged greater wings and planum of the sphenoid
B point	B	The deepest part of the anterior mandible
D point	D	The center of the cross-section of the mandibular symphysis
Upper 6	U6	The mesial contact point of the maxillary first molar
Lower 6	L6	The mesial contact point of the mandibular first molar
Lower incisor	L1	The tip of the incisal edge of the mandibular central incisor
Upper incisor	U1	The tip of the incisal edge of the maxillary central incisor
Posterior nasal spine	PNS	The most posterior point on the bony hard palate
Sella	S	The center of the pituitary fossa
Nasion	N	The most anterior point of the frontonasal suture
Gonion	Go	The most anterior and inferior point at the angle of the mandible
Menton	Me	The most inferior point of the mandibular symphysis
Functional occlusal plane	FOP	Plane drawn through the occlusal contact points of the molars and premolars

**Figure 1.** Diagram of pitchfork analysis [Maxilla + Mandible = ABCH; ABCH + U6 + L6 = 6/6; ABCH + U1 + L1 = 1/1] (modified from Johnston²¹).

movements and mesial mandibular skeletal and dental movements, which aid in Class II correction, were assigned positive values. Movements that worsen Class II relations were assigned negative values. Incisor movements that affect overjet were also measured and summarized. All measurements were made at the level of the functional occlusal plane, which was drawn through the occlusal contact points of the molars and premolars.

Because the Forsus and Class II elastics were expected to produce vertical and angular changes of the dentition not described by the PFA, seven additional measurements were included:

- maxillary incisor (U1) angulation to the sella-nasion line (SN);
- U1 incisal edge vertical distance perpendicular to ANS-PNS;
- maxillary molar (U6) mesial contact point vertical distance perpendicular to anterior nasal spine-posterior nasal spine (ANS-PNS);
- mandibular incisor (L1) angulation to the mandibular plane (Go-Me);
- L1 incisal edge vertical distance perpendicular to Go-Me;

Table 3. Pretreatment Comparison of Elastics and Forsus Groups for Matched Variables

Variable	Elastics		Forsus		Sig ^a
	mean	SD	mean	SD	
ANB, deg	4.6	1.7	5.3	1.5	.10
L1-GoMe, deg	95.7	6.3	93.8	7.2	.25
SN-GoMe, deg	32.4	5.1	33.1	5.2	.52
Treatment duration, years	2.4	0.9	2.7	0.9	.12

^a Sig indicates significance.

- mandibular molar (L6) mesial contact point vertical distance perpendicular to GoMe;
- functional occlusal plane (FOP) to SN.

Statistical Methods

Statistical analysis was performed using SPSS version 14.0 (SPSS Incorporated, Chicago, Ill). The skewness and kurtosis statistics indicated normal distributions. Mean and standard deviation were used to describe central tendencies and dispersion. Independent *t*-tests were used to evaluate group differences. Paired *t*-tests were used to evaluate changes over time.

To ensure intraexaminer reliability, nine randomly selected radiographs were retraced and remeasured. The Cronbach alpha test for reliability showed that the intraclass correlation was 0.987.

RESULTS

Cephalometric Comparison: Vertical and Angular Treatment Changes

No significant ($P < .05$) pretreatment (T1) differences existed between the two treatment groups for the variables used for matching (ANB, L1-GoMe, SN-GoMe, and treatment duration) (Table 3). The pretreatment ANB was 0.7° greater in the Forsus group.

Table 4. Comparison of Pretreatment and Posttreatment Variables and Treatment Changes in the Elastics and Forsus Groups^a

Variable	Pretreatment					Posttreatment					Treatment Changes				
	Elastics		Forsus		Sig	Elastics		Forsus		Sig	Elastics		Forsus		Sig
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
U1-SN, deg	103.1 ^a	7.9	98.3 ^a	8.5	.01 ^a	103.7	5.8	102.0	7.3	.28	0.6	9.3	3.7*	8.9	.16
U1-ANSPNS, mm	25.9	2.8	26.6	2.8	.21	27.0	3.1	27.2	3.5	.80	1.2**	2.1	0.5	2.3	.24
U6-ANSPNS, mm	18.3	2.2	18.4	2.3	.87	20.3	2.4	19.9	2.5	.41	2.0**	2.0	1.5**	1.7	.20
L1-GoMe, deg	95.8	6.2	94.6	8.0	.48	99.7	5.9	100.9	8.2	.49	3.8**	5.5	6.3**	7.0	.11
L1-GoMe, mm	81.1	6.3	79.8	7.4	.41	77.4 ^a	6.0	74.0 ^a	7.9	.04 ^a	-3.7**	5.4	-5.9**	6.4	.14
L6-GoMe, mm	26.1	2.0	25.2	2.8	.16	29.3	2.6	28.5	3.1	.28	3.2**	1.9	3.3**	2.0	.86
OP-SN, deg	17.9	3.8	19.2	4.1	.16	16.9 ^a	4.0	19.0 ^a	4.1	.03 ^a	-1.0	3.2	-0.2	3.3	.34

^a Statistical significance between groups ($P < .05$); SD indicates standard deviation; Sig, significance.
 * Changes are significant at $P < .05$.
 ** Changes are significant at $P < .01$.

L1-GoMe, SN-GoMe, and treatment duration were closely matched. U1-SN angulation was significantly larger in the elastics group than in the Forsus group (103.1° and 98.3°, respectively).

Statistically significant ($P < .05$) group differences were found posttreatment (T2) between the groups for L1-GoMe and the OP-SN angle (Table 4). None of the other posttreatment differences between the groups were statistically significant.

The vertical and angular treatment changes showed no statistically significant ($P < .05$) group differences. For both groups, the U1-SN and L1-GoMe angulations increased, the upper incisor tip moved inferiorly, and the lower incisor tip moved closer to GoMe. The upper and lower molars increased their vertical distances from ANS-PNS and GoMe, respectively. The occlusal plane rotated clockwise in both groups.

Treatment Changes Measured By Pitchfork

The PFA showed that the maxilla and mandible moved mesially 1.5 mm and 3.8 mm, respectively, in the elastics group; the average apical base change was 2.3 mm (Table 5, Figure 2). The maxillary molar moved mesially 0.6 mm, and the mandibular molar moved mesially 0.7 mm. Including the apical base change, total molar change was 2.4 mm. The upper incisor moved mesially 0.3 mm, and the lower incisor moved mesially 0.8 mm. Total incisor change was 2.8 mm. All changes except maxillary incisor movement were statistically significant ($P < .05$).

In the Forsus group, the maxilla moved mesially 1.7 mm, and the mandible moved mesially 4.4 mm; the average apical base change was 2.6 mm. The maxillary molar moved mesially 1.2 mm, and the mandibular molar moved mesially 1.8 mm. The total molar change was 3.2 mm. The upper incisor moved mesially 0.7 mm, and the lower incisor moved mesially 1.2 mm. Total incisor change was 3.2 mm. All changes except

Table 5. Pitchfork Analysis Comparison of Treatment Changes in Elastics and Forsus Groups. ^aPositive Signs Indicate Movements in a Direction Which Aids Class II Correction (Distal Movements in the Maxilla/Mesial Movements in the Mandible). Negative Signs Indicate Movements Which Make Class II Occlusion More Severe (Mesial Movements in the Maxilla/Distal Movements in the Maxilla)

Variable	Elastics Group		Forsus Group		Sig
	Mean	SD	Mean	SD	
Max, mm	-1.5**	1.3	-1.7**	1.1	.47
Mand, mm	3.8**	2.5	4.4**	2.2	.33
ABCH, mm	2.3**	1.7	2.6**	1.8	.44
U6, mm	-0.6**	1.1	-1.2**	1.5	.06
L6, mm	0.7** ^a	1.3	1.8** ^a	1.5	<.001 ^a
U6/L6, mm	2.4** ^a	1.2	3.2** ^a	1.7	.03 ^a
U1, mm	-0.3	2.6	-0.7	2.0	.50
L1, mm	0.8*	2.0	1.2**	2.2	.42
U1/L1, mm	2.8**	2.2	3.2**	1.9	.47

^a Statistical significance between groups ($P < .05$); Sig indicates significance.
 * Changes are significant at $P < .05$.
 ** Changes are significant at $P < .01$.

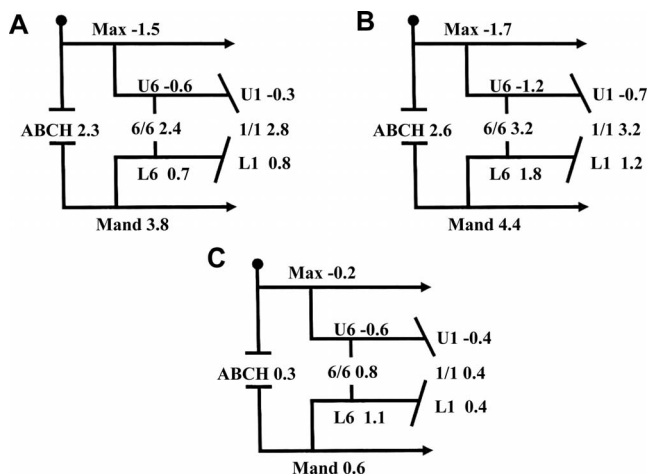


Figure 2. Pitchfork summaries of treatment changes. (A) Treatment changes in the elastics group. (B) Treatment changes in the Forsus group. (C) Summary of differences between groups (Forsus vs elastics).

maxillary incisor movement were significantly greater than zero ($P < .05$).

The pitchfork analysis showed group differences for the lower molar movements and total molar corrections (Figure 2). The Forsus group displayed 1.1 mm more mesial movement and 0.8 mm greater molar correction. During treatment, the mandible and maxilla moved mesially, with the mandible moving more than the maxilla in both groups. The upper molars, and the upper and lower incisors, were moved mesially in similar amounts in both groups. Overjet was improved in both groups.

DISCUSSION

The molar relationships of patients treated with elastics were corrected primarily due to mandibular growth changes. Anterior mandibular displacement accounted for 3.8 mm or approximately 158% of the 2.4 mm molar correction. Mesial mandibular molar movements accounted for 29% of the total correction.

In contrast, treatment changes in the maxilla worked against the molar corrections, with anterior maxillary skeletal and dental movements limiting the correction by approximately 63% and 25%, respectively. Similar amounts of mandibular and maxillary advancements have been previously reported for Class II elastic treatments.²²⁻²⁴ Mesial movement of the maxilla is commonly found in elastics patients, even with the use of headgear.^{23,24} Nonextraction Class II patients treated with standard edgewise appliances, Class II elastics, and headgears show mandibular displacements and dental movements accounting for approximately 66% and 22% of the Class II correction, and distal maxillary molar movement contributed another 29%; anterior maxillary skeletal movements limit the correction by approximately 20%.²³

The use of a prescription appliance without headgear could account for the maxillary molar anchorage loss observed in this study. Molar anchorage can be enhanced with headgear or Begg anchor bends.^{23,25} According to a personal communication from Dr L. Johnson of St. Louis Mo, anchorage loss in patients treated with prescription appliances is approximately 1 mm greater than with standard edgewise treatment. Because total molar correction was less than previously reported with the PFA, suggesting a less severe initial Class II relationship, greater maxillary molar anchorage loss could be tolerated while achieving satisfactory occlusal results.^{23,25} Nelson et al showed similar amounts of molar correction in patients successfully treated with Class II elastics and the Begg appliance.²⁴

The vertical relationships of the teeth and occlusal plane in the elastics patients indicate treatment modi-

fications of normal growth. Maxillary and mandibular molars, as well as the maxillary incisors, erupted during treatment, as previously reported for elastics treatment.^{2,26,27} Untreated controls show similar or slightly greater amounts of maxillary molar eruption over a comparable time span, but less mandibular molar eruption.¹⁶ This suggests that Class II elastics may have extruded the mandibular molars during treatment. Since neither practitioner placed a curve of Spee nor anchorage bends into the archwires, the mandibular molar extrusion might have been compensation to the more limited amounts of maxillary molar eruption that occurred. The OP-SN decreased (rotated counterclockwise) 1.0°, which was contrary to the clockwise rotation previously reported for elastics, but the differences are relatively small.² Differences could be attributed to the use of the functional occlusal plane in this study, rather than the more commonly used Down's occlusal plane or Pancherz's occlusal line.^{2,14,15,18,20} The functional occlusal plane is less likely to rotate clockwise when the upper incisors procline, than occlusal planes that rely on the incisors.

Molar correction for the patients treated with the Forsus FRD appliance was also predominately due to mesial mandibular skeletal and dental movements. Anterior mandibular displacement and mesial mandibular molar movements accounted for approximately 138% and 56% of Class II correction, respectively. Treatment changes with the Forsus also worked against molar correction, as mesial maxillary skeletal and dental movement limited correction by 91%. DeVincenzo,¹³ who quantified the skeletal and dental contributions to Class II correction with the Eureka Spring, showed distal movements of the maxilla and maxillary molars (contributing 11% and 33%, respectively), mesial mandibular molar movement contributing an additional 60%, and relative posterior movement of the mandible limiting molar correction by 4%. However, DeVincenzo used the pterygoid vertical reference line to calculate dental and skeletal changes.

The functional occlusal plane, which was used as a reference in this study, tends to show relatively greater skeletal contributions in Class II correction.²⁸ Karacay et al²⁹ reported no maxillary movement, approximately 1 mm anterior mandibular displacement, and equal amounts of distal maxillary molar and mesial mandibular molar movements in patients treated with the Forsus Nitinol Flat Spring (NFS). Distal movements of maxillary molars have been previously reported with the Forsus NFS and similar appliances.^{11,16,20,29,30} The studies showing the greatest distal movements of the maxillary molars measured the effects immediately after interarch appliance removal.^{11,18,20} Mesial movement with growth and anchorage loss due to additional orthodontic treatment may mask or negate these distal

movements. After Class I molar occlusion is achieved and appliances are removed, mesial maxillary molar movement might be expected to keep pace with the mandibular molars.

The Forsus group produced less vertical change than the elastics group. The eruption of the maxillary and mandibular molars compares well with previous reports of Forsus NFS and Jasper Jumper treatments.^{11,12,18,29} Immediately after appliance removal, the Forsus NFS, Jasper Jumper, and Eureka Spring have been shown to intrude the maxillary molars.^{11-13,18,30} If intrusion was initially achieved with Forsus treatment, it was followed by eruption, probably associated with normal growth. The change in L1-GoMe angulation was 2.5° greater in the Forsus group than in the elastics group, but this difference was not statistically significant. As the lower incisor tip proclined, the vertical distance from incisal tip to mandibular border should be expected to decrease in proportion to its proclination.

A number of the group differences appeared to be clinically relevant but were not statistically significant. This was due to the amount of variation in treatment changes seen between subjects in each group. Large variation in treatment changes is a common finding among treated Class II patients and is likely due to the movements required to correct the different types and extents of dental compensations.^{2,11-13,16,19,29} Finally, it has been reported that the PFA overestimates the skeletal and underestimates the dental changes, although the differences between it and Björk's approach were small when applied to sample data.²⁸ However, the differences between the methods appear to be systematic and might be expected to affect the two groups similarly because there were no group differences in the vertical molar movements or occlusal plane changes.

CONCLUSIONS

- The Forsus FRD is an acceptable substitute for Class II elastics for patients who appear to be non-compliant.
- Greater forward displacement of the mandible is the predominant factor contributing to success when treating Class II patients with either Class II elastics or the Forsus FRD appliance.

ACKNOWLEDGMENTS

The authors wish to acknowledge Drs Kevin Walde and William Vogt for generously providing the records, to Dr Heidi Israel for statistical advice, and to Dr Lysle E. Johnston Jr for assistance during this project.

REFERENCES

1. Proffit WR, Fields HW Jr, Moray LJ. Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. *Int J Adult Orthodon Orthognath Surg.* 1998;13:97-106.
2. Ellen EK, Schneider BJ, Sellke T. A comparative study of anchorage in bioprogressive versus standard edgewise treatment in Class II correction with intermaxillary elastic force. *Am J Orthod Dentofacial Orthop.* 1998;114:430-436.
3. Gianelly AA, Arena SA, Bernstein L. A comparison of Class II treatment changes noted with the light wire, edgewise, and Frankel appliances. *Am J Orthod.* 1984;86:269-276.
4. Nelson B, Hansen K, Hagg U. Class II correction in patients treated with class II elastics and with fixed functional appliances: a comparative study. *Am J Orthod Dentofacial Orthop.* 2000;118:142-149.
5. Remmer KR, Mamandras AH, Hunter WS, Way DC. Cephalometric changes associated with treatment using the activator, the Frankel appliance and the fixed appliance. *Am J Orthod.* 1985;88:363-372.
6. Adams CD, Meikle MC, Norwick KW, Turpin DL. Dentofacial remodeling produced by intermaxillary forces in Macaca mulatta. *Arch Oral Biol.* 1972;17:1519-1535.
7. Hanes RA. Bony profile changes resulting from cervical traction compared with those resulting from intermaxillary elastics. *Am J Orthod.* 1959;45:353-364.
8. Brandao M, Pinho HS, Urias D. Clinical and quantitative assessment of headgear compliance: a pilot study. *Am J Orthod Dentofacial Orthop.* 2006;129:239-244.
9. Beckwith FR, Ackerman RJ Jr, Cobb CM, Tira DE. An evaluation of factors affecting duration of orthodontic treatment. *Am J Orthod Dentofacial Orthop.* 1999;115:439-447.
10. Skidmore KJ, Brook KJ, Thomson WM, Harding WJ. Factors influencing treatment time in orthodontic patients. *Am J Orthod Dentofacial Orthop.* 2006;129:230-238.
11. Cope JB, Buschang PH, Cope DD, Parker J, Blackwood HO 3rd. Quantitative evaluation of craniofacial changes with Jasper Jumper therapy. *Angle Orthod.* 1994;64:113-122.
12. Covell DA Jr, Trammell DW, Boero RP, West R. A cephalometric study of class II Division 1 malocclusions treated with the Jasper Jumper appliance. *Angle Orthod.* 1999;69:311-320.
13. DeVincenzo J. The Eureka Spring: a new interarch force delivery system. *J Clin Orthod.* 1997;31:454-467.
14. Pancherz H. Treatment of class II malocclusions by jumping the bite with the Herbst appliance. A cephalometric investigation. *Am J Orthod.* 1979;76:423-442.
15. Pancherz H. The effects, limitations, and long-term dentofacial adaptations to treatment with the Herbst appliance. *Semin Orthod.* 1997;3:232-243.
16. Pangrazio-Kulbersh V, Berger JL, Chermak DS, Kaczynski R, Simon ES, Haerian A. Treatment effects of the mandibular anterior repositioning appliance on patients with Class II malocclusion. *Am J Orthod Dentofacial Orthop.* 2003;123:286-295.
17. Stromeyer EL, Caruso JM, DeVincenzo JP. A cephalometric study of the Class II correction effects of the Eureka Spring. *Angle Orthod.* 2002;72:203-210.
18. Stucki N, Ingervall B. The use of the Jasper Jumper for the correction of Class II malocclusion in the young permanent dentition. *Eur J Orthod.* 1998;20:271-281.
19. Valant JR, Sinclair PM. Treatment effects of the Herbst appliance. *Am J Orthod Dentofacial Orthop.* 1989;95:138-147.
20. Weiland FJ, Bantleon HP. Treatment of Class II malocclu-

- sions with the Jasper Jumper appliance—a preliminary report. *Am J Orthod Dentofacial Orthop.* 1995;108:341–350.
21. Johnston LE Jr. Balancing the books on orthodontic treatment: an integrated analysis of change. *Br J Orthod.* 1996;23:93–102.
 22. Egolf RJ, BeGole EA, Upshaw HS. Factors associated with orthodontic patient compliance with intraoral elastic and headgear wear. *Am J Orthod Dentofacial Orthop.* 1990;97:336–348.
 23. Johnston LE Jr. A comparative analysis of Class II treatments. In: Vig PS, Ribbens KA, eds. *Science and Clinical Judgment in Orthodontics.* Ann Arbor, Mich: Center for Human Growth; 1986:103–148.
 24. Nelson B, Hansen K, Hagg U. Overjet reduction and molar correction in fixed appliance treatment of class II, division 1, malocclusions: sagittal and vertical components. *Am J Orthod Dentofacial Orthop.* 1999;115:13–23.
 25. Reddy P, Kharbanda OP, Duggal R, Parkash H. Skeletal and dental changes with nonextraction Begg mechanotherapy in patients with Class II division 1 malocclusion. *Am J Orthod Dentofacial Orthop.* 2000;118:641–648.
 26. Bien SM. Analysis of the components of force used to effect distal movement of teeth. *Am J Orthod.* 1951;37:508–521.
 27. Zingesser M. Vertical response to Class II division 1 therapy. *Angle Orthod.* 1964;34:58–64.
 28. Mannchen R. A critical evaluation of the pitchfork analysis. *Eur J Orthod.* 2001;23:1–14.
 29. Karacay S, Akin E, Olmez H, Gurton AU, Sagdic D. Forsus Nitinol Flat Spring and Jasper Jumper corrections of Class II division 1 malocclusions. *Angle Orthod.* 2006;76:666–672.
 30. Heinig N, Goz G. Clinical application and effects of the Forsus spring. A study of a new Herbst hybrid. *J Orofac Orthop.* 2001;62:436–450.