Original Article

Treatment effects of the Forsus Fatigue Resistant Device used with miniscrew anchorage

Belma I. Aslan[a]; Ebru Kucukkaraca[a]; Cagri Turkoz[b]; Mufide Dincer[c]

ABSTRACT

Objective: To evaluate the dentofacial effects of the Forsus Fatigue Resistant Device (FRD) used with miniscrew anchorage (FRDMS) and compare them with those of conventional FRD and an untreated Class II control group.

Materials and Methods: The sample consisted of 48 Class II subjects. Sixteen patients (13.68 ± 1.09 years of age) were treated with FRDMS, whereas 17 subjects (14.64 ± 1.56 years of age) were treated with only FRD. Also, a control sample of 15 untreated Class II subjects (14.13 ± 1.50 years of age) was constructed. Angular and linear measurements were made on 96 lateral cephalograms. Paired *t*, one-way analysis of variance, and Tukey tests were used for statistical analysis.

Results: Class I molar relationship and overjet correction were achieved in an average period of 6.5 ± 1.97 and 5.5 ± 1.80 months in the FRDMS and FRD groups, respectively. No skeletal effect was determined in both treatment groups. Greater overbite correction was found in the FRD group. Retrusion and extrusion of maxillary incisors, distalization of maxillary molars, and extrusion of mandibular molars were significant in both treatment groups. Labial tipping of mandibular incisors was significantly greater in the FRD group than in the FRDMS group.

Conclusion: Overjet and molar correction was totally dentoalveolar. Unfavorable labial tipping of mandibular incisors was effectively minimized with the usage of miniscrews. (*Angle Orthod.* 2014;84:76–87.)

KEY WORDS: Forsus; Mini-screw; Fixed functional appliance; Class II correction

INTRODUCTION

Several removable or fixed functional appliances are used for treatment of Class II division 1 malocclusions with mandibular deficiency in order to stimulate mandibular growth by forward positioning of the mandible. Unlike removable functional appliances, fixed functional devices have the advantage of not requiring patient compliance, and they can also be used concurrently with brackets.[1]

Fixed functional devices are categorized as rigid (Herbst, MARA) and semirigid (Jasper Jumper and Forsus Fatigue Resistance Device[FRD]) fixed interarch appliances.[2–4] The Forsus FRD (3M Unitek Corp, Monrovia, Calif) is a semirigid fixed functional appliance that was developed to overcome breakage problems seen with the Jasper Jumper. The FRD is a three-piece, telescoping system incorporating a superelastic nickel-titanium coil spring that is easy to install and thus saves chair time.[5] Distal and intrusive movement of maxillary molars, mesial movement of mandibular molars, retrusion of maxillary incisors, labial tipping of mandibular incisors, and varying amounts of skeletal effects have been reported in previous studies with this appliance.[4–10]

Data from the literature demonstrates the increasing use and popularity of miniscrews in orthodontic practice for mesiodistal and intrusion movements of teeth.[11] However, there are no studies where miniscrews have been used with functional appliances.

Like other fixed functional appliances, an unfavorable effect of the FRD is flaring of the mandibular anteriors, which limits the skeletal effects of the appliance.[4,8,10]

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Therefore, we hypothesized that during the usage of an FRD, mandibular growth could be stimulated and tipping of mandibular incisors could be avoided by increasing the anchorage of mandibular dentition with the use of miniscrews. Consequently, in this study our aim was to evaluate the response of dentofacial structures to FRD treatment used with miniscrew anchorage (FRDMS) and compare the results with a group in which conventional FRD is used and also with a matched untreated Class II control group.

MATERIALS AND METHODS

Study Design

This study was carried out after institutional approval for use of humans was obtained from the Ethical Committee Board of Gazi University, Medical Faculty (B.30.2.GUN.0.20-6138). The sample consisted of 48 patients (33 treated, 15 untreated) exhibiting Class II malocclusion with mandibular retrognathia. Patient selection criteria included the following:

- at least half Class II molar relationship,
- horizontal or normal growth pattern,
- minimum (up to 3 mm) or no crowding,
- no extracted or missing permanent teeth (third molars were excluded),
- active growth period.

Twenty-six subjects had an Angle Class II division 1 (13 in the FRDMS group, 13 in the FRD group) and seven a division 2 malocclusion (three in FRDMS, four in FRD). The patients that were going to be treated were randomly divided into two groups. Sixteen patients (13.68 $\pm$ 1.09 years of age; five boys, 11 girls) were treated by FRDMS to encourage the anchorage of the mandibular dental arch. In the second treatment group, 17 patients (14.64 $\pm$ 1.56 years of age; 10 boys, seven girls) were treated with conventional FRD. The treatment was performed during circumpubertal phases of skeletal development as assessed with hand-wrist radiographs. To eliminate growth and development effects in treatment groups, an untreated control group of 15 subjects (14.13 $\pm$ 1.50 years of age; seven boys, eight girls) that were compatible with the patient selection criteria were obtained from the archives of the Orthodontics Department of Dentistry Faculty of Gazi University. The observation period (5.6 $\pm$ 2.19 months) of the control group matched the treatment duration of treatment groups.

Treatment Methods

Fixed Roth appliances with 0.018-inch slots were attached. In the FRDMS group, mandibular canines were bonded with 0.018 $\times$ 0.018-inch vertical slot brackets for attachment to miniscrews. In this group, miniscrews (Spider screw 1.5 $\times$ 8; Ortho Technology Inc, Tampa, Fla) were inserted between the mandibular canine and first premolar root area bilaterally at least 1 week before FRD application. An indirect anchorage was established by using a 0.018 $\times$ 0.025-inch stainless steel archwire between the vertical slot of the mandibular canine bracket and the miniscrew slot (Figure 1). FRD was inserted after an overjet increase in seven Class II division 2 patients; leveling of maxillary and mandibular arches in patients with mild crowding was achieved. In Class II division 1 cases with well-aligned or slightly crowded arches, the FRD was applied without an initial leveling phase. Stainless steel continuous archwires (0.016 $\times$ 0.022 inches) were engaged passively in both arches just before the insertion of the FRD. No lingual crown torque was given to the anterior part of the lower archwire. Both arches were cinched back, and all of the teeth were "figure 8" ligatured to minimize the adverse effects of the FRD and prevent slippage. The size of the FRD was selected according to the manufacturer's instructions. The maxillary end of

Figure 1. Spider screw inserted between the canine and first premolar root area.

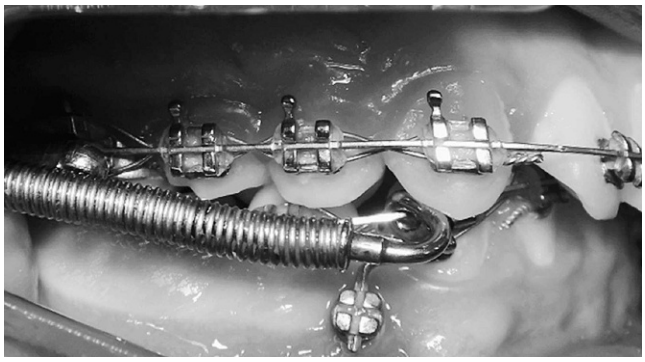

Figure 2. Forsus FRD used with miniscrews.

Figure 3. Before and after lateral cephalograms and photos of a patient in the FRDMS group.

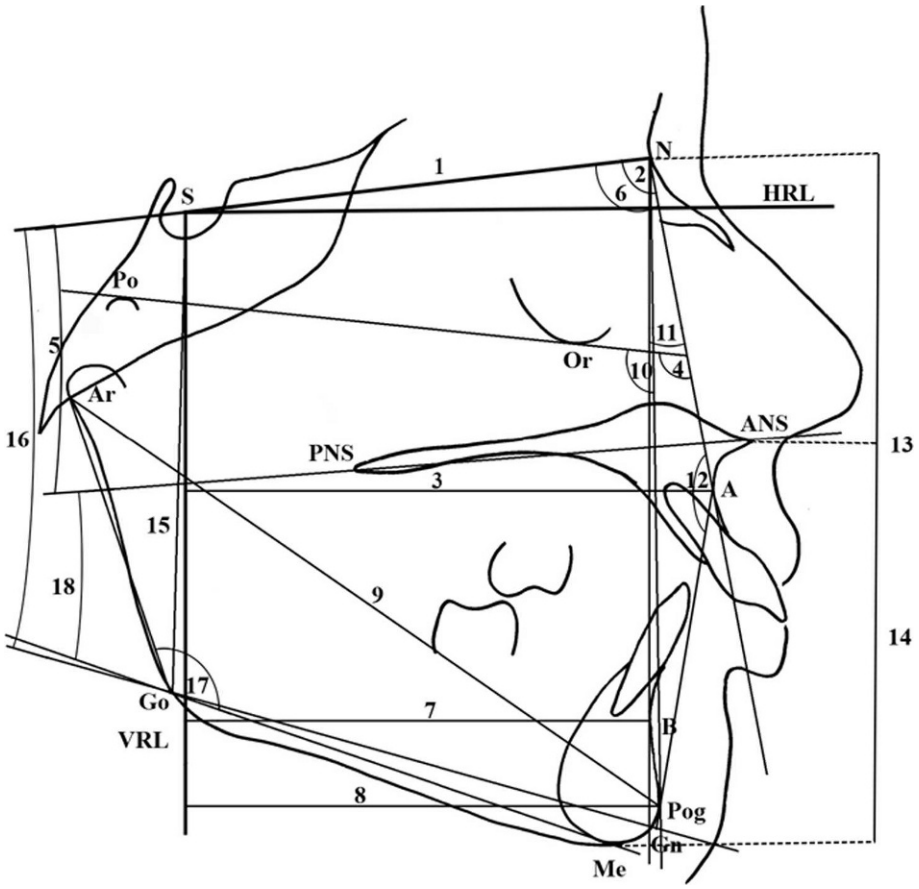

Figure 4. Skeletal measurements on lateral cephalograms. VRL indicates vertical reference line, which is perpendicular to the HRL. HRL indicates horizontal reference line constructed by drawing a line having a 7° difference with the SN plane. 1: SN (mm); 2: SNA (°); 3: A-VRL (mm); 4: FH/NA (°); 5: SN/ANSPNS (°); 6: SNB (°); 7: B-VRL (mm); 8: Pog-VRL (mm); 9: Ar-Pog (mm); 10: FH/NPog (°); 11: ANB (°); 12: N-A-Pog (°); 13: N-Me (mm); 14: ANS-Me (mm); 15: S-Go (mm); 16: SN/GoGn (°); 17: Ar-Go-Me (°); 18: ANSPNS/GoMe (°).

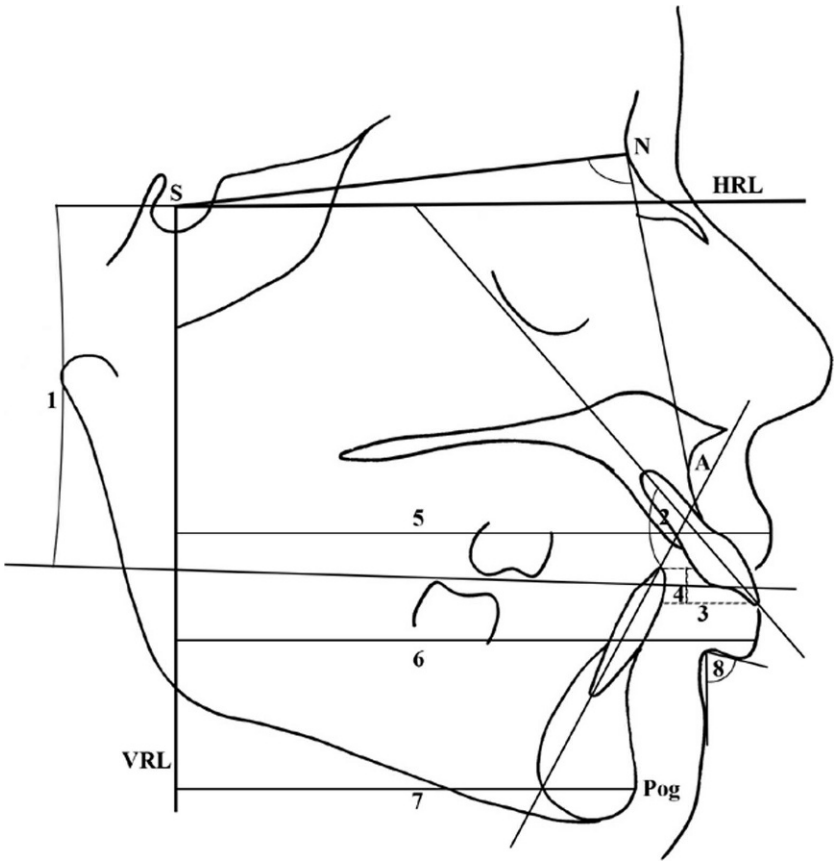

Figure 5. Dental and soft tissue measurements on lateral cephalograms. 1: SN/OP (°); 2: U1/L1 (°); 3: Overjet (mm); 4: Overbite (mm); 5: Lbsup-VRL (mm); 6: Lbinf-VRL (mm); 7: Pog'-VRL (mm); 8: Labiomental angle (°).

the FRD was inserted into the headgear tube of the maxillary molars. The rods of the FRD were placed onto the mandibular arch wire, distal to the canine brackets (Figure 2). Patients were observed at 4-week intervals, and activation was performed as needed by crimping stoppers onto the pushrod. The subjects were seated upright in a dental chair during the assessment of occlusal change. The FRD was removed when a Class I molar relationship was achieved, which eventuated in a mean time of 6.5 ± 1.97 months in the FRDMS group and 5.5 ± 1.80 months in the FRD group (Figure 3). Thereafter, fixed appliances were maintained in order to finalize the occlusion, and light Class II elastics were used for retention of treatment results.

Cephalometric Analysis

This investigation was carried out on lateral cephalograms obtained just before insertion of FRD (T1) and after Class I molar relationship was achieved (T2) in both treatment groups, and the beginning (T1) and end (T2) of the observation period in the control group. All of the lateral cephalograms were obtained by a single technician as the Frankfurt Horizontal plane parallel to the horizontal plane on the same radiology machine (Orthophos XG5/Ceph; Sirona Gmbh, Salzburg, Germany). Initial and final radiograms of each patient were traced manually at the same time and superimposed on acetate paper by only one examiner to minimize any method error. The cephalometric landmarks and skeletal, dental, and soft tissue measurements are illustrated in Figures 4–6. The perpendicular to a constructed horizontal line, 7° to SN plane, was taken as the reference plane. The reference lines used in this study were also used in previous investigations.[10,12]

Statistical Method

Data analysis was performed by using the Statistical Package for Social Sciences version 22.0 software (SPSS Inc, Chicago, Ill). Shapiro-Wilk test was performed to verify normal distribution of the data. Data were expressed as the mean ± standard deviation. Whether the differences between pre-and posttreatment measurements (intragroup) were statistically significant was evaluated by a Bonferroni-adjusted paired-samples *t*-test. The differences between groups were compared with a one-way analysis of variance test. If a statistically significant difference was found, a Tukey multiple-comparison test was used

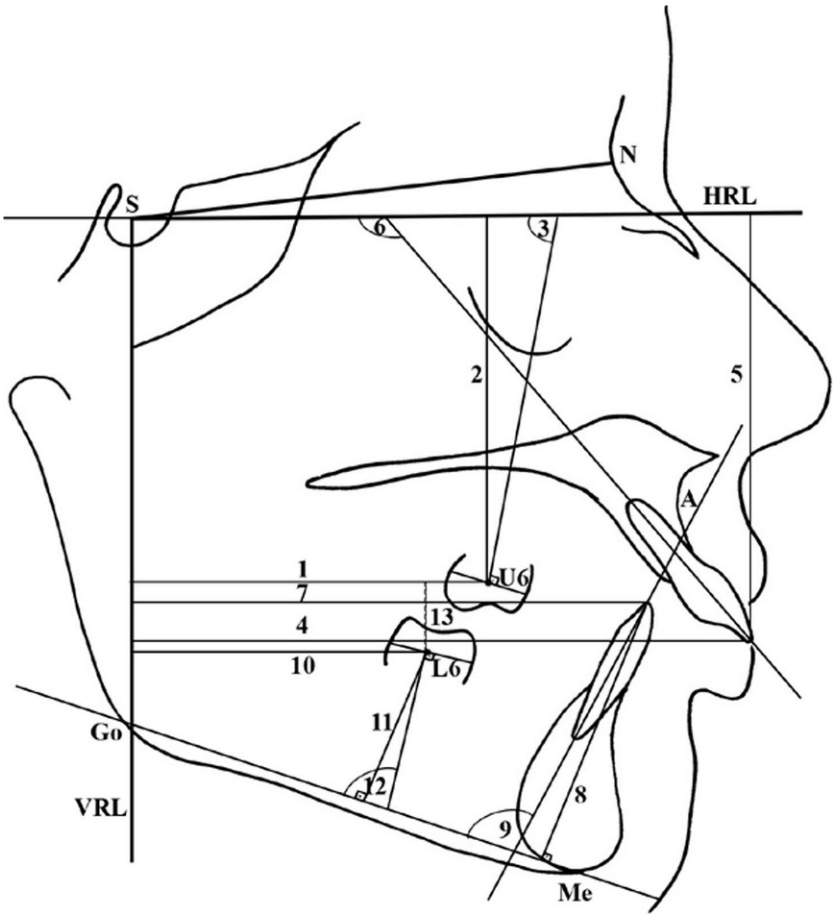

Figure 6. Horizontal, vertical, and angular measurements of the maxillary and mandibular incisor and molars related to the reference lines. 1: U6-VRL (mm); 2: U6-HRL (mm); 3: U6/HRL (°); 4: U1-VRL (mm); 5: U1-HRL (mm); 6: U1/HRL (°); 7: L1-VRL (mm); 8: L1-GoMe (mm); 9: L1/GoMe (°); 10: L6-VRL (mm); 11: L6-GoMe (mm); 12: L6/GoMe (°); 13: Molar relationship (mm).

to identify which groups were different. To compare unequal values, a chi-square test was used. Significance level was set at $P < .01$. When mean differences were tested according to an *F*-test, the mean statistical power was calculated as 0.84 (PASS. Professional Licance Version 11.07 Copyright 1983-2011 NCSS, LLC, Kayesville, Utah, USA).

Method Error

The same examiner assessed the magnitude of method error by retracing and measuring 20 randomly selected cephalograms after an interval of 20 days. Intraclass correlation coefficients ranged from 0.99 to 1.00 (Table 1).

RESULTS

Appliance breakage was observed in two patients (one with FRDMS, the other with FRD), and mobility of miniscrews during FRD application was determined bilaterally in another two patients, in which cases appliances and miniscrews were replaced. Differences in male-female ratios in the treatment and control groups were not significant ($\chi^2 = 2.530$, $P = .282$), which is important to avoid the effects of sexual dimorphism on craniofacial size and changes. Comparison of initial cephalometric values, mean chronological and skeletal ages, and mean treatment or observation duration in treatment and control groups are shown in Table 2.

Skeletal, dentoalveolar, and soft tissue cephalometric findings of treatment and control groups were shown in Tables 3–5, respectively. Comparisons between treatment groups and the control group during FRD application (T2–T1) were shown in Tables 6 and 7.

Skeletal Changes

Total anterior facial height (2.25 ± 1.94, $P < .01$), lower anterior facial height (1.81 ± 1.54, $P < .01$), and posterior facial height (1.53 ± 1.67, $P < .01$) increased in the FRDMS group, whereas only posterior facial height (1.26 ± 1.79, $P < .01$) demonstrated increment in the FRD group (Tables 3 and 4).

Table 1. Intraclass Correlation Coefficients[a]

	ICC	*P* value	Difference Mean	Difference SD	Repeatability
SN, mm	0.99	<.001	0.08	0.19	0.54
SNA, °	0.99	<.001	0.03	0.18	0.50
A-VRL, mm	1.00	<.001	0.05	0.09	0.25
FH/NA, °	0.99	<.001	−0.06	0.20	0.56
SN/ANSPNS, °	0.99	<.001	0.06	0.28	0.78
SNB, °	1.00	<.001	0.00	0.00	0.00
B-VRL, mm	1.00	<.001	0.00	0.00	0.00
Pog-VRL, mm	1.00	<.001	0.00	0.00	0.00
Ar-Pog, mm	0.99	<.001	0.02	0.18	0.49
FH/NPog, °	0.99	<.001	−0.04	0.14	0.38
ANB, °	1.00	<.001	0.01	0.05	0.14
N-A-Pog, °	1.00	<.001	−0.02	0.08	0.21
N-Me, mm	0.99	<.001	0.18	0.21	0.59
ANS-Me, mm	1.00	<.001	0.04	0.19	0.52
S-Go, mm	1.00	<.001	0.07	0.14	0.39
SN/GoGn, °	0.99	<.001	0.13	0.20	0.56
Ar-Go-Me, °	0.99	<.001	0.13	0.27	0.75
ANSPNS/GoMe, °	1.00	<.001	0.04	0.13	0.36
U6-VRL, mm	1.00	<.001	0.00	0.00	0.00
U6-HRL, mm	1.00	<.001	0.01	0.05	0.14
U6/HRL, °	1.00	<.001	0.00	0.00	0.00
L6-VRL, mm	1.00	<.001	−0.01	0.05	0.14
L6-MP, mm	1.00	<.001	0.00	0.00	0.00
L6/MP, °	1.00	<.001	0.01	0.09	0.25
U1-VRL, mm	1.00	<.001	0.02	0.07	0.21
U1-HRL, mm	1.00	<.001	0.01	0.05	0.14
U1/HRL, °	1.00	<.001	−0.03	0.22	0.61
L1-VRL, mm	1.00	<.001	0.00	0.00	0.00
L1-MP, mm	1.00	<.001	−0.02	0.14	0.38
L1/MP, °	1.00	<.001	0.00	0.00	0.00
SN/OP, °	0.99	<.001	−0.03	0.12	0.29
U1/L1, °	1.00	<.001	0.14	0.23	0.62
OJ, mm	0.99	<.001	−0.05	0.14	0.39
OB (mm)	0.99	<.001	−0.05	0.11	0.30
Molar rel., mm	1.00	<.001	0.00	0.00	0.00
Lbsup-VRL, mm	1.00	<.001	0.00	0.00	0.00
Lbinf-VRL, mm	1.00	<.001	0.00	0.00	0.00
Pog'-VRL, mm	1.00	<.001	0.01	0.05	0.14
Labiomental, °	1.00	<.001	−0.23	0.59	1.64

[a] ICC indicates intraclass correlation coefficient; SD, standard deviation.

Dentoalveolar and Soft Tissue Changes

In the control group, the extrusion of maxillary and mandibular incisors was found to be significant (Table 5; $P < .01$).

In the posterior segment, maxillary molars moved distally (2.11 ± 1.66, $P < .01$), and mandibular molars extruded (1.43 ± 1.40, $P < .01$) in the FRDMS group (Table 3). However, in the FRD group, distalization (1.45 ± 0.83, $P < .01$) and distal tipping (-3.92 ± 3.34, $P < .01$) of maxillary molars as well as mesial movement (1.95 ± 1.33, $P < .01$), extrusion (1.53 ± 1.46, $P < .01$), and mesial tipping (3.24 ± 3.19, $P < .01$) of mandibular molars were determined (Table 4). Mesial tipping of mandibular molars in the FRD group was greater than that in both the FRDMS and control groups (Table 7; $P < .01$).

In the anterior region, the maxillary incisors retruded (3.16 ± 1.90, $P < .01$), extruded (2.01 ± 1.79, $P < .01$), and retroclined in the FRDMS group (8.94 ± 5.70, $P < .01$). However, in the FRD group, maxillary incisors retruded (1.79 ± 1.90, $P < .01$) and extruded (0.77 ± 0.91, $P < .01$), and the lower incisors protruded (2.34 ± 1.68, $P < .01$), intruded (1.45 ± 1.27, $P < .01$), and proclined (9.29 ± 3.81, $P < .01$) (Tables 3 and 4). Retroclination of maxillary incisors in the FRDMS group was greater than in the FRD and control groups ($P < .01$). Proclination of lower incisors was greater in the FRD group than in the FRDMS and control groups ($P < .01$). Intrusion of lower incisors in the treatment groups was significant ($P < .01$) when compared to the control group (Table 7). The occlusal plane rotated in a clockwise direction in both the

Table 2. The Initial Mean Values of Skeletal, Dental, and Soft Tissue Parameters, Age, and Treatment/Control Duration in Each Group and Significance Values of the Differences Between FRDMS (1), FRD (2), and Control (3) Groups[a]

	1 (n = 16)	2 (n = 17)	3 (n = 15)	*P*	*P* (1–2)	*P* (1–3)	*P* (2–3)
SN, mm	74.70 ± 3.70	76.87 ± 3.13	74.66 ± 3,46	.082			
SNA, °	80.53 ± 3.76	78.27 ± 2.19	78.14 ± 3.02	.067			
A-VRL, mm	70.03 ± 3.50	72.32 ± 3.72	69.54 ± 3.29	.079			
FH/NA, °	89.57 ± 2.53	87.70 ± 2.71	88.16 ± 2.73	.124			
SN/ANSPNS, °	8.46 ± 2.23	9.23 ± 3.03	9.57 ± 3.72	.465			
SNB, mm	74.81 ± 2.51	73.97 ± 2.57	74.18 ± 1.90	.577			
B-VRL, mm	58.84 ± 4.69	61.55 ± 5.78	57.66 ± 4.53	.051			
Pog-VRL, mm	59.50 ± 6.06	63.00 ± 6.94	59.50 ± 5.86	.052			
Ar-Pog, mm	107.26 ± 6.19	110.35 ± 5.83	107.96 ± 6.16	.060			
FH/NPog, °	85.19 ± 2.51	85.61 ± 2.32	86.78 ± 2.84	.216			
ANB, °	5.71 ± 2.28	4.30 ± 2.38	3.95 ± 2.55	.053			
N-A-Pog, °	9.46 ± 5.82	6.60 ± 5.95	5.82 ± 5.30	.070			
N-Me, mm	121.34 ± 5.79	124.11 ± 6.17	121.93 ± 6.70	.066			
ANS-Me, mm	66.84 ± 4.20	67.52 ± 4.68	65.46 ± 5.66	.800			
S-Go, mm	80.81 ± 4.43	83.85 ± 7.26	81.78 ± 4.21	.069			
SN/GoGn, °	31.84 ± 3.84	29.41 ± 4.90	30.05 ± 5.57	.518			
Ar-Go-Me, °	122.90 ± 5.64	123.52 ± 9.52	121.70 ± 7.39	0,797			
ANSPNS/GoMe, °	25.89 ± 4.84	23.00 ± 6.37	21.14 ± 5.10	.063			
U6-VRL, mm	37.26 ± 4.04	39.07 ± 4.09	35.79 ± 4.36	.071			
U6-HRL, mm	65.62 ± 3.38	68.68 ± 4.59	65.58 ± 3.46	.062			
U6/HRL, °	77.93 ± 5.40	79.55 ± 3.65	76.38 ± 4.76	.107			
L6-VRL, mm	35.20 ± 3.90	36.35 ± 4.59	33.36 ± 4.09	.056			
L6-MP, mm	28.71 ± 2.34	28.29 ± 2.87	29.30 ± 2.47	.133			
L6/MP, °	76.84 ± 5.15	76.94 ± 4.67	79.90 ± 5.37	.0174			
U1-VRL, mm	74.81 ± 4.77	75.58 ± 4.76	67.82 ± 4.84	<.001*		*	*
U1-HRL, mm	75.75 ± 4.33	79.33 ± 4.28	77.93 ± 6.16	.125			
U1/HRL, °	112.03 ± 5.11	110.17 ± 5.31	95.55 ± 9.62	<.001*		*	*
L1-VRL, mm	68.00 ± 3.98	68.91 ± 4.66	64.10 ± 4.14	<.001*		*	*
L1-MP, mm	43.26 ± 2.24	43.01 ± 2.47	42.14 ± 2.87	.057			
L1/MP, °	98.53 ± 5.42	96.61 ± 8.38	92.07 ± 6.39	.002*		*	*
SN/OP, °	15.34 ± 3.23	14.55 ± 3.75	13.95 ± 4.50	.216			
OJ, mm	7.31 ± 2.43	6.52 ± 1.95	4.41 ± 1.95	.001*		*	*
OB, mm	4.54 ± 2.10	5.29 ± 1.92	5.28 ± 2.91	.586			
U1/L1, °	122.96 ± 9.00	127.38 ± 10.23	147.45 ± 12.49	<.001*		*	*
Molar Rel, mm	2.06 ± 1.96	2.71 ± 1.61	2.43 ± 1.44	.325			
LbSup-VRL, mm	88.00 ± 4.24	91.08 ± 5.77	84.63 ± 4.84	.003*			*
Lbinf-VRL, mm	78.50 ± 4.19	82.94 ± 5.14	81.70 ± 5.04	.058			
Pog'-VRL, mm	71.53 ± 5.12	76.17 ± 7.08	72.44 ± 4.54	.062			
Labiomental, °	110.66 ± 17.67	100.67 ± 10.17	106.73 ± 18.69	.205			
Chronological age, y	13.68 ± 1.09	14.64 ± 1.56	14.13 ± 1.50	.061			
Skeletal age, y	13.50 ± 1.25	14.34 ± 1.85	14.25 ± 1.75	.087			
Treatment duration, mo	6.50 ± 1.97	5.50 ± 1.80	5.60 ± 2.19	.340			

[a] FRD indicates fatigue resistant device; FRDMS, FRD treatment used with miniscrew anchorage. Values for groups 1, 2, and 3 are expressed as the mean ± the standard deviation.

* $P < .01$; one-way analysis of variance.

FRDMS (3.66 ± 3.24, $P < .01$) and FRD (3.78 ± 3.33, $P < .01$) groups (Tables 3 and 4).

The interincisal angle (6.09 ± 4.42, $P < .01$) decreased in the FRD group significantly compared to the FRDMS and control groups (Table 4 and 7). Both the FRDMS and FRD groups exhibited a significant reduction in overjet (4.28 ± 2.15, 4.08 ± 2.02, respectively, $P < .01$) and overbite (1.53 ± 1.19, 2.68 ± 1.52, respectively, $P < .01$) and a significant improvement in molar relationship (3.50 ± 2.06, 3.39 ± 1.72, respectively, $P < .01$). However, overbite decreased more ($P < .01$) in the FRD group compared to the FRDMS group (Tables 3, 4, and 7).

The lower lip protruded (1.47 ± 1.77, $P < .01$) and the labiomental angle increased (14.56 ± 13.17, $P < .01$) only in the FRD group (Table 4).

DISCUSSION

There were significant differences in initial values of U1-VRL, U1/HRL, L1-VRL, L1/MP, U1/L1, overjet, and Lbsup-VRL variables between treatment and control groups related to Class II division 2 subjects in the control group. Leveling was performed in treatment groups, which affected initial values. Besides these variables, both skeletal maturity groups were comparable in terms of malocclusion severity.

Table 3. Mean Values and 95% Confidence Intervals of Parameters at the Beginning (T1) and End (T2) of FRD Application in the FRDMS Group and Significance Values of Differences (T2-T1)[a]

	FRDMS Group				
	T1	95% CI	T2	95% CI	*P*
SN, mm	74.70 ± 3.70	(73.16, 76.46)	75.14 ± 2.84	(73.68, 76.87)	.006*
SNA, °	80.53 ± 3.76	(78.24, 82.49)	80.04 ± 3.94	(77.61, 82.00)	.074
A-VRL, mm	70.03 ± 3.50	(67.99, 72.00)	70.15 ± 4.08	(67.76, 72.43)	.633
FH/NA, °	89.57 ± 2.53	(88.06, 90.95)	89.23 ± 2.88	(87.48, 90.74)	.313
SN/ANSPNS, °	8.46 ± 2.23	(7.15, 9.71)	8.88 ± 2.07	(7.68, 10.05)	.052
SNB, °	74.81 ± 2.51	(73.51, 76.34)	74.63 ± 2.52	(73.13, 76.02)	.498
B-VRL, mm	58.84 ± 4.69	(56.63, 61.76)	58.81 ± 4.97	(56.05, 61.74)	.940
Pog-VRL, mm	59.50 ± 6.06	(57.03, 62.86)	59.66 ± 5.27	(56.84, 62.84)	.486
Ar-Pog, mm	107.26 ± 6.19	(104.24, 110.81)	108.31 ± 4.96	(105.56, 111.23)	.070
FH/NPog, °	85.19 ± 2.51	(84.11, 86.76)	85.14 ± 2.31	(83.95, 86.55)	.882
ANB, °	5.71 ± 2.28	(4.29, .56)	5.40 ± 2.15	(4.06, 6.40)	.312
N-A-Pog, °	9.46 ± 5.82	(6.52, 12.41)	9.10 ± 5.10	(6.27, 11.92)	.468
N-Me, mm	121.34 ± 5.79	(118.07, 124.72)	123.59 ± 5.87	(120.23, 126.96)	<.001*
ANS-Me, mm	66.84 ± 4.20	(64.25, 68.94)	68.65 ± 4.31	(65.98, 70.75)	<.001*
S-Go, mm	80.81 ± 4.43	(78.64, 83.55)	82.34 ± 425	(79.92, 84.80)	.002*
SN/GoGn, °	31.84 ± 3.84	(29.44, 33.49)	32.55 ± 3.44	(30.43, 34.27)	.042
Ar-Go-Me, °	122.90 ± 5.64	(119.37, 125.35)	123.23 ± 5.56	(119.74, 125.54)	.300
ANSPNS/GoMe, °	25.89 ± 4.84	(22.90, 28.27)	25.88 ± 4.51	(23.17, 28.29)	.983
U6-VRL, mm	37.26 ± 4.04	(34.92, 39.56)	35.15 ± 4.56	(32.63, 37.85)	<.001*
U6-HRL, mm	65.62 ± 3.38	(64.06, 67.73)	65.62 ± 3.68	(64.14, 67.92)	1.000
U6/HRL, °	77.93 ± 5.40	(74.98, 81.15)	75.40 ± 7.85	(72.22, 80.31)	.046
L6-VRL, mm	35.20 ± 3.90	(33.23, 37.59)	36.59 ± 4.25	(34.09, 38.96)	.022
L6-MP, mm	28.71 ± 2.34	(27.35, 30.04)	30.15 ± 2.56	(28.56, 31.41)	.001*
L6/MP, °	76.84 ± 5.15	(74.06, 79.93)	77.14 ± 5.44	(73.76, 79.76)	.686
U1-VRL, mm	74.81 ± 4.77	(71.95, 77.38)	71.65 ± 4.42	(68.98, 74.01)	<.001*
U1-HRL, mm	75.75 ± 4.33	(73.48, 78.38)	77.76 ± 4.02	(75.57, 80.16)	<.001*
U1/HRL, °	112.03 ± 5.11	(108.85, 114.47)	103.09 ± 4.52	(100.47, 105.65)	.001*
L1-VRL, mm	68.00 ± 3.98	(65.82, 70.37)	69.09 ± 4.36	(66.42, 71.31)	.025
L1-MP, mm	43.26 ± 2.24	(41.91, 44.46)	42.53 ± 2.66	(40.98, 44.03)	.056
L1/MP, °	98.53 ± 5.42	(95.28, 101.45)	102.14 ± 8.17	(97.02, 105.67)	.012
SN/OP, °	15.34 ± 3.23	(13.34, 16.92)	19.00 ± 3.03	(17.11, 20.12)	<.001*
U1/L1, °	122.96 ± 9.00	(119.00, 128.59)	126.68 ± 9.67	(122.39, 132.73)	.037
OJ, mm	7.31 ± 2.43	(5.78, 8.34)	3.03 ± 1.43	(2.34, 3.91)	<.001*
OB, mm	4.54 ± 2.10	(3.37, 5.78)	3.01 ± 1.89	(2.17, 4.20)	.001*
Molar Rel., mm	2.06 ± 1.96	(0.83, 2.83)	−1.43 ± 1.69	(−2.19, −0.37)	<.001*
Lbsup-VRL, mm	88.00 ± 4.24	(85.65, 90.34)	87.60 ± 4.59	(85.05, 90.14)	.429
Lbinf-VRL, mm	81.70 ± 5.04	(78.90, 84.49)	81.93 ± 5.29	(79.00, 84.86)	.679
Pog'-VRL, mm	71.53 ± 5.12	(68.69, 74.37)	71.10 ± 6.02	(67.76, 74.43)	.427
Labiomental, °	110.66 ± 17.67	(100.88, 120.45)	118.80 ± 13.07	(111.55, 126.04)	.012

[a] Values for T1 and T2 are the mean ± the standard deviation. FRD indicates fatigue resistant device; FRDMS, FRD treatment used with miniscrew anchorage; CI, confidence interval.

* $P < .01$; paired-sample *t*-test.

In the present study, both the rate of miniscrew failure and breakage of FRD were quite low. Except the failure of miniscrews in two patients during FRD application, there was also mobility in three other patients just after 1 or 2 weeks of miniscrew insertion, which could be due to thin cortical bone or poor oral hygiene. The failure rate of miniscrews in our study was close to the value of a meta-analysis reported by Papageorgiou et al.[13] The breakage rate of FRD was low in our study compared to that in the survey study by Bowman et al.,[14] which might be related to patients' cooperation level.

In this investigation, we hypothesized that we could improve mandibular advancement and minimize unfavorable protrusion of lower incisors during FRD treatment by increasing the anchorage of lower dentition with miniscrews. However, we found that the FRD device used with or without miniscrews had no significant effects on maxillary or mandibular sagittal and vertical position, yet protrusion of lower incisors was effectively minimized in the FRDMS group.

Regarding maxilla, our results are consistent with the findings of Günay et al.[9] and Weiland and Bantleon.[15] However, some authors[4,6,12,16–21] reported significant maxillary growth restraint effect at either the peak or postpeak period with different fixed interarch appliances. This contradiction may be related to the variance of sample groups, different treatment mechanics, or treatment duration.

Table 4. Mean Values and 95% Confidence Intervals of Parameters at the Beginning (T1) and End (T2) of FRD Application in the FRD Group and Significance Values of Differences (T2-T1)[a]

	FRD Group				
	T1	95% CI	T2	95% CI	*P*
SN, mm	76.87 ± 3.13	(76.26, 79.48)	77.33 ± 3.12	(76.72, 79.94)	.039
SNA, °	78.27 ± 2.19	(77.14, 79.40)	78.18 ± 2.33	(76.98, 79.38)	.511
A-VRL, mm	72.32 ± 3.72	(70.40, 74.23)	72.39 ± 3.76	(70.46, 74.32)	.793
FH/NA, °	87.70 ± 2.71	(86.31, 89.09)	87.44 ± 2.45	(86.17, 88.70)	.269
SN/ANSPNS, °	9.23 ± 3.03	(7.67, 10.79)	9.64 ± 3.54	(7.82, 11.47)	.222
SNB, °	73.97 ± 2.57	(72.64, 75.29)	73.94 ± 2.60	(72.59, 75.28)	.881
B-VRL, mm	61.55 ± 5.78	(58.58, 64.53)	61.80 ± 6.20	(58.61, 64.99)	.537
Pog-VRL, mm	63.00 ± 6.94	(59.42, 66.57)	62.91 ± 7.36	(59.12, 66.69)	.825
Ar-Pog, mm	110.35 ± 5.83	(107.35, 113.35)	111.26 ± 6.01	(108.17, 114.35)	.129
FH/NPog, °	85.61 ± 2.32	(84.42, 86.81)	85.32 ± 2.48	(84.04, 86.59)	.181
ANB, °	4.30 ± 2.38	(3.18, 5.41)	4.18 ± 1.75	(3.28, 5.09)	.608
N-A-Pog, °	6.60 ± 5.95	(3.85, 9.45)	6.67 ± 5.14	(4.03, 9.32)	.890
N-Me, mm	124.11 ± 6.17	(120.94, 127.29)	125.39 ± 6.27	(122.17, 128.61)	.029
ANS-Me, mm	67.52 ± 4.68	(65.12, 69.93)	68.70 ± 5.22	(66.02, 71.39)	.013
S-Go, mm	83.85 ± 7.26	(80.11, 87.58)	85.11 ± 7.45	(81.28, 88.95)	.004*
SN/GoGn, °	29.41 ± 4.90	(26.88, 31.93)	29.61 ± 4.61	(27.24, 31.99)	.499
Ar-Go-Me, °	123.52 ± 9.52	(118.63, 128.42)	123.36 ± 9.83	(118.30, 128.42)	.724
ANSPNS/GoMe, °	23.00 ± 6.37	(19.72, 26.27)	22.55 ± 6.33	(19.29, 25.81)	.362
U6-VRL, mm	39.07 ± 4.09	(36.96, 41.17)	37.61 ± 4.03	(35.54, 39.69)	<.001*
U6-HRL, mm	68.68 ± 4.59	(66.32, 71.04)	68.05 ± 4.69	(65.64, 70.47)	.046
U6/HRL, °	79.55 ± 3.65	(77.68, 81.43)	75.63 ± 3.61	(73.77, 77.49)	<.001*
L6-VRL, mm	36.35 ± 4.59	(33.99, 38.71)	38.30 ± 4.43	(36.02, 40.58)	<.001*
L6-MP, mm	28.29 ± 2.87	(26.81, 29.77)	29.82 ± 2.47	(28.55, 31.09)	.001*
L6/MP, °	76.94 ± 4.67	(74.53, 79.34)	80.17 ± 5.01	(77.59, 82.75)	.002*
U1-VRL, mm	75.58 ± 4.76	(73.13, 78.03)	73.79 ± 5.01	(71.21, 76.37)	.001*
U1-HRL, mm	79.33 ± 4.28	(77.13, 81.53)	80.10 ± 4.65	(77.71, 82.49)	.003*
U1/HRL, °	110.17 ± 5.31	(107.44, 112.91)	107.50 ± 6.15	(104.33, 110.66)	.029
L1-VRL, mm	68.91 ± 4.66	(66.51, 71.31)	71.24 ± 4.26	(69.05, 73.43)	<.001*
L1-MP, mm	43.01 ± 2.47	(41.74, 44.28)	41.55 ± 2.49	(40.27, 42.84)	<.001*
L1/MP, °	96.61 ± 8.38	(92.30, 100.92)	105.91 ± 8.58	(101.49, 110.32)	<.001*
SN/OP, °	14.55 ± 3.75	(12.62, 16.48)	18.33 ± 3.79	(16.38, 20.28)	<.001*
U1/L1, °	127.38 ± 10.23	(122.11, 132.64)	121.29 ± 9.05	(116.63, 125.94)	<.001*
OJ, mm	6.52 ± 1.95	(5.52, 7.53)	2.45 ± 1.56	(1.64, 3.25)	<.001*
OB, mm	5.29 ± 1.92	(4.30, 6.28)	2.61 ± 1.78	(1.69, 3.52)	<.001*
Molar Rel., mm	2.71 ± 1.61	(1.88, 3.55)	−0.67 ± 1.42	(−1.40, 0.05)	<.001*
Lbsup-VRL, mm	91.08 ± 5.77	(88.11, 94.05)	90.67 ± 6.27	(87.44, 93.90)	.324
Lbinf-VRL, mm	82.94 ± 5.14	(80.29, 85.58)	84.41 ± 5.20	(81.73, 87.08)	.003*
Pog'-VRL, mm	76.17 ± 7.08	(72.53, 79.81)	76.76 ± 7.59	(72.85, 80.66)	.286
Labiomental, °	100.67 ± 10.17	(95.44, 105.90)	115.23 ± 18.11	(105.92, 124.54)	<.001*

[a] Values for T1 and T2 are the mean ± the standard deviation. FRD indicates fatigue resistant device; CI, confidence interval.
* $P < .01$; paired-sample *t*-test.

Similar to the maxilla, no significant effect was found in either the sagittal position of the mandible or the mandibular length in both treatment groups. In other fixed functional therapies, the results of some authors[9,12,16,19] are in accordance with ours; however, the results of other authors[4,6,15,18,20] are in conflict with ours. Recently, Aras et al.[8] and Franchi et al.[21] reported that the influence of FRD on mandibular anterior translation was limited. Appliance strength is also important in providing stimulation of mandibular growth. Pronounced increment in mandibular growth was determined with Herbst, which is a rigid fixed functional appliance.[2] In the present study, we hypothesized that using Forsus FRD with miniscrew anchorage may ensure stable promotion of the mandible into a more advanced therapeutic position instead of protruding the lower dentition; thus, mandibular growth could be simulated efficiently. However, contrary to our hypothesis, no effect could be achieved on the mandible, which may be related to resistance of miniscrews to the forward force direction of the FRD. On the other hand, a 6-month period may not be enough duration for mandibular growth.

According to the results of previous studies, generally the SNGoGn angle was maintained with fixed functional appliances, which is in agreement with our results.[6,8,12,18,20]

In the present study, dentoalveolar changes were more prominent in the FRD group, which is in accordance with other fixed functional appliance

Table 5. Mean Values and 95% Confidence Intervals of Parameters at the Beginning (T1) and End (T2) of the Observation Period in the Control Group and Significance Values of Differences (T2-T1)

	Control Group				
	T1	95% CI	T2	95% CI	*P*
SN, mm	74.66 ± 3.46	(72.74, 76.58)	75.20 ± 3.31	(73.36, 76.03)	.008*
SNA, °	78.14 ± 3.02	(76.46, 79.81)	78.10 ± 3.13	(76.36, 79.84)	.832
A-VRL, mm	69.54 ± 3.29	(67.71, 71.37)	69.80 ± 3.37	(67.93, 71.66)	.28
FH/NA, °	88.16 ± 2.73	(86.64, 89.67)	88.11 ± 2.75	(86.58, 89.64)	.750
SN/ANSPNS, °	9.57 ± 3.72	(7.51, 11.63)	9.66 ± 3.69	(7.61, 11.70)	.74
SNB, °	74.18 ± 1.90	(73.13, 75.23)	74.28 ± 2.29	(73.01, 75.54)	.685
B-VRL, mm	57.66 ± 4.53	(55.14, 60.17)	58.12 ± 5.02	(55.33, 60.90)	.441
Pog-VRL, mm	59.50 ± 5.27	(56.57, 62.42)	59.66 ± 5.89	(56.39, 63.07)	.486
Ar-Pog, mm	107.96 ± 6.16	(104.80, 111.22)	109.00 ± 5.93	(105.71, 112.28)	.017
FH/NPog, °	86.78 ± 2.84	(85.20, 88.35)	86.52 ± 3.27	(84.71, 88.33)	.357
ANB, °	3.95 ± 2.55	(2.72, 5.17)	3.82 ± 1.75	(2.85, 4.80)	.501
N-A-Pog, °	5.82 ± 5.30	(3.13, 8.40)	5.45 ± 4.24	(3.10, 7.80)	.405
N-Me, mm	121.93 ± 6.70	(118.22, 125.64)	123.24 ± 7.64	(119.00, 127.47)	.006*
ANS-Me, mm	65.46 ± 5.66	(62.32, 68.59)	66.36 ± 6.36	(62.84, 69.88)	.005*
S-Go, mm	81.78 ± 4.21	(79.45, 84.12)	82.64 ± 4.28	(80.26, 85.01)	.060
SN/GoGn, °	30.05 ± 5.57	(26.96, 33.14)	30.25 ± 5.96	(26.95, 33.55)	.491
Ar-Go-Me, °	121.70 ± 7.39	(117.60, 125.79)	121.76 ± 7.53	(117.59, 125.93)	.872
ANSPNS/GoMe, °	21.14 ± 5.10	(18.31, 23.96)	21.32 ± 5.84	(18.09, 24.56)	.603
U6-VRL, mm	35.79 ± 4.36	(33.39, 38.08)	36.11 ± 4.32	(33.71, 38.51)	.291
U6-HRL, mm	65.58 ± 3.46	(63.66, 67.49)	66.50 ± 3.80	(64.39, 68.60)	.014
U6/HRL, °	76.38 ± 4.76	(73.74, 79.02)	76.18 ± 4.41	(73.73, 78.62)	.784
L6-VRL, mm	33.36 ± 4.09	(31.09, 35.63)	33.93 ± 4.01	(31.71, 36.15)	.145
L6-MP, mm	29.30 ± 2.47	(27.92, 30.67)	29.68 ± 2.79	(28.13, 31.22)	.069
L6/MP, °	79.90 ± 5.37	(76.92, 82.87)	80.10 ± 4.46	(77.62, 82.57)	.809
U1-VRL, mm	67.82 ± 4.84	(65.14, 70.51)	68.18 ± 4.70	(65.57, 70.78)	.351
U1-HRL, mm	77.93 ± 6.16	(74.52, 81.34)	78.91 ± 6.64	(75.23, 82.59)	.001*
U1/HRL, °	95.55 ± 9.62	(90.22, 100.88)	95.68 ± 9.45	(90.44, 100.91)	.834
L1-VRL, mm	64.10 ± 4.14	(61.80, 66.39)	64.40 ± 4.46	(61.92, 66.87)	.432
L1-MP, mm	42.14 ± 2.87	(40.55, 43.73)	42.88 ± 3.13	(41.14, 44.61)	.002*
L1/MP, °	92.07 ± 6.39	(88.53, 95.61)	91.47 ± 6.82	(87.69, 95.25)	.338
SN/OP, °	13.95 ± 4.50	(11.45, 16.45)	13.68 ± 4.85	(10.99, 16.36)	.648
U1/L1, °	147.45 ± 12.49	(140.53, 154.37)	147.47 ± 13.50	(139.99, 154.95)	.980
OJ, mm	4.41 ± 1.95	(3.33, 5.49)	4.44 ± 1.91	(3.37, 5.50)	.908
OB, mm	5.28 ± 2.91	(3.66, 6.89)	5.38 ± 3.07	(3.68, 7.09)	.400
Molar Rel., mm	2.43 ± 1.44	(1.65, 3.25)	2.18 ± 1.40	(1.40, 2.95)	.036
Lbsup-VRL, mm	84.63 ± 4.84	(81.94, 87.31)	85.01 ± 5.06	(82.20, 87.81)	.487
Lbinf-VRL, mm	78.50 ± 4.19	(76.17, 80.82)	78.90 ± 4.50	(76.40, 81.39)	.489
Pog'-VRL, mm	72.44 ± 4.54	(69.92, 74.96)	72.86 ± 4.88	(70.16, 75.57)	.450
Labiomental, °	106.73 ± 18.69	(96.38, 117.08)	105.23 ± 20.91	(93.64, 116.81)	.583

[a] Values for T1 and T2 are the mean ± the standard deviation. CI indicates confidence interval.
* $P < .01$; paired-sample *t*-test.

studies.[4,6,9,12,15–17,19,20] Molar intrusion and distalization with FRD is an expected result because of the vertical and distal force vectors of the appliance.[4–6,15] In this investigation, less intrusion in both treatment groups may be due to engagement of maxillary teeth in a thick, rectangular stainless steel archwire, with "figure 8" ligature forming one unit. The distally directed force of the FRD caused maxillary incisor extrusion and retrusion in both treatment groups, but only palatal tipping in the FRDMS group. This could be explained by insignificant greater retrusion of maxillary incisors and distalization of maxillary molars in the FRDMS.

Labial tipping of mandibular incisors is a well-known, unfavorable effect of functional therapy. In the current study, proclination of mandibular incisors was effectively minimized in the FRDMS group with the use of miniscrews, which may be an advantage in the treatment of Class II malocclusions already with protrusive mandibular incisors. In the literature, various options, such as using negative-torqued lower incisor brackets[4,8,9,12,21] or using fixed functional appliances on sectional arches,[4,8,12] have been used to prevent incisor proclination, but none of these systems was successful.

The Forsus device applies downward and forward forces to the mandibular dentition, and because of this effect, mandibular molars extruded in both treatment groups. However, mesial movement and tipping of the mandibular molars was not significant in the FRDMS group, like mandibular incisors, which were related to

Table 6. The Mean Differences (T2-T1) and 95% Confidence Intervals of Skeletal Parameters in Each Group and Significance Values of the Differences Between FRDMS (1), FRD (2), and Control (3) Groups[a]

	1	95% CI	2	95% CI	3	95% CI	*P*	*P* (1–2)	*P* (1–3)	*P* (2–3)
SN, mm	0.44 ± 0.54	(0.16, 0.77)	0.46 ± 0.85	(0.03, 0.90)	0.53 ± 0.66	(0.16, 0.90)	.071			
SNA, °	−0.49 ± 1.01	(−1.11, 0.01)	−0.08 ± 0.50	(−0.34, 0.18)	−0.03 ± 0.59	(−0.36, 0.30)	.345			
A-VRL, mm	0.13 ± 1.02	(−0.48, 0.68)	0.07 ± 1.08	(−0.49, 0.63)	0.25 ± 0.82	(−0.20, 0.71)	.869			
FH/NA, °	−0.34 ± 1.31	(−1.14, 0.34)	−0.26 ± 0.95	(−0.76, 0.23)	−0.05 ± 0.55	(−0.35, 0.26)	.655			
SN/ANSPNS, °	0.42 ± 0.86	(−0.06, 0.93)	0.41 ± 1.33	(−0.28, 1.10)	0.09 ± 0.99	(−0.46, 0.64)	.630			
SNB, mm	−0.17 ± 1.00	(−0.76, 0.06)	−0.03 ± 0.80	(−0.44, 0.38)	0.09 ± 0.87	(−0.39, 0.58)	.707			
B-VRL, mm	−0.03 ± 1.63	(−1.01, 0.41)	0.25 ± 1.61	(−0.58, 1.08)	0.46 ± 1.65	(−0.46, 1.38)	.705			
Pog-VRL, mm	0.17 ± 1.85	(−0.92, 0.61)	−0.09 ± 1.62	(−0.92, 0.75)	0.31 ± 1.69	(−0.63, 1.25)	.809			
Ar-Pog, mm	1.05 ± 2.14	(−0.28, 2.12)	0.91 ± 2.34	(−0.29, 2.12)	1.03 ± 1.48	(0.21, 1.85)	.529			
FH/NPog, °	−0.05 ± 1.32	(−0.88, 0.50)	−0.29 ± 0.86	(−0.74, 0.15)	−0.25 ± 1.02	(−0.82, 0.32)	.792			
ANB, °	−0.31 ± 1.19	(−0.83, 0.43)	−0.11 ± 0.88	(−0.57, 0.34)	−0.13 ± 0.71	(−0.52, 0.27)	.507			
N-A-Pog, °	−0.36 ± 1.90	(−1.42, 0.68)	0.07 ± 2.24	(−1.07, 1.23)	−0.36 ± 1.65	(−1.28, 0.54)	.571			
N-Me, mm	2.25 ± 1.94	(1.09, 3.31)	1.28 ± 2.18	(0.15, 2.40)	1.31 ± 1.56	(0.44, 2.17)	.148			
ANS-Me, mm	1.81 ± 1.54	(0.89, 2.65)	1.18 ± 2.25	(0.02, 2.34)	0.91 ± 1.04	(0.33, 1.48)	.103			
S-Go, mm	1.53 ± 1.67	(0.52, 2.01)	1.26 ± 1.79	(0.34, 2.19)	0.85 ± 1.61	(−0.04, 1.75)	.546			
SN/GoGn, °	0.71 ± 1.27	(0.29, 1.49)	0.21 ± 1.14	(−0.38, 0.80)	0.20 ± 1.09	(−0.41, 0.81)	.383			
Ar-Go-Me, °	0.33 ± 1.21	(−0.41, 0.97)	−0.16 ± 1.89	(−1.14, 0.81)	0.07 ± 1.58	(−0.81, 0.94)	.679			
ANSPNS/GoMe, °	−0.01 ± 1.13	(−0.40, 0.70)	−0.44 ± 1.94	(−1.44, 0.56)	0.19 ± 1.35	(−0.57, 0.94)	.495			

[a] FRD indicates fatigue resistant device; FRDMS, FRD treatment used with miniscrew anchorage; CI, confidence interval. Values for groups 1, 2, and 3 are expressed as the mean distance ± the standard deviation.

* $P < .01$; one-way analysis of variance.

Table 7. The Mean Differences (T2-T1) and 95% Confidence Intervals of Dentoalveolar and Soft Tissue Parameters in Each Group and Significance Values of the Differences Between FRDMS (1), FRD (2), and Control (3) Groups[a]

	1	95% CI	2	95% CI	3	95% CI	*P*	*P* (1–2)	*P* (1–3)	*P* (2–3)
U6-VRL, mm	−2.11 ± 1.66	(−2.92, −1.08)	−1.45 ± 0.83	(−1.88, −1.02)	0.32 ± 1.13	(−0.32, 0.95)	<.001*		*	*
U6-HRL, mm	0.00 ± 1.28	(−0.54, 0.80)	−0.63 ± 1.20	(−1.25, −0.01)	0.92 ± 1.24	(0.23, 1.61)	.003*			*
U6/HRL, °	−2.53 ± 4.66	(−3.88, 0.28)	−3.92 ± 3.34	(−5.64, −2.20)	−0.21 ± 2.86	(−1.79, 1.38)	.024			
L6-VRL, mm	1.39 ± 1.83	(0.28, 1.96)	1.95 ± 1.33	(1.27, 2.64)	0.57 ± 1.42	(−0.22, 1.35)	.054			
L6-MP, mm	1.43 ± 1.40	(0.55, 2.03)	1.53 ± 1.46	(0.78, 2.28)	0.38 ± 0.74	(−0.03, 0.79)	.026			
L6/MP, °	0.30 ± 2.91	(−1.37, 0.90)	3.24 ± 3.19	(1.59, 4.88)	0.20 ± 3.13	(−1.54, 1.94)	.010*	*		*
U1-VRL, mm	−3.16 ± 1.90	(−4.26, −2.08)	−1.79 ± 1.90	(−2.77, −0.81)	0.35 ± 1.41	(−0.43, 1.14)	<.001*		*	*
U1-HRL, mm	2.01 ± 1.79	(0.92, 2.95)	0.77 ± 0.91	(0.30, 1.24)	0.98 ± 0.93	(0.46, 1.50)	.063			
U1/HRL, °	−8.94 ± 5.70	(−11.78, −5.42)	−2.68 ± 4.43	(−4.95, −0.40)	0.13 ± 2.29	(−1.15, 1.40)	<.001*	*	*	
L1-VRL, mm	1.09 ± 1.76	(0.09, 1.44)	2.34 ± 1.68	(1.47, 3.20)	0.30 ± 1.43	(−0.50, 1.10)	.004*			*
L1-MP, mm	−0.73 ± 1.41	(−1.48, 0.12)	−1.45 ± 1.27	(−2.11, −0.80)	0.73 ± 0.72	(0.33, 1.14)	<.001*		*	*
L1/MP, °	3.61 ± 5.07	(0.46, 5.52)	9.29 ± 3.81	(7.33, 11.25)	−0.60 ± 2.34	(−1.90, 0.70)	<.001*	*		*
SN/OP, °	3.66 ± 3.24	(1.67, 5.30)	3.78 ± 3.33	(2.06, 5.49)	−0.27 ± 2.26	(−1.53, 0.98)	.000*		*	*
U1/L1, °	3.72 ± 6.51	(0.03, 7.50)	−6.09 ± 4.42	(−8.36, −3.82)	0.02 ± 3.01	(−1.65, 1.69)	<.001*	*		*
OJ, mm	−4.28 ± 2.15	(−4.87, −2.99)	−4.08 ± 2.02	(−5.12, −3.03)	0.03 ± 0.87	(−0.46, 0.51)	<.001*		*	*
OB, mm	−1.53 ± 1.19	(−2.01, −0.78)	−2.68 ± 1.52	(−3.46, −1.90)	0.11 ± 0.47	(−0.16, 0.37)	<.001*	*	*	*
Molar Rel, mm	−3.50 ± 2.06	(−3.92, −2.32)	−3.39 ± 1.72	(−4.28, −2.51)	−0.41 ± 0.69	(−0.80, −0.03)	<.001*		*	*
LbSup-VRL, mm	−0.40 ± 1.90	(−1.45, 0.65)	−0.41 ± 1.67	(−1.27, 0.44)	0.38 ± 2.06	(−0.76, 1.52)	.415			
Lbinf-VRL, mm	0.23 ± 2.13	(−0.95, 1.41)	1.47 ± 1.77	(0.55, 2.38)	0.40 ± 2.18	(−0.80, 1.60)	.115			
Pog'-VRL, mm	−0.43 ± 2.05	(−1.65, 0.70)	0.59 ± 2.19	(−0.54, 1.71)	0.42 ± 1.90	(−0.63, 1.47)	.343			
Labiomental, °	8.13 ± 10.94	(2.07, 14.19)	14.56 ± 13.17	(7.78, 21.33)	−1.50 ± 10.33	(−7.22, 4.22)	.001*			*

[a] FRD indicates fatigue resistant device; FRDMS, FRD treatment used with miniscrew anchorage; CI, confidence interval. Values for groups 1, 2, and 3 are expressed as the mean distance ± the standard deviation.

* $P < .01$; one-way analysis of variance.

increased anchorage of mandibular dentition with miniscrews.

The decrease in overbite was greater in the FRD group than in the FRDMS group due to a combination of insignificant greater relative intrusion of mandibular incisors and less extrusion of maxillary incisors in the FRD group. In both treatment groups, overjet correction was totally dentoalveolar, mostly by retrusion of maxillary incisors in the FRDMS group, whereas lower incisor protrusion was greater in the FRD group.

Likewise overjet correction, molar correction was completely dentoalveolar in both treatments. In the FRDMS group, 3.50-mm molar correction was achieved by a contribution of 2.11 mm of maxillary molar distalization and 1.39 mm of mandibular molar mesialization, whereas in the FRD group, 3.39 mm of molar correction consisted of 1.45 mm of maxillary molar distalization and 1.95 mm of mandibular molar mesialization. Consequently, distal movement of maxillary dentition was more apparent in the FRDMS group due to increased anchorage of mandibular dentition by miniscrews; the force constructed by FRD was mostly transmitted to the posterior maxillary dentition. In another FRD study, Jones et al.[5] reported that molar correction was predominately due to mesial mandibular skeletal and dental movements; however, treatment duration was 2.7 years. Karacay et al.[4] reported equal amounts of distal maxillary molar and mesial mandibular molar movements with the Forsus Nitinol Flat Spring. In the present study, the lower lip protruded and the labiomental angle increased significantly only in the FRD group due to prominent dentoalveolar changes. These findings are similar to those of Nalbantgil et al.[12]

CONCLUSIONS

- Overjet and molar correction was totally dentoalveolar in both treatment groups.
- Usage of miniscrews during FRD application was effective in minimizing labial tipping of mandibular incisors when miniscrews stay stable during treatment.

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ERRATUM—Aslan BI, Kucukkaraca E, Turkoz C, Dincer M. Treatment effects of the Forsus fatigue resistant device used with miniscrew anchorage. *Angle Orthod*. 2014;84:76–87. Page 76 of the article states that ''The FRD is a three-piece, telescoping system incorporating a superelastic nickel-titanium coil spring…'' The spring is actually a stainless steel coil spring. We apologize for the error.