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Comparison of the effects of fixed and removable functional appliances on the skeletal and dentoalveolar structures

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Objective: To compare and analyse the effects of activator and Forsus FRD EZ appliances in the treatment of skeletal Class II division I malocclusion.

Methods: Lateral cephalograms and hand-wrist radiographs were collected from 24 Class II division I growing patients (14 females, 10 males). The patients were randomly divided into two equal groups and either treated with an activator appliance (Mean age 12.67 ± 1.24 years) or with a Forsus FRD EZ appliance (Mean age 12.31 ± 1.09 years). Pretreatment and post-treatment cephalometric radiographs were obtained, traced, superimposed and data analysed using paired *t*-tests and the Wilcoxon signed rank test.

Results: The results demonstrated that the Forsus FRD EZ effectively corrected the Class II malocclusion, but the changes were mainly dentoalveolar. The Forsus FRD EZ appliance induced a clockwise rotation of the occlusal plane without significant alteration in the vertical facial dimension. Skeletally, maxillary growth was restricted and pogonion moved forward which improved the profile.

Conclusion: The Forsus FRD EZ appliance may be an effective dentoalveolar treatment method to manage a skeletal imbalance and improve the profile in growing patients.

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Introduction

The skeletal and dental characteristics plus the timing and methods of treatment of Angle Class II division 1 malocclusions have been studied widely. The main reason for the extensive investigations is the high prevalence of this malocclusion in the population which is reported to constitute 12-49 per cent of all orthodontic disorders.[1,2] According to McNamara, the most common single characteristic of Class II malocclusions is mandibular skeletal retrusion, rather than maxillary prognathism.[3] Consequently, the modification and redirection of mandibular growth, by posturing of the mandible into a more forward position, remains the main goal of Class II treatment protocols.[4–7] This has been reported to produce orthopaedic and orthodontic effects.[8,9]

The first documented fixed functional appliance was developed in 1909 by Herbst.[10] The original appliance was stiff, non-flexible, impeded chewing and tooth cleaning and made treatment uncomfortable for the patient. Additionally, construction and placement were complex and time- and cost-intensive.[11,12] It was not until the1970s that the Herbst appliance was rediscovered and gained orthodontic popularity.

In the 1920s, Andresen introduced the activator appliance which remains a widely and successfully-used functional appliance.[13] Because this appliance is removable, more reliance is placed on patient cooperation. Treatment effects in skeletal Class II malocclusions have been reported to be a 2-4 mm per year increase in mandibular growth.[14-18]

Jasper developed and patented a 'Bite Jumper' in 1987. It was designed as a flexible, covered helical compression spring which could be positioned between the upper and lower jaws during fixed orthodontic treatment.[10] Although force application can be large and damage often caused to the buccal mucosa, the 'Jumper' was usually well tolerated by

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patients.[19] Disadvantages of the appliance include deformation and the risk of breakage with time.[20]

The Forsus Nitinol Flat Spring (FNFS) is an alternative fixed functional appliance described by Vogt in 2001.[21] The FNFS appliance is thinner than other functional appliances and therefore more comfortable for patients. However, application is reportedly more difficult in the posterior area.[22–24] More recently, the Forsus Fatigue-resistant Device (FRD) EZ module was developed and has the advantage of ease of application onto molar band headgear tubes, without additional implementation. Although this is of clinical convenience, the appliance was reported to be fragile and prone to fracture in use.[24]

Because there are few reports in the literature regarding the effects of the Forsus FRD EZ appliance, the purpose of this study was to compare the dental and skeletal changes obtained using this new appliance with the Andresen-type activator.

Method

Twenty-four patients (14 males, 10 females) with Class II division I malocclusions were selected after a diagnostic analysis of their pretreatment cephalograms. The patients were randomly divided into two groups. The Forsus FRD EZ group consisted of 12 patients, with a mean age of 12.31 ± 1.09 years. The mean age of the 12 patients in the activator group was 12.67 ± 1.24 years (Table I). A control group was not considered in the present study, as several reports have indicated that it is unethical and difficult to follow an untreated group of Class II patients.[25-27]

Patients were selected and matched according to the following criteria: 1) patients were in an active growth period, 2) possessed a Class II skeletal relationship due to a retrognathic mandible, 3) had an increased overjet, 4) normal or reduced incisor-mandibular plane angle, 5) well-aligned lower arch and 6) a normal or forward growth pattern. Skeletal age was used for selecting the patients and peak growth period was defined using hand-wrist radiographs and the cervical vertebral maturation (CVM) method.[28]

Fixed appliance design and application

The orthodontic appliances used upper bands with triple attachments and 0.018 inch Roth metal brackets (Gemini, 3M Unitek, Monrovia, CA, USA). After levelling (mean time, 6 months), 0.017 x 0.025 inch stainless steel arch wires were engaged in both arches, after which, the Forsus FRD EZ was placed. The appliance was supplied in four lengths of 25, 29, 32 and 35 mm. Appropriate selection was based on the manufacturer's instructions after measurement of the distance from the distal end of the upper molar tube to a point distal to the cuspid bracket when the patient closed in centric occlusion. The assembled Forsus FRD EZ was inserted into the headgear tube and attached anteriorly to a stainless steel bypass arch (Figure 1).



Figure 1. Intra-oral photograph of the Forsus FRD EZ.

Activator design and application

An acrylic activator, retained by upper Adams' clasps and incorporating a central expansion screw, was manufactured from a construction bite that positioned the mandible anteriorly to an edge-to-edge incisor relationship.[29] The height of the bite registration exceeded the freeway space by 2-4 millimetres and was obtained 3 mm short of maximum protrusion, with care taken to ensure that mandibular lateral displacement did not occur. The incisal edges and 2 mm of the labial surfaces of the

Table I. Pretreatment age differences between the samples.

Groups	Mean	SD	*p*
Activator	12.67	1.24	ns (.41)
Forsus FRD EZ	12.31	1.09	

ns, not significant

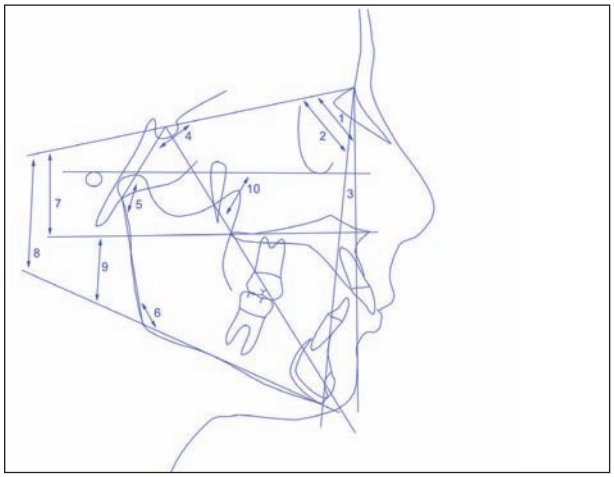


Figure 2. Skeletal angular measurements used in the study. 1, SNA; 2, SNB; 3, ANB; 4, S; 5, Ar; 6, Go; 7, SN/PP; 8, SN/MP; 9, PP/MP; 10, y-axis.

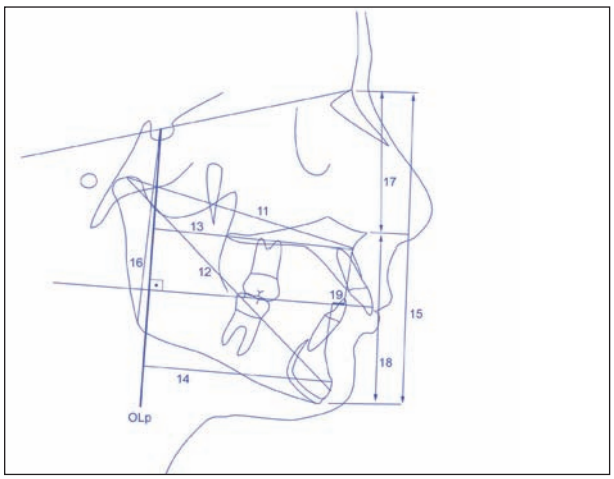


Figure 3. Skeletal linear measurements used in the study. 11, Co-A; 12, Co-Gn; 13, A-OLP; 14, Pog-OLP; 15, N-ME; 16, S-Go; 17, N-ANS; 18, ANS-ME; 19,WITS.

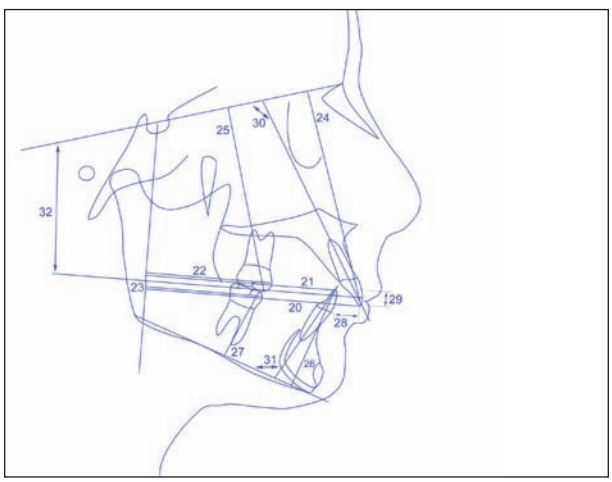


Figure 4. Dental angular and linear measurements used in the study. 20, U1–OLP; 21, L1–OLP; 22, U6–OLP; 23, L6–OLP; 24, U1–SN; 25, U6–SN; 26, L1–MP; 27, L6–MP; 28, Overjet; 29, Overbite; 30, U1/SN; 31, L1/MP; 32, SN/Occ.

maxillary and mandibular incisors were capped to prevent tipping and avoid undesirable anterior dental movement. Acrylic contact was maintained between the appliance and the maxillary posterior teeth while the mandibular posterior teeth were encouraged to erupt by acrylic clearance on the occlusal and lingual aspects. The patients were instructed to wear the appliance 24 hours per day.

Patients were reviewed at 4-weekly intervals and the appliances were activated as needed. The average treatment periods for the Forsus FRD EZ and activator appliances were approximately six months. After a Class I molar relationship was obtained, the Forsus FRD EZ appliance was removed and treatment continued with Class II elastics for retention of the treatment results. For retention, activator patients continued to wear their appliance at night for three months. Lateral cephalograms were taken after the levelling phase and immediately after removal of the Forsus appliance. Cephalometric radiographs were also taken before and at the end of six months of activator appliance use.

Cephalometric analysis

All cephalograms were digitised using Nemoceph (Nemoceph, NX 2006, v. 6.0, Madrid, Spain) by the same operator. An analysis of anteroposterior linear changes was performed using the method described by Pancherz.[30-32] A coordinate system consisting of a perpendicular line through sella to the occlusal line (OL) was drawn on the cephalograms taken after Forsus group levelling and before treatment in the activator group. These reference lines were transferred to the final cephalogram by superimposition via the cranial base. The cephalometric points, planes, and parameters measured are shown in Figures 2 to 4.

Statistical methods

Cephalograms of 10 randomly chosen patients were retraced and re-measured to determine measurement error (ME). The reliability of a single measurement was calculated using Dahlberg's[33] formula: $ME = \sqrt{(\Sigma d^2/2n)}$ where d is the difference between the two determinations and n is the number of double registrations. Measurement error was found to be 0.215 for linear and angular measurements.

Statistical analyses were performed using the SPSS 15.0 statistical package (SPSS Inc., Chicago, IL, USA).

The data obtained from the cephalometric tracings were evaluated using the paired *t*-test. The Wilcoxon signed rank test was used to compare groups. A Power test (Minitab 14.0) between pretreatment and post-treatment primary result variables determined that a minimum of 20 subjects was necessary for difference comparisons.

Results

A dental Class I molar relationship was achieved and the overjet decreased with the fixed functional and activator appliances. All patients were corrected to a super-Class I relationship in a mean time of six months. Cephalometric findings of the activator and Forsus FRD EZ treatment groups are shown in Table II.

Skeletal parameters revealed similar improvements in the Forsus FRD EZ and activator treatment groups. Angle ANB decreased in both groups and resulted from mandibular advancement in the activator group and, as a result of maxillary retrusion in the Forsus group. Although maxillary change was inhibited, effective maxillary length (Co–A) increased in the activator group because of condylar changes which also increased posterior face height (S–Go). N–Me and ANS–Me measurements increased but no statistically significant change in posterior mandibular rotation (y-axis) was observed. Similarly, no statistically significant change in L1–SN or IMP angle was noted in the activator group, but protrusion of the mandibular anterior teeth was evident in the Forsus FRD EZ group (Table II).

Dental changes revealed that upper incisors retroclined, extruded, and distally tipped (U1–OLP decreased and U1–SN increased), whereas the lower incisors proclined, intruded, and were labially tipped (L1–OLP increased and L1–MP decreased) in the Forsus group. In addition, upper molar teeth distalised and intruded (decreased U6–OLP and U6–SN). In contrast, lower molars moved mesially and extruded (L6–OLP and L6–MP increased). The dental changes were not limited to the anterior teeth but also involved a posterior rotation of the occlusal plane (SN–Occ increased; Table II).

When pre-and post-treatment measurement group differences were evaluated, only L1–MP measurements showed significance. All other difference measurements between the groups were insignificant.

Discussion

In Europe, distocclusion has an incidence of approximately 37 per cent and is therefore the malocclusion of highest prevalence. Headgear and functional orthodontic appliances have been a valuable means of treating sagittal jaw discrepancies[12,25,34,35] but in contradistinction to headgear, functional appliances endeavour to reposition the mandible forward in growing patients. The activator has been a preferred mandibular repositioning appliance but can inhibit speech, breathing and lateral jaw movement. These disadvantages may lead to decreased patient compliance.

The different effects of the various fixed Class II appliances have been widely described.[11,12,19-24] The most popular appliances used in Europe remain the Herbst appliance, the Jasper Jumper, and the Forsus spring. However, the recently introduced Forsus FRD EZ appliance has received clinical attention and formed the basis of the present study.

Compared with activator effects, a statistically significantly decreased SNA angle was found in the Forsus group, indicating that the appliance was effective in inhibiting forward growth of the maxilla. However, the distance between point A and OLP did not change. It is known that point A is influenced by the dentition and, when upper incisors retrocline, labial tipping of the roots can move point A anteriorly. Although the maxilla was retruded, it was likely that backward displacement of point A was masked because of the dental changes.

The inhibition of the maxilla seen in the present study is at variance with other published studies.[10,20,32,35,36] However, inhibition of maxillary growth following Herbst appliance[37,38] and Forsus treatment has been previously reported.[22-24]

Forward displacement of the mandible was measured in the activator treatment group, but was not found in the Forsus group. A slight posterior mandibular rotation was noted that slightly increased lower anterior face height. These activator findings were similar to those in previous studies examining functional appliances.[39-41]

Dentoalveolar changes were also evident in both appliance groups. The maxillary first molars were significantly intruded and distalised, mimicking a highpull-headgear effect. Intrusion of the upper molars also allowed eruption of the mandibular

Table II. A comparison of pre- and post-treatment changes.

	Activator group					Forsus FRD EZ group				
	Pretreatment		Post-treatment			Pretreatment		Post-treatment		
Values	Mean	SD	Mean	SD	*p*	Mean	SD	Mean	SD	*p*
Angular										
SNA	79.49	3.57	79.03	3.90	n.s.	81.01	2.15	79.82	1.90	*
SNB	73.67	2.14	74.89	2.43	**	73.93	2.15	73.95	2.40	n.s.
ANB	5.83	2.21	4.14	1.93	****	7.09	2.51	5.88	1.93	**
Saddle	125.71	4.95	126.19	5.50	n.s.	127.75	3.71	127.93	3.64	n.s.
Ar	146.13	8.73	144.71	7.95	n.s.	144.89	4.71	145.34	5.01	n.s.
Go	119.77	8.33	120.81	8.24	n.s.	118.38	5.16	118.63	4.09	n.s.
SN/PP	8.57	3.05	9.19	2.50	n.s.	7.84	2.67	8.50	2.43	n.s.
SN/GoMe	32.74	6.23	33.62	6.01	*	32.90	4.07	33.12	4.54	n.s.
PP/MP	24.18	6.22	24.46	5.45	n.s.	25.05	5.05	24.59	5.59	n.s.
Y Axis	60.80	3.42	60.40	3.18	n.s.	61.08	2.70	61.72	2.86	n.s.
U1/SN	106.40	11.1	98.21	5.70	*	106.20	6.03	93.80	8.88	***
Impa	94.88	8.35	98.64	9.75	n.s.	98.06	2.83	105.49	6.06	**
Occ/SN	17.01	3.17	17.08	3.13	n.s.	16.06	3.56	15.91	3.45	n.s.
Linear										
Co-A	81.65	5.62	81.78	5.83	n.s.	84.08	4.65	84.20	3.83	n.s.
Co-Gn	100.99	6.25	104.96	6.68	*	103.28	4.78	104.53	4.85	n.s.
A-OLP	69.88	5.75	69.75	6.66	n.s.	70.37	4.43	69.93	3.74	n.s.
Pog-OLP	67.97	6.06	69.88	7.89	n.s.	66.27	2.91	66.45	3.01	n.s.
N-Me	108.33	7.85	111.22	8.85	n.s.	111.15	2.55	112.47	2.37	n.s.
S-Go	72.35	5.77	74.99	8.29	*	75.89	4.66	75.80	4.09	n.s.
N-ANS	50.05	2.60	50.54	2.87	n.s.	50.24	3.34	50.87	2.61	n.s.
ANS-Me	61.14	6.79	63.18	7.35	*	63.78	2.27	64.60	3.16	n.s.
Wits	5.21	2.90	2.70	2.36	***	6.87	3.23	5.23	4.16	*
U1-OLP	77.67	6.84	74.99	7.75	n.s.	76.56	3.79	72.52	3.36	***
L1-OLP	68.64	6.61	71.78	7.86	*	68.23	3.82	71.67	3.75	****
U6-OLP	47.97	5.53	46.79	6.66	**	46.26	3.29	44.07	3.13	**
L6-OLP	45.82	5.58	49.67	6.74	n.s.	44.41	3.63	48.88	3.29	****
U1-SN	75.89	5.50	76.17	6.00	n.s.	76.59	1.80	78.32	1.68	**
U6-SN	65.09	4.38	64.92	5.65	n.s.	65.54	2.34	63.85	2.11	*
L1-MP	37.85	3.65	37.21	3.30	n.s.	38.38	1.72	35.31	1.99	****
L6-MP	23.78	2.59	25.19	2.51	****	26.30	1.41	27.39	1.11	***
Overjet	9.04	2.91	3.14	0.97	****	8.37	2.28	0.95	2.68	****
Overbite	4.76	1.72	2.49	1.62	*	2.98	1.81	0.51	1.08	**

ns, not significant

* $p < .05$, ** $p < .01$, *** $p < .001$, **** $p < .0001$

molars. The vector of appliance force was considered below and behind the centre of rotation of the maxillary dentition. The molar effects also influenced the incisors through the archwire and the maxillary central incisors extruded and retroclined.

The mandibular incisors were significantly proclined and intruded. Both activator and Forsus FRD EZ appliances applied downward and forward forces to the mandibular dentition and allowed the mandibular molars to extrude and move mesially. Greater lower incisor proclination was evident in the Forsus FRD EZ group than in the activator group. The increase in the IMP angle was also found to be statistically significant in the Forsus FRD EZ group. As a result of the molar and incisal changes, an obvious posterior rotation was noted in the occlusal plane. These dentoalveolar findings correspond to those reported in previous studies using fixed functional appliances.[10,11,20,25-27,30-32,35,36]

As expected, a significant decrease in overjet was seen in both treatment groups. It was considered that the decrease in overjet was dependent on changes in the dentoalveolar structures at the end of the treatment.[6,26,42] Because of the retroclination of the upper incisors and the proclination of lower incisors, the overjet decreased. However, Reey and Eastwood[43] claimed that the overjet decrease was a result of a stimulation of forward mandibular growth, in addition to a retraction of the upper incisors.

Overbite decreased significantly in both treatment groups. This was likely attributed to an increase in the height of the upper and lower posterior processes. In agreement with other studies, the increase in posterior alveolar height was related to a beneficial decrease in the overbite.[7,44]

Conclusions

1. The Forsus FRD EZ appliance provides an alternative to other functional Class II systems.
2. Dental effects, rather than skeletal effects, were observed as corrective benefits in the Forsus FRD EZ group.

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