DOI: 10.2478/aoj-2014-0001

An assessment of late fixed functional treatment and the stability of Forsus appliance effects

Gao Weimin, Li Xiangdong and Bai Yuxing
Department of Orthodontics, School of Stomatology, Capital Medical University, Beijing, China

Objective: To evaluate the treatment effects and stability of Forsus appliance therapy.
Methods: Thirty-one patients (15 males, 16 females) with a mean age of 15.8 ± 3.1 years (range 13 to 17.6 years, 15.3 ± 1.2 years for females and 16.5 ± 1.6 years for males) were selected. All patients had passed beyond their pubertal growth phase (after CS4 or MP3cap). Lateral cephalograms and three-dimensional (3D) models were analysed before treatment (T0), at the end of treatment (T1) and at a follow-up visit (T2). The mean period from T1 to T2 was 25 months and ranged from 17 to 32 months. Tooth position and angulations, together with maxillary and mandibular position, were measured on cephalograms. The inclinations and vertical distance changes of mandibular incisors were measured on a 3D digital model.
Results: The Forsus appliance produced significant skeletal and dental changes during treatment (from T0 to T1). In the sagittal plane, mandibular length (Co-Gn) increased 6.47 mm, the maxillary incisors and molars uprighted (∠U1-SN decreased 8.97° and ∠U6-SN decreased 3.51°), the mandibular incisors proclined (∠L1-MP increased 3.93°) and the mandibular molars advanced (L6-SP increased 3.61 mm). In the vertical plane, the maxilla and mandible rotated clockwise (∠PP-SN, ∠MP-SN, ∠OP-SN increased significantly) and the mandibular molars extruded (L6-MP increased 3.06 mm). All of the changes remained relatively stable after treatment. Cephalometric sagittal and vertical changes affecting the mandibular incisors from T1 to T2 were statistically insignificant ($p > 0.05$) except for lower incisor extrusion (L1-MP, $p < 0.05$).
Conclusion: The Forsus appliance induced significant skeletal and dental changes, which remained relatively stable during the observation period. The mandibular incisors, in particular, were stable two years after treatment.
(Aust Orthod J 2014; 1: 2-10)

Received for publication: December 2012
Accepted: March 2014

Gao Weimin: gaoweimin520@126.com; Li Xiangdong: eastlee1974@163.com; Bai Yuxing: byuxing@263.net

Introduction

Mandibular retrognathic patients are commonly seen in clinical practice. Successful management may involve the manipulation of mandibular growth or the harnessing of residual growth by a fixed-functional appliance therapy after puberty. The Forsus appliance (Forsus Fatigue Resistant Device, 3M Unitek, St. Paul, MN, USA) is a fixed-functional appliance introduced in 2001.[1] Employing a super-elastic, nickel-titanium, coil spring, its mandibular propulsive force is gently released. Studies have reported skeletal and dental effects which may involve growth restraint of the maxilla, an increase in mandibular length, the correction of overjet and the molar relationship, as well as intrusion, protrusion and labial tipping of the mandibular incisors.[2-5] Jones et al.[3] compared treatment changes produced by the Forsus appliance with Class II elastics, and found that there were no statistically significant treatment differences and that the Forsus appliance could be an acceptable substitute for Class II elastics in non-compliant patients. Karacay et al.[2] revealed that the Forsus appliance and the Jasper Jumper produced nearly the same improvements in skeletal, dental, and soft tissue parameters. However, arguments arose when the effects on the TMJ were considered. Arici et al.[6] observed that the condyle was more posteriorly positioned in the glenoid fossa following Forsus treatment and suggested that it was the result of posterior growth of the condyle and anterior remodelling of the posterior border of the glenoid fossa. However Aras et al.,[5] using a magnetic resonance imaging (MRI) analysis, found

Figure 1. Forsus appliance in the mouth.

no positional changes of the mandibular condyle in relation to the glenoid fossa and concluded that the Forsus appliance did not cause significant increases in patient mandibular dimensions during late puberty. Therefore, whether the mandibular dimension increased and mandibular position changed, are still uncertain. Previous studies have reported lower incisor proclination as a consequence of Forsus therapy; however, no studies have reported on long-term incisor stability.

In recent years, 3D digital dental models have been used for orthodontic diagnosis and treatment planning. Non-contact surface laser scanners perform excellent and quick scanning on dental models and acquire a detailed, high-resolution image. Many studies have compared 3D digital models with traditional plaster models and found that accuracy and reproducibility of measurements are comparable and clinically acceptable.[7-12] While 3D digital models have a variety of clinical applications,[13,14] no previous study has used 3D dental models to assess the position of mandibular incisors after Forsus appliance treatment.

By the analysis of cephalograms and digital 3D dental models, the present study aims to describe the effects and stability of mandibular retrognathic patients treated with a Forsus appliance.

Materials and methods

Samples

Thirty-one patients (15 males, 16 females) were selected from the Department of Orthodontics, Beijing Stomatological Hospital, Capital Medical University, China. The mean age was 15.8 ± 3.1 years, (ranging from 13 to 17.6 years; 15.3 ± 1.2 years for females; 16.5 ± 1.6 years for males,) at the beginning of treatment. All subjects (or their parents) agreed to treatment and signed informed consent. The criteria for patient selection were (1) a skeletal Class II pattern with a retrognathic mandible, (2) a permanent dentition with a Class II molar relationship, (3) an overjet exceeding 6 mm, an ANB angle greater than 5° and horizontal or normal skeletal divergency, (4) beyond the pubertal peak growth period (after CS4 on cephalograms or MP3 capping on hand-wrist radiograms), and (5) no facial asymmetry, signs of TMD, or history of orthodontic treatment. Following a previous incomplete treatment plan, eight patients had their maxillary first premolars extracted. For ethical reasons, no control group was designated.

Clinical application

All patients were treated with 0.022 inch slot, straight-wire brackets. After levelling and aligning, 0.019 x 0.025 inch stainless steel rectangular wires, with -5° torque in the mandibular incisor segment, were engaged in both arches. The mandibular archwire was consistently cinched back. In addition, stainless steel ligature wires tightly laced the entire mandibular arch. A Forsus appliance of the appropriate size was applied between the distal end of the maxillary first molar and the mandibular canine (Figure 1). The patients were observed at 4-weekly intervals, and the springs activated every 8 weeks. After the molars had attained a Class I relationship and the anterior teeth were related in an edge-to-edge pattern without overjet, the Forsus appliance was removed in an average treatment period of 6 months. After orthodontic treatment, a Hawley retainer was inserted in all patients.

Cephalometric analysis

Cephalograms were taken before treatment (T0), after orthodontic treatment at appliance removal (T1) and at follow-up (T2). The mean period between the end of treatment and review was 25 months, and ranged from 17 to 32 months. Cephalometric landmarks were located manually, while angular and linear parameters

Table I. Definitions of abbreviations of the less usual cephalometric variables used.

Parameters	Definition
Sagittal distance	
A-SP	Linear distance from Point A to SP line
B-SP	Linear distance from Point B to SP line
L1-SP	Linear distance from the mandibular central incisor edge to SP line
L1R-SP	Linear distance from the mandibular central incisor apex to SP line
L6-SP	Linear distance from the mandibular first molar mesial point to SP line
L6R-SP	Linear distance from the mandibular first molar apical point to SP line
Sagittal angulation	
∠U6-SN	Angle formed by maxillary first molar long axis and SN line
∠L6-MP	Angle formed by mandibular first molar long axis and MP line
Vertical distance	
U1-PP	Linear distance from the maxillary central incisor edge to PP (ANS-PNS) line
L1-MP	Linear distance from the mandibular central incisor edge to MP line
U6-PP	Linear distance from the maxillary mesial point to PP line
L6-MP	Linear distance from the mandibular mesial point to MP line
Vertical angulation	
∠PP-SN	Angle formed by PP line and SN line
∠MP-SN	Angle formed by MP line and SN line
∠OP-SN	Angle formed by occlusal line and SN line

Table II. Measurements before, after treatment with Forsus appliance and follow up.

	T0		T1		T2	
	Mean	SD	Mean	SD	Mean	SD
Sagittal distance						
A-SP	60.64	8.89	61.31	9.62	60.83	6.22
B-SP	46.43	9.46	49.19	13.12	49.16	11.65
L1-SP	57.53	7.06	60.73	9.54	61.04	7.84
L1R-SP	42.33	8.51	44.44	10.31	45.69	10.12
L6-SP	27.29	6.67	30.90	9.19	32.13	7.45
L6R-SP	23.86	6.92	27.76	9.78	29.04	8.52
Overjet	7.16	2.77	2.40	1.63	2.49	0.80
Overbite	2.36	0.85	1.43	1.03	1.83	1.04
Cd-Gn	100.06	8.71	106.53	9.62	107.14	9.60
Sagittal angulation						
SNA	82.47	6.74	81.71	6.73	81.51	5.58
SNB	73.43	4.95	74.61	6.12	74.87	6.87
ANB	9.04	2.94	7.10	3.54	6.89	2.36
∠U1-SN	109.26	9.50	100.29	5.99	100.04	6.05
∠U6-SN	76.40	4.60	72.89	6.18	72.51	6.36
∠L1-MP	104.34	4.84	108.27	5.66	106.67	5.67
∠L6-MP	79.29	3.61	75.29	5.02	75.56	3.74
Vertical distance						
U1-PP	28.63	3.43	30.65	4.31	30.57	4.53
L1-MP	39.91	3.98	41.44	2.93	42.03	2.88
U6-PP	18.81	1.77	21.17	1.93	22.89	2.07
L6-MP	29.91	3.48	32.97	3.48	33.33	3.83
ANS-Me	66.00	4.83	70.47	4.13	71.44	4.30
Vertical angulation						
∠PP-SN	8.30	3.44	10.00	4.07	9.94	4.27
∠MP-SN	39.36	8.57	40.79	9.43	40.67	9.73
∠0P-SN	23.79	5.47	24.69	6.29	24.49	6.27

were analysed by software (Wincep 8.0, Rise Corp., Miyagi, Japan) to an accuracy of ± 0.1 mm. One investigator (GWM) performed all measurements at two different time intervals, and mean values were used in the final evaluation. The method error ranged from 0.14° to 0.58° for angular measurements and from 0.23 to 0.42 mm for linear measurements.

Coordinate axes were constructed with S-point (sella) as the origin. A line drawn from sella at an angle of -7° to the SN plane was defined as the horizontal plane. A line perpendicular to the horizontal plane through sella was defined as the vertical plane.

Parameters indicating sagittal distances (A-SP, B-SP, L1-SP, L1R-SP, L6-SP, L6R-SP, overjet, overbite, Co-Gn), sagittal angulations (SNA, SNB, ANB, ∠U1-SN, ∠U6-SN, ∠L1-MP, ∠L6-MP), vertical distances (U1-PP, L1-MP, U6-PP, L6-MP, ANS-Me), vertical angulations (∠PP-SN, ∠P-SN, ∠OP-SN) were measured (Table I, Figure 2).

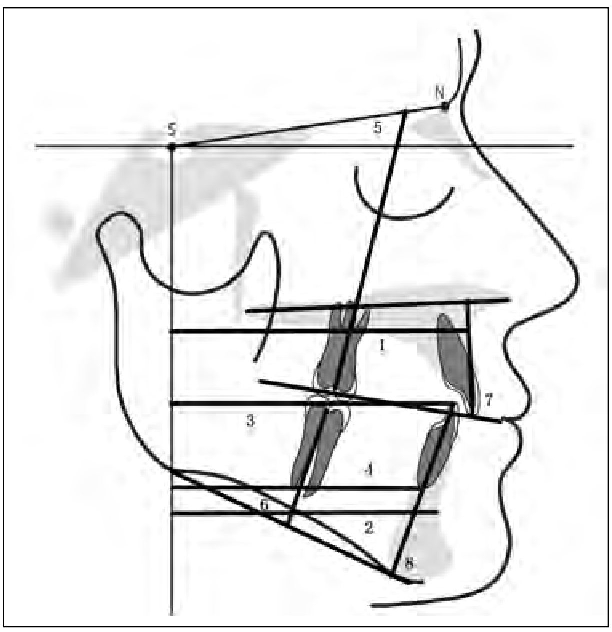

Figure 2. Some of the cephalometric analysis measurements: 1, A-SP; 2, B-SP; 3, L1-SP; 4, L1R-SP; 5, ∠U6-SN; 6, ∠L6-MP; 7, U1-PP; 8, L1-MP.

Analysis of 3D digital dental models

Plaster dental casts were also taken at T1 and T2. A non-contact surface laser scanner (Range 7, Konica-Minolta, Osaka, Japan) was used to scan all of the models. The scanning procedure required that the study models be placed on a rotary stage which automatically turned in 10° increments. Each model was scanned 36 times to produce one revolution, which converted the surface to a lattice of 1.31 million connected points. The 3D images were subsequently reconstructed by computer software (Polygon Editing Tool, Konica-Minolta) and 3D digital dental models with an accuracy of ± 0.02 mm were generated.

For the measurements on 3D digital dental models, a horizontal reference plane was established by a software programme (Rapidform XOV/Verifier, INUS Technology, Seoul, South Korea), according to the following procedure: (1) the facial surface of the mandibular teeth (except for the incisors) was manually selected with the help of the software, (2) the geometric centre of the selected areas was generated automatically and used as a landmark, and (3) a horizontal reference plane was software constructed automatically, so that there were minimal vertical distances to all the generated landmarks.

The midpoints of the incisal edges of the mandibular central and lateral incisors were identified. The vertical distance between these points and the reference plane was recorded at T1 and T2. The distance reflected dental change and therefore stability of the mandibular incisors in the vertical plane (Figure 3).

Planes tangent to the labial surface of each mandibular incisor were established and the axes of the clinical crowns were projected onto these planes. The angles

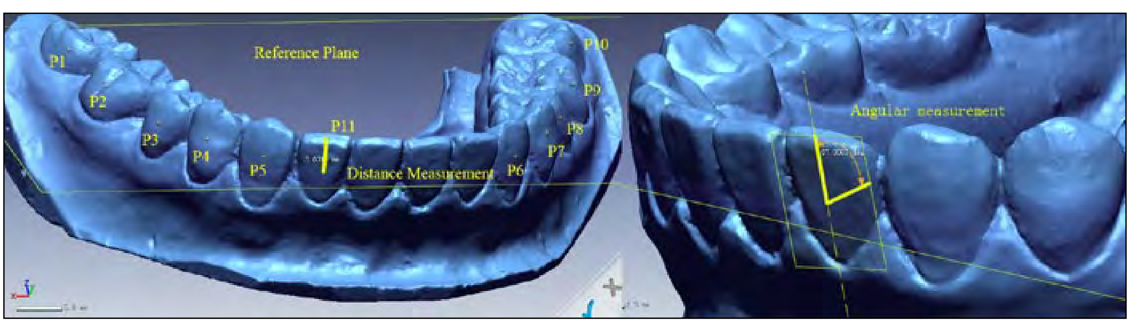

Figure 3. Established reference plane and measurement of 3D digital dental models.

Table III. Treatment changes and stability of Forsus appliance.

	T0-T1		T1-T2		F
	Mean	p	Mean	p	
Sagittal distance					
A-SP	0.67	0.882	0.19	0.967	0.012
B-SP	2.76	0.659	-0.03	0.996	0.133
L1-SP	3.20	0.475	0.31	0.944	0.393
L1R-SP	2.11	0.688	1.24	0.813	0.215
L6-SP	3.61	0.040*	1.23	0.773	5.721
L6R-SP	3.90	0.041*	1.29	0.780	5.708
Overjet	-4.76	0.000**	0.09	0.934	14.175
Overbite	-0.93	0.000**	0.40	0.452	11.600
Co-Gn	6.47	0.021*	0.61	0.903	3.242
Sagittal angulation					
SNA	-0.76	0.827	-0.20	0.954	0.044
SNB	1.19	0.717	0.26	0.937	0.114
ANB	-1.94	0.239	-0.21	0.895	0.352
∠U1-SN	-8.97	0.035*	-0.24	0.951	3.560
∠U6-SN	-3.51	0.046*	-0.37	0.905	5.967
∠L1-MP	3.93	0.019*	-1.60	0.586	2.936
∠L6-MP	-4.00	0.090	0.27	0.904	2.010
Vertical distance					
U1-PP	2.02	0.001**	0.08	0.096	11.732
L1-MP	1.53	0.398	0.59	0.044*	5.764
U6-PP	2.36	0.340	1.71	0.113	7.897
L6-MP	3.06	0.037*	0.36	0.954	3.044
ANS-Me	4.47	0.034*	0.97	0.686	3.009
Vertical angulation					
∠PP-SN	1.70	0.043*	-0.06	0.979	5.419
∠MP-SN	1.43	0.048*	-0.11	0.982	5.051
∠0P-SN	0.90	0.037*	-0.20	0.760	4.419

*$p < 0.05$; **$p < 0.01$
F, one-way ANOVA

between the projections and the reference plane were measured at T1 and T2, and considered to reflect the stability of the mandibular incisors in the sagittal plane (Figure 3).

Statistical methods

Statistical analysis was performed using SPSS version 17.0 (SPSS Corp., Chicago, IL, USA). Mean and standard deviations were used to describe central tendencies and dispersion. Paired *t*-tests and one-way ANVOA (F test) were used to evaluate changes over time. $P < 0.05$ was regarded as statistically significant.

Results

Cephalometric analysis

The cephalometric analysis (Tables II and Table III) indicated that the Forsus appliance induced significant skeletal and dental changes. In the sagittal direction, total mandibular length increased (Co-Gn) increased by 6.47 mm. Dental changes included the retroclination of the maxillary incisors (∠U1-SN decreased 8.97°), distal tipping of the maxillary molars (∠U6-SN decreased 3.51°), proclination of the mandibular incisors (∠L1-MP increased 3.93°) and the mesial movement of the mandibular molars

Table IV. Descriptive statistics and statistical comparisons of the inclination changes between T1 and T2 for 3D model measurement.

	T1		T2		T1-T2			
	Mean	SD	Mean	SD	Mean	SD	*t*-test	*p*
31	93.52	6.85	91.65	7.82	-1.86	0.65	-1.504	0.167
32	89.06	6.58	86.94	7.75	-2.12	1.05	-1.060	0.317
41	92.01	7.83	89.58	7.85	-2.43	0.93	-1.383	0.200
42	89.54	7.46	89.31	8.08	-0.23	0.74	-0.163	0.874

Table V. Descriptive statistics and statistical comparisons of the vertical distance changes between T1 and T2 for 3D model measurement.

	T1		T2		T1-T2			
	Mean	SD	Mean	SD	Mean	SD	*t*-test	*p*
31	3.41	1.05	3.58	0.67	0.17	0.11	0.822	0.432
32	2.92	0.79	3.27	0.51	0.35	0.10	1.807	0.104
41	3.39	1.05	3.70	0.71	0.32	0.09	1.838	0.099
42	3.16	0.82	3.45	0.58	0.29	0.10	1.496	0.169

(L6-SP increased by 3.61 mm). The maxilla and mandible rotated in a clockwise direction (∠OP-SN increased 0.90°, ∠MP-SN increased 1.43° and ∠PP-SN increased 1.70°). Dental changes included the extrusion of maxillary incisors (U1-PP increased 2.02 mm) and mandibular molars (L6-MP increased 3.06 mm).

Angular and linear measurements reflecting changes of the maxilla and mandible in the sagittal and vertical planes from T1 to T2 are shown in Table I and Figure 3. All of the skeletal and dental differences were statistically insignificant ($p > 0.05$) except for L1-MP ($p < 0.05$). Sagittal linear measurements indicated insignificant movement of the mandibular incisors (L1-SP and L1R-SP increased), while angular measurements identified insignificant retroclination (∠L1-MP slightly decreased). Vertical parameters revealed significant extrusion (L1-MP increased 0.86 mm).

3D digital model analysis

Tables IV and V show the angular and linear parameters analysed on the 3D digital models. Mandibular incisor inclination decreased slightly (0.23°- 2.43°) from T1 to T2, but the changes were of no statistical significance ($p > 0.05$). In addition, the mandibular incisors extruded slightly (0.17 - 0.35 mm) from T1 to T2 but the changes were again statistically insignificant ($p > 0.05$).

Discussion

Cephalometric analysis

The Forsus appliance can produce skeletal and dental effects in the sagittal and vertical planes.[1-5] Similar to the Jasper Jumper and the Eureka Spring,[15-17] the appliance effects are mainly dentoalveolar, while the Herbst and MARA[18-20] have been shown to have a moderate skeletal effect.

Most studies have indicated that the Forsus appliance may stimulate mandibular sagittal growth, inhibit maxillary growth, advance and protrude the mandibular incisors and advance the mandibular molars.[1-5] In the present study, a slight inhibition of maxillary growth (A-SP and SNA were reduced) and an increase in mandibular length were observed, indicating that the appliance possibly affected mandibular growth. As all of the patients were in their late pubertal stage, the mandibular changes may be explained by Forsus appliance stimulation of residual growth. In addition, the appliance likely re-established the mandible in a forward and downward position and promoted changes to the condyle in a superior and posterior direction, along with anterior remodelling of the glenoid fossa.

For ethical considerations, no control group was assigned to this study. However, records of growth changes in untreated Class II subjects attained from longitudinal growth studies (the University of Michigan Growth Study and the Denver Growth

Study) showed that Co-Gn increased 1.9 mm on average from CS5 to CS6, and 1.0 mm from CS6 to adulthood in caucasians.[21,22] In the present study, Co-Gn increased 6.43 mm, which was considerable even allowing for ethnic differences. The maxillary incisors were uprighted and retruded, which assisted in correction of the overjet, and the maxillary molars distalised. As the force produced by the Forsus appliance was at a distance from the rotation centre of the molars and, as the propulsive force was slightly above the centre of resistance of the clinical crowns, proclination and protrusion of the mandibular incisors were inevitable. A biomechanical finite element model analysis has indicated that the anterior region of the mandibular dentition experiences the most tensile stress.[23] In clinical practice, mandibular incisor proclination is also the most pronounced dentoalveolar side effect seen during fixed functional appliance treatment.[23-27]

The mandibular incisors were intruded during Forsus treatment and influenced by the vertical vector of the propulsive force. Accompanying the extrusion of the mandibular molars, the occlusal plane rotated in a clockwise direction.[20,24]

The forward and downward Forsus force vectors rotated the mandible clockwise and accordingly, also rotated the maxillary occlusal plane clockwise (∠PP-SN, ∠MP-SN, ∠OP-SN increased significantly). The rotations, combined with proclination of the mandibular incisors, improved the overbite, which was beneficial to patients who had a reduced or average mandibular plane angle. However, for patients possessing a high mandibular plane angle, the rotations would exacerbate the maxillary and mandibular discrepancy and damage the profile.

The present study found that the Forsus appliance induced skeletal and dental changes and that the changes remained relatively stable after treatment. The occlusal plane angle (∠OP-SN) was 24° after Forsus treatment and was within a normal vertical range (21.2 ± 3.8°). A stable occlusal relationship was established which assisted the stability of the clockwise rotation of the maxilla and mandible. Skeletal changes were in accordance with previous studies which examined the Herbst appliance,[20,24] and indicated that the stability of the Forsus appliance compared favourably.

Incisor stability

The proclination, protrusion, and intrusion of the mandibular incisors alleviated overjet and overbite disharmony during treatment. However, the short-term and long-term stability of the incisors remains questionable. Since the former lip-tongue muscle balance was disturbed as the mandibular incisors were forced into new positions, the teeth tended to move towards their original positions. Reports on the stability of the Herbst appliance indicated that approximately 90% of dental change occurred during the first 6 months after treatment.[28] During this period in the present study, the mandibular incisors retroclined 0.3° to 2.5°, retruded 2.1 to 3.4 mm, extruded 0.6 to 0.9 mm and continued to change in the long term until the end of growth.[29-33] Although relapse of the mandibular incisors was observed post-treatment, most investigators concluded that the changes were clinically acceptable and that treatment with the Herbst appliance showed good occlusal stability.[29-33] Ghislanzoni et al.[19] also found that the mandibular incisors had a relapse tendency post-MARA treatment, but the tendency was clinically insignificant.

Many studies have cephalometrically assessed the effectiveness and stability of fixed-functional appliances.[29-33] As it is difficult to find a reproducible reference plane on a plaster model, these studies only assessed arch width, crowding, or occlusal traits without reporting on incisor inclination. Artun et al.[34] measured available mandibular anterior space and the irregularity index on plaster models of patients treated with the Herbst appliance. It was found that the available space remained almost unchanged and that the irregularity index decreased from 2.8 to 2.4 mm in the first 6 months following treatment, while the available space decreased by 0.8 mm and the irregularity index increased by 2.0 mm thereafter.

No report on Forsus appliance stability has been published and no study has assessed lower incisor stability using digital models. The present study is therefore the first to investigate the stability of Forsus-treated cases, on cephalograms and on digital models. A reproducible reference plane was necessary as traditional measurements of mandibular plaster models often used the occlusal plane as a guide. The present study focussed on the changes in the mandibular incisors and so a reference plane with minimal vertical distance to the clinical crown centre of the mandibular cusps and posterior teeth was selected. None of the patients had previously experienced restorative or prosthetic treatment, and so the contour of the teeth did not change during the observation period (T1 to T2). In addition, all of the patients wore a Hawley retainer 24 hours each day, which maintained the positions of posterior teeth. It may therefore be assumed that the reference plane, popularised by Pancherz and Wiechmann,[35] remained relatively stable and the method had a high level of reproducibility.

The inclination of the mandibular incisors was measured on the cephalogram and on the digital model at the end of treatment and at follow-up. Measurements showed that the mandibular incisors retroclined slightly during the observation period (0.82° on cephalometric study and 0.23° - 2.43° on the digital models). The measurements differed because, on the cephalogram, the images of the incisors overlapped, and on digital models, each incisor was measured separately. The noted changes were minor and statistically insignificant compared with those reported following Herbst appliance treatment.[29-33] Because the Forsus appliance has a spring pushrod structure, the mandible is advanced gently, in a manner similar to physiological tooth movement. In addition, the compatibility of the Forsus appliance with multi-bracketed appliances enables lacing of the entire mandibular arch and the application of 5° of labial root torque, via the full-size stainless steel wire inserted into the mandibular anterior attachments. These features enhanced the anchorage of the mandibular dentition and possibly reinforced stability as the proclined mandibular incisors remained relatively stable during the observation period.

In the present study, the mandibular incisors extruded 0.86 mm on the cephalogram (statistically significant) and 0.17 - 0.35 mm on the digital model. The mandibular incisors likely continued to erupt, even after the pubertal growth spurt in untreated deep-bite individuals thereby increasing the overbite. Studies[21,22] of untreated Class II individuals have confirmed lower incisor extrusion which has ranged from 0.6 to 1.0 mm. A further possible explanation may relate to maxillofacial muscle balance. Continuous forward movement of the mandible, relative to the maxilla, has a spatial influence on mandibular incisor position and soft tissue balance. The increased strength of the perioral musculature exceeds lingual pressure, which causes the mandibular incisors to upright and extrude under the pressure of the lower lip. This tendency was supported by the present study over an average observation period of two years. The findings suggest that, when treating skeletal retrognathic patients with the Forsus appliance, the proclination and intrusion of the mandibular incisors should be kept within physiological limits.

The observation period of this study was relatively short and extended over 25 months post-treatment on average (the longest was 32 months). The samples were limited and so, in future, additional samples should be included and the observation period extended so that long-term stability of Forsus appliance treatment can be determined.

Conclusion

The Forsus appliance can produce noticeable skeletal and dental changes even in patients beyond their maximum growth phase. The effects can remain relatively stable two years after treatment, except for extrusion of the mandibular incisors. The present study suggests that proclination and intrusion of mandibular incisors should be kept within physiological limits when using the Forsus appliance.

Corresponding author

Dr Bai Yuxing
Beijing Stomatological Hospital
4th Tiantan Xili
Dongcheng District Beijing
China

Email: byuxing@263.net

References

1. Heinig N, Göz G. Clinical application and effects of the Forsus spring. A study of a new Hebst hybrid. J Orofac Orthop 2001;62:436-50.
2. 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;76:666-72.
3. Jones G, Buschang PH, Kim KB, Oliver DR. Class II non-extraction patients treated with the Forsus Fatigue Resistant Device versus intermaxillary elastics. Angle Orthod 2008;78:332-8.
4. Franchi L, Alvetro L, Giuntini V, Masucci C, Defraia E, Baccetti T. Effectiveness of comprehensive fixed appliance treatment used with the Forsus Fatigue Resistant Device in Class II patients. Angle Orthod 2011;81:678-83.
5. Aras A, Ada E, Saracoğu H, Gezer NS, Aras I. Comparison of treatments with the Forsus fatigue resistant device in relation to skeletal maturity: A cephalometric and magnetic resonance imaging study. Am J Orthod Dentofacial Orthop 2011;140:616-25.
6. Arici S, Akan H, Yakubov K, Arici N. Effects of fixed functional appliance treatment on the temporomandibular joint. Am J Orthod

Dentofacial Orthop 2008;133:809-14.
7. Smith R, Zaitoun H, Coxon T, Karmo M, Kaur G, Townsend G et al. Defining new dental phenotypes using 3-D image analysis to enhance discrimination and insights into biological processes. Arch Oral Biol 2009;54:S118-25.
8. Sousa MV, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofacial Orthop 2012;142:269-73.
9. Choi DS, Jeong YM, Jang I, Jost-Brinkmann PG, Cha BK. Accuracy and reliability of palatal superimposition of three-dimensional digital models. Angle Orthod 2010;80:497-503.
10. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: a systematic review. Orthod Craniofac Res 2011;14:1-16.
11. Abizadeh N, Moles DR, O'Neill J, Noar JH. Digital versus plaster study models: how accurate and reproducible are they? J Orthod 2012;39:151-9.
12. Luu NS, Nikolcheva LG, Retrouvey JM, Flores-Mir C, El-Bialy T, Carey JP et al. Linear measurements using virtual study models. Angle Orthod 2012;82:1098-106.
13. Cha BK, Lee JY, Jost-Brinkmann PG, Yoshida N. Analysis of tooth movement in extraction cases using three-dimensional reverse engineering technology. Eur J Orthod 2007;29:325-31.
14. Lee SJ, Jang SY, Chun YS, Lim WH. Three-dimensional analysis of tooth movement after intrusion of a supraerupted molar using a mini-implant with partial-fixed orthodontic appliances. Angle Orthod 2013;83:274-9.
15. Stromeyer EL, Caruso JM, DeVincenzo JP. A cephalometric study of the Class II correction effects of the Eureka Spring. Angle Orthod 2002;72:203-10.
16. de Oliveira JN Jr, Rodrigues de Almeida R, Rodrigues de Almeida M, de Oliveira JN. Dentoskeletal changes induced by the Jasper jumper and cervical headgear appliances followed by fixed orthodontic treatment. Am J Orthod Dentofacial Orthop 2007;132:54-62.
17. Herrera FS, Henriques JF, Janson G, Francisconi MF, de Freitas KM. Cephalometric evaluation in different phases of Jasper jumper therapy. Am J Orthod Dentofacial Orthop 2011;140:e77-84.
18. Gönner U, Ozkan V, Jahn E, Toll DE. Effect of the MARA appliance on the position of the lower anteriors in children, adolescents and adults with Class II malocclusion. J Orofac Orthop 2007;68:397-412.
19. Ghislanzoni LT, Toll DE, Defraia E, Baccetti T, Franchi L. Treatment and posttreatment outcomes induced by the Mandibular Advancement Repositioning Appliance; a controlled clinical study. Angle Orthod 2011;81:684-91.
20. Pancherz H. The Herbst appliance-its biologic effects and clinical use. Am J Orthod 1985;87:1-20.
21. Stahl F, Baccetti T, Franchi L, McNamara JA Jr. Longitudinal growth changes in untreated subjects with Class II Division 1 malocclusion. Am J Orthod Dentofacial Orthop 2008;134:125-37.
22. Baccetti T, Stahl F, McNamara JA Jr. Dentofacial growth changes in subjects with untreated Class II malocclusion from late puberty through young adulthood. Am J Orthod Dentofacial Orthop 2009;135:148-54.
23. Panigrahi P, Vineeth V. Biomechanical effects of fixed functional appliance on craniofacial structures. Angle Orthod 2009;79:668-75.
24. Pancherz H. Treatment of Class II malocclusion by jumping the bite with the Herbst appliance: a cephalometric investigation. Am J Orthod 1979;76:423-42.
25. Jasper JJ, McNamara JA Jr. A correction of interarch malocclusions using a fixed force module. Am J Orthod Dentofacial Orthop 1995;108:641-60.
26. Weiland FJ, Bantleon HP. Treatment effect of Class II malocclusion with Jasper Jumper appliance-a preliminary report. Am J Orthod Dentofacial Orthop 1995;108:341-50.
27. 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;20:271-81.
28. Pancherz H. The effects, limitations, and long-term dentofacial adaptations to treatment with the Herbst appliance. Semin Orthod 1997;3:232-43.
29. Hansen K, Koutsonas TG, Pancherz H. Long-term effects of Herbst treatment on the mandibular incisor segment: a cephalometric and biometric investigation. Am J Orthod Dentofacial Orthop 1997;112:92-103.
30. Omblus J, Malmgren O, Pancherz H, Hägg U, Hansen K. Long-term effects of Class II correction in Herbst and Bass therapy. Eur J Orthod 1997;19:185-93.
31. Bock N, Ruf S. Post-treatment occlusal changes in Class II division 2 subjects treated with the Herbst appliance. Eur J Orthod 2008;30:606-13.
32. Pancherz H. The nature of Class II relapse after Herbst appliance treatment: a cephalometric long-term investigation. Am J Orthod Dentofacial Orthop 1991;100:220-33.
33. Wieslander L. Long-term effect of treatment with the headgear-Herbst appliance in the early mixed dentition. Stability or relapse? Am J Orthod Dentofacial Orthop 1993;104:319-29.
34. Artun J, Garol JD, Little RM. Long-term stability of mandibular incisors following successful treatment of Class II, Division 1, malocclusions. Angle Orthod 1996;66:229-38.
35. Wiechmann D, Schwestka-Polly R, Pancherz H, Hohoff A. Control of mandibular incisors with the combined Herbst and completely customized lingual appliance-a pilot study Head Face Med 2010;6:3-7.