Dental Research Journal

Original Article

Effects of Sabbagh Universal Spring 2 appliance on cephalometric indices in patients with Class II division 1 versus division 2 malocclusions: A preliminary before–after clinical trial

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ABSTRACT

Background: Since there is no comparison between the effects of Sabbagh Universal Spring 2 (SUS2) appliance on Class II division 1 (div 1) versus Class II division 2 (div 2) patients, this preliminary study was conducted to comparatively assess, for the first time, the effects of SUS2 on 34 cephalometric indices in Class II/1 versus Class II/2 patients.

Materials and Methods: This before–after clinical trial was conducted on 75 observations of 25 patients with Class II malocclusion, of whom 12 (9 females and 3 males) had Class II div 1 and 13 (11 females and 2 males) had Class II div 2 malocclusion diagnosed by clinical examination and cephalometric assessment. The growth level of all patients had to be CS3 according to the cervical vertebral maturation index. Lateral cephalographs were obtained before treatment (T0) and the patients underwent fixed orthodontic treatment. Lateral cephalographs were taken again (T1) and the patients received SUS2 functional appliance for 6 months. A final lateral cephalograph (T2) was then obtained. Thirty-four dentoskeletal indices were measured on lateral cephalographs, and changes in indices over time were determined and compared using repeated-measures analysis of variance, *post hoc* test, and *t*-test (α =0.05).

Results: Within-group comparisons showed significant changes over time in SNB, sella nasion (SN)/occlusal plane, ANB, articular (Ar)-pogonion (Pog), L1-NB, condylion (Co)-gnathion , S-Ar/Ar-G, B-RL1, L1/nasion-point B (NB), U6-RL2, incisor mandibular plane angle, overjet, overbite, U1-RL1, and L1-RL2 ($P < 0.05$). The two groups were significantly different in terms of changes occurred to overjet, interincisal angle, U1/RL1, L1-NB, U1-NA, U1/NA, the Jarabak ratio, A-RL1, U1/SN, Pog-NB, and Co-A ($P < 0.05$).

Conclusion: The SUS2 showed therapeutic efficacy for both Class II div 1 and 2 patients although it more commonly caused dentoalveolar rather than skeletal changes. Our study showed no considerable difference between the two groups after using this appliance, and the difference in the Jarabak ratio indicated better long-term growth pattern of div 2 patients and its conformity with camouflage treatments (mild or moderate Class II).

Key Words: Class II malocclusion, division 1, Class II malocclusion, division 2, malocclusion, fixed functional appliance

Received: 17-Oct-2019
Revised: 07-Mar-2020
Accepted: 03-May-2020
Published: 24-May-2021

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Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480

How to cite this article: Hemmatpour S, Molladavoodi P, Oliadarani FK, Bahrani H, Rakhshan V. Effects of Sabbagh Universal Spring 2 appliance on cephalometric indices in patients with Class II division 1 versus division 2 malocclusions: A preliminary before-after clinical trial. Dent Res J 2021;18:38.

INTRODUCTION

Patients with Class II malocclusion divisions (div) 1 or 2 comprise a large portion of those attending dental and orthodontic clinics. They often complain of esthetic and functional problems associated with this type of malocclusion.[1] Correct treatment planning for young patients with Class II malocclusion is challenging for orthodontists.[2,3] The high prevalence of Class II malocclusion (which might be more than 30%[4]) necessitates establishing effective treatment modalities.

Several treatment methods are available for the correction of Class II malocclusions, including the use of fixed and removable functional appliances, camouflage treatments, and surgery.[5-8] If not treated in time, this malocclusion can cause significant complications. After completion of growth period, correction of Class II malocclusion requires more invasive techniques such as surgery.[6]

Sabbagh Universal Spring 2 (SUS2) is a type of functional appliance used for the correction of Class II malocclusion after aligning and leveling of the teeth. SUS was introduced by Sabbagh in 1997 and then was modified recently as SUS2.[8] SUS2 is a combination of Herbst and Jasper Jumper appliances aiming to benefit from their advantages and minimizing their disadvantages.[8] It comes in one general size and is adjusted for patients based on the required amount of forward movement of the mandible. This appliance corrects Class II malocclusion with the help of fixed orthodontic treatment.[8] In addition, it has been reported that appropriate and on-time use of this appliance can induce bite jumping and dental effects, such as retrusion of maxillary anterior teeth and protrusion of mandibular anterior teeth.[8]

Studies have reported the success of this appliance for the treatment of Class II malocclusion.[8,9] Oztoprak *et al*.[9] reported that SUS2 was as effective as Forsus appliance for the treatment of Class II malocclusion. However, despite the significance of this topic, studies on this appliance are a few and controversial, and no comparisons have been made regarding the efficacy of this appliance in Class II div 1 versus Class II div 2 patients. Hence, this study aimed to comparatively assess the effect of SUS2 on cephalometric indices in Class II div 1 and Class II div 2 patients.

MATERIALS AND METHODS

This before–after clinical trial was conducted on Class II malocclusion patients. The sample size was determined as 75 observations on 25 patients, based on previous research. Patients were selected among those presenting to the orthodontics department. The study was approved in the Ethics Committee of the university. Written informed consent of the patients and volunteers was obtained following a detailed explanation of the procedures that they may undergo. The inclusion criteria were: all patients were in the age range of 11–15 years during the treatment. Class II div 1 patients had overjet ≥5 mm, full Class II molar relationship or Class II tendency, ANB ≥4°, mandibular deficiency, and normal growth patterns. Class II div 2 patients had Class II molar relationship or Class II tendency, ANB ≥4°, overbite >50%, retroclination of the first premolars or two anterior teeth, U1/NA <18°, mandibular deficiency, and normal growth patterns. The growth level of all patients had to be at CS3 according to the cervical vertebral maturation (CVM) index. The exclusion criteria were history of any oral habits, orthodontic treatment, maxillofacial surgeries, or extraction treatment. Included were 12 Class II div 1 patients (9 girls and 3 boys, with an average age of 11.8 ± 0.4 years) and 13 Class II div 2 patients (11 girls and 2 boys, with an average age of 12.7 ± 0.4 years).

The diagnosis of Class II malocclusion was made based on the clinical examination and cephalometric indices. The growth level of all patients was evaluated and confirmed to be at CS3 according to the CVM index in which C2, C3, and C4 cervical vertebrae were evaluated (treatment of Class II patients with functional appliance must be started when these vertebrae are at the CS3 stage; in this stage, C2 and C3 have an unclear notch in the inferior part and C4 has a trapezoid shape[10]).

All orthodontic phases were performed by the same orthodontist using wire 22 (MBT system) technique. All patients underwent fixed orthodontic treatment for dental leveling and aligning before the placement of SUS2 fixed orthodontic appliance; this stage took about 6–9 months. The appliance had to remain in their mouth for about 6 months [Figures 1 and 2].

Lateral cephalographs were obtained from all patients in natural head position before the onset of fixed orthodontic treatment (T0), after the treatment and before the placement of the SUS2 appliance in the mouth (T1), and after completion of SUS2 treatment (T2). Cephalographs were true-size and

Figure 1: An example of Class II division 1 treatment. Intraoral photographs on the left and right sides represent before-treatment condition and after-treatment outcome, respectively. The top and bottom profiles show the before-treatment condition and after-treatment outcome, respectively.

Figure 2: Treatment of Class II Division 2. Intraoral photographs on the left and right sides represent before-treatment condition and after-treatment outcome, respectively. The top and bottom profiles show the before-treatment condition and after-treatment outcome, respectively.

traced on an acetate paper by the corresponding author who had been trained by an orthodontist (the first author). The operator was not blinded to groupings. The first author re-landmarked and retraced almost all measurements in every cephalograph to ensure that land-marking and tracing have been carried

out accurately. In the case of any errors, the values measured by the orthodontist were recorded. If the sella nasion (SN)/Frankfort horizontal angle was smaller or larger than normal (7°), this difference was applied to the angles affected by the SN plane, and standardization was performed.[11]

The following 34 cephalometric indices were measured at the each of the three time points:

SNA°, SNB°, ANB°, SN/palatal plane (PP)°, SN/mandibular plane (MP)°, pogonion-nasion-point B (Pog-NB) (mm), Articular (Ar)-Pog (mm), A-RL_2 (mm), B-RL_2 (mm), A-RL_1 (mm), B-RL_1 (mm), anterior nasal spine (ANS)-Me/N-Me %, Jarabak ratio %, S-Ar/Ar-gonion (Go) %, Co-A (mm), Y-axsis°, posterior nasal spine (PNS)-RL_1 (mm), U6-RL_2 (mm), N-A-Pog°, Co-Gn (mm), U_1/SN°, U_1/RL_1°, incisor mandibular plane angle (IMPA)°, L_1-RL_2, interincisal angel°, SN/occlusal plane (OP)°, L_1-NB (mm), U_6-RL_1 (mm), U_1-RL_1 (mm), overjet (mm), overbite (mm), U_1/NA°, U_1-NA (mm), and L_1/NB°. Definitions used by Pancherz[12] were also used in this study for the aforementioned cephalometric indices. Definitions of landmarks and parameters are as follows: S (sella tursica): Geometrical center of the bone cavity occupied by the pituitary gland. N (nasion): The most anterior point on the nasofrontal suture in the sagittal plane. A (subspinal): The posterior midpoint of the anterior contour of the maxillary alveolar ridge between the ANS and the prosthion. B (supramental): The posterior point in the outer contour of the mandibular alveolar ridge between the Pog and the infradental. Condylion (Co): The highest and most posterior point on the condyle head. Pog: The most anterior point of the chin bone on the midsagittal plane. Gnathion (Gn): The most anterior and inferior point on the chin bone. Menton (Me): The lowest point on the mandible symphysis. Go: The point obtained from the intersection of the tangents to the posterior edge of the ramus and the inferior edge of the mandible. Ar: The point obtained from the intersection of the image of the posterior edge of the ramus with the outer edge of the base of the skull. ANS: The most anterior point of the nasal spine on the midsagittal plane. PNS: The intersection of the anterior wall of the maxillary pterygoid fissure and the nasal floor. Anterior cranial base (SN): A line extending from point S to point N. S-Ar (posterior cranial base): The distance from point S to point Ar. PP: A line extending from PNS to ANS. MP: A line extending from point Go to point Me. NA: A line extending from point N to point A. NB: A line extending from point N to point B. OP: A line intersecting the overlap of the first molars and the overbite of incisors. RL1: The true horizontal line that crosses the S point. RL2: The true perpendicular line passing through point S. ANS-Me (lower anterior facial height): The ANS-Me distance is used in McNamara analysis to assess the lower anterior facial height. N-Me (anterior facial height): The distance between nasion and Me that determines the anterior facial height. S-Go (posterior facial height): The S-Go distance that defines the posterior height of the face. Ar-Go (ramus length): The distance from Ar to Go. SNA: An angle that represents the anterior–posterior position of the point A relative to the anterior cranial base. SNB: An angle that represents the anterior–posterior position of the point B relative to the anterior cranial base. ANB: This angle represents the difference between the angles SNA and SNB in which the anterior cranial slope changes play no role and reflects the anterior–posterior position of the maxilla relative to the mandible. SN/PP: The angle between the SN and PP planes. SN/MP: The angle between the SN and MP. This angle is a diagnostic parameter of the growth pattern. SN/OP: The angle between SN plane and OP. Pog-NB: The distance between the Pog point and the NB line. Ar-Pg: The distance of the point Ar to Pg. A-RL1: The distance between point A and true horizontal line. A-RL2: The distance between point A and true vertical line. B-RL1: The distance between point B and true horizontal line. B-RL2: The distance between point B and true vertical line. ANS-Me (l anterior facial height): The distance from the ANS to Me is used in the McNamara analysis to evaluate the lower anterior facial height. ANS-Me/N-Me: Ratio of anterior-inferior height to anterior face height expressed as a percentage. Jarabak ratio: Ratio of posterior to anterior facial height. If this percentage increases, it indicates a growth pattern in the horizontal direction, and if it decreases, it is a sign of vertical growth. S-Ar/Ar-Go: Ratio of posterior cranial height to ramus length. Co-A (effective midfacial length): The distance of Co to point A, which, according to McNamara's analysis, indicates the effective length of the middle face. Co-Gn (effective mandibular length): Co to Gn point, which is the effective mandibular length according to McNamara's analysis. Y-axsis (N-S-Gn): The angle between the S-N and S-Gn lines. N-A-Pog: The angle of facial convexity. PNS-RL1: The distance between the PNS and true horizontal line. U1/SN: The lower posterior angle between the maxillary incisor axis and the SN line. U1/NA: The angle between the

long axis of the upper incisor teeth and the NA line. U1-NA: The distance between upper incisor edge and the NA line.

U1/RL1: Inferior posterior angle between upper incisor axis with RL1. U1-RL1: The distance between center of resistance of upper central tooth and RL1. L1/RL2: Upper anterior angle between lower incisor axis with RL2. L1/NB: The angle between the long axis of the lower incisors and the NB line. L1-NB: The distance between the lower incisor edge and the NB line. U6-RL1: The distance between center of resistance of the first maxillary molar with RL1. Interincisal angle: The angle between the long axes of the upper and lower incisors. IMPA: The upper posterior angle between mandibular incisor axis with MP. U6-RL2: The distance between the most mesial point on the upper molar crown and the true vertical line. Overjet: The horizontal overlap of maxillary and mandibular incisal teeth. Overbite: The vertical overlap of maxillary and mandibular incisors.

Statistical analysis

Considering the normal distribution of data, means and standard errors were calculated for all measurements. Estimations were (1) alterations in cephalometric indices after fixed orthodontic treatment compared to the baseline values, (2) changes after using SUS2 compared to values obtained after fixed orthodontic treatment, and (3) changes after completion of treatment (removal of appliance) compared to baseline. These changes were analyzed statistically using repeated-measures analysis of variance. Pairwise comparisons were carried out using a *post hoc* test. Independent-samples *t*-test was applied to compare the two groups at each time point. Data analysis was carried out using SPSS version 22 (IBM, Armonk, NY, USA) and STATA 11 (StataCorp., College Station, Texas, USA). Level of significance was predetermined as 0.05.

RESULTS

There was not a significant difference between age of two groups (*t*-test $P = 0.13$). Gender distributions across groups were similar as well (Chi-square $P = 0.5$).

Within-group changes of cephalometric indices between T1 and T2

Class II division 1

Changes in SNB, ANB, SN/OP, Ar-Pog, B-RL1, S-Ar/Ar-Go, U1/SN Co-Gn, U1/NA, U1-NA, U1/RL1, L1-RL2, L1-NB, L1/NB, U6-RL2, IMPA, overjet, and overbite were statistically significant [$P < 0.05$, Table 1].

Class II division 2

Changes in SNB, ANB, SN/OP, Ar-Pog, B-RL1, Jarabak ratio, S-Ar/Ar-Go, Co-Gn, U1/NA, U1/RL1, L1-RL2, L1-NB, L1/NB, U6-RL2, IMPA, overjet, and overbite were also statistically significant [$P < 0.05$, Table 2].

Between-group comparison of changes in cephalometric indices between T1 and T2

The changes in the Jarabak ratio and U1/SN were statistically significant [$P < 0.05$, Table 3].

DISCUSSION

The results showed that SUS2 corrected Class II malocclusion mainly by dentoalveolar changes. The two groups of div 1 and div 2 were not significantly different following the use of SUS2 in terms of most variables. In our study, during T0–T1 (leveling and aligning phase), significant changes were noted in Ar-Pog, A-RL2, B-RL1, Co-Gn, Co-A, and PNS-RL1 skeletal indices, which may be attributed to the growth of patients during this period. Dental changes such as increased U6-RL1, U6-RL2, and U1-RL1 also followed the skeletal and developmental changes in patients. In div 1 and div 2 groups, dental indices including the U1/SN, L1-RL2, U1/RL1, U1/NA, U1-NA, L1-NB, L1/NB, and overjet increased while overbite decreased. These changes may be related to proclination of the teeth. Due to the retroclination of teeth in div 2 group, these changes were clinically and statistically greater in this group. During T1–T2 (using appliance), SNB increased while ANB decreased significantly. Phan *et al*.[13] and Hanandeh and El-Bialy[8] reported similar results. In the study by Oztoprak *et al*.,[9] SNA and ANB underwent a significant reduction in SUS2 group. This difference may be attributed to forward repositioning of point N in the process of growth of the cranial base[9] or distal remodeling of point A due to primary flaring of the maxillary anterior teeth, rather than the efficacy of the device in limiting the maxillary growth.[14] However, it should be noted that in our study, lack of significant changes in the SNA parameter may be due to the limiting effect of the appliance on the maxillary growth, which has been previously reported for the Herbst appliance as well.[15] However, since we did not have a control group due to ethical reasons,

Table 1: Mean±standard errors of cephalometric indices in Class II division 1 patients at the three time points, as well as *P* values calculated by comparing time groups

Parameters	Measurements			P		
	T0	T1	T2	T0-T1	T1-T2	T0-T2
SNA°	81.9±1	81.9±1	82.1±0.9	1.0	0.32	0.32
SNB°	76.3±0.7	76.4±0.7	77±0.6	0.5	0.01	0.002
ANB°	5.7±0.7	5.5±0.7	5±0.8	0.48	0.048	0.01
SN/PP°	5.5±1.1	5.5±1.1	5.6±1.1	1.0	0.51	0.52
SN/MP°	30.5±1.4	30.2±1.5	30±1.9	0.57	0.6	0.28
SN/OP°	14±1	13.8±1	17.3±1.1	0.74	<0.001	<0.001
Pog-NB (mm)	2.8±0.5	3±0.5	3.2±0.6	−0.12	0.16	0.004
Ar-Pog (mm)	93.3±1.6	95.6±1.3	97.9±1.5	0.003	0.03	<0.001
A-RL1 (mm)	43.8±1.1	44.9±1.1	45.7±1.1	0.45	0.63	0.22
A-RL2 (mm)	64.3±1.2	65.1±1.2	65.5±1.2	0.018	0.27	<0.001
B-RL1 (mm)	76.5±1.7	78.4±1.7	80±1.7	0.001	0.03	<0.001
B-RL2 (mm)	55±1.4	56.2±1.4	57±1.4	0.06	0.65	0.001
ANS-Me/N-Me (%)	57±0.7	56.9±0.7	56.8±0.7	0.61	0.94	0.4
Jarabak Ratio (%)	66.5±1.2	66.56±1.2	66.9±1.2	0.91	0.61	0.36
S-Ar/Ar-Go (%)	82.8±2.2	81.1±2.2	78.5±2.2	0.09	0.005	<0.001
Co-Gn (mm)	101±1.5	103.7±1.5	105.5±1.5	<0.001	0.007	<0.001
Co-A (mm)	79.7±1.3	81±1.3	81.4±1.3	0.006	0.48	0.001
y-axsis°	68±1	68.8±1	69±1	0.05	0.42	0.006
N-A-Pog°	156±11.5	156.6±11.5	142±11.5	0.95	0.09	0.11
PNS-RL1 (mm)	39.9±0.8	40.2±0.8	40.8±0.8	<0.001	0.09	<0.001
U1/SN°	106.1±2.3	110.3±2.3	105±2.3	0.04	0.01	0.58
U1/NA°	23.1±2.3	27.5±2.3	23.5±2.3	0.007	0.01	0.82
U1-NA (mm)	4.01±0.7	4.2±0.7	2.3±0.7	0.74	0.002	0.005
U1/RL1°	112.3±2.1	116.6±2.1	112.4±2.1	0.03	0.03	0.95
U1-RL1 (mm)	51.3±1.4	52.4±1.4	53.9±1.4	0.009	0.001	<0.001
L1-RL2 (mm)	61.8±1.2	62.9±1.2	64.7±1.2	0.05	0.001	<0.001
L1-NB (mm)	4.4±0.6	4.7±0.6	6±0.6	0.48	0.001	<0.001
L1/NB°	25.8±1.6	28±1.6	33±1.6	0.12	<0.001	<0.001
U6-RL1 (mm)	54.2±1.2	56±1.2	56.2±1.2	0.001	0.68	<0.001
U6-RL2 (mm)	40.4±1	41.5±1	40±1	0.01	0.004	0.77
Interincisal angle°	125.3±2.5	119.8±2.5	118.4±2.5	0.04	0.6	0.01
IMPA°	99±1.6	101.3±2.5	106.1±2.5	0.08	<0.001	<0.001
Overjet (mm)	6.4±0.3	6.4±0.3	2.5±0.3	1.0	<0.001	<0.001
Overbite (mm)	5.6±0.4	3.9±0.4	2.7±0.4	0.001	0.02	<0.001

Definitions of parameters and landmarks are explained in the Methods section

definite judgment in this respect is not possible. The Ar-Pog index showed a significant increase in this study, which was the same as the findings of Oztoprak *et al*.[9] Schaefer *et al*.[16] did not report a significant increase in this parameter, which may be due to different age range of the patients. Significant changes seen in this index in our sample may be attributed to anterior repositioning of the mandible, altered position of Pog, and backward and upward repositioning of the Ar point.[9] Our results also indicated a significant increase in Co-Gn, which was in line with the studies by McNamara *et al*.[17] and Ghislanzoni *et al*.[18] However, Henriques *et al*.,[19] in their study on the effect of Jasper Jumper, did not report such a finding. This difference may be due to the different mechanisms of action of Jasper Jumper compared to SUS2. In general, significant changes in the skeletal indices in the sagittal plane may be attributed to anterior repositioning of the mandible: Because in the mandibular advancement, the condyle moves downward and forward and a suitable space is created for the condylar cartilage in the posterior–superior position and for the glenoid fossa in the anterior–inferior position in order for the proliferation to occur.[20]

The S-Ar/Ar-Go in our study was reduced significantly, which was in agreement with the findings of Oztoprak *et al*.[9] These changes may be attributed to increased natural growth of the ramus. The B-RL1 parameter in our study experienced a significant

Table 2: Mean±standard errors of cephalometric indices in Class II division 2 patients at the three time points, as well as *P* values calculated by comparing time groups

Parameters	Measurements			*P*		
	T0	T1	T2	T0-T1	T1-T2	T0-T2
SNA°	80.6±0.8	80.4±0.7	80.4±0.8	0.24	1.0	0.24
SNB°	74.9±0.6	75±0.6	75.9±0.7	0.52	<0.001	<0.001
ANB°	5.7±0.5	5.4±0.4	4.5±0.3	0.13	<0.001	<0.001
SN/PP°	8.9±0.8	9.2±0.9	8.9±0.9	0.35	0.21	0.75
SN/MP°	32.4±1.1	32.1±1.2	31.4±1.4	0.5	0.11	0.03
SN/OP°	17.5±1.1	17±1	19.2±0.9	0.27	<0.001	0.001
Pog-NB (mm)	3.5±0.5	3.5±0.5	3.4±0.6	0.61	0.57	0.28
Ar-Pog (mm)	92.9±1.2	93.8±1.2	95.5±1.1	0.22	0.02	0.001
A-RL1 (mm)	43.7±1	44.1±1	44.4±1	0.81	0.82	0.65
A-RL2 (mm)	64.1±1.2	64.2±1.2	64.4±1.2	0.74	0.51	0.31
B-RL1 (mm)	74.5±1.7	75.2±1.7	76.9±1.7	0.15	0.001	<0.001
B-RL2 (mm)	55.8±1.3	56.2±1.3	57.6±1.3	0.51	0.47	0.04
ANS-Me/N-Me (%)	54.8±0.7	54.9±0.7	54.7±0.7	0.54	0.67	0.79
Jarabak Ratio (%)	65.6±1.1	66±1.1	67±1.1	0.41	0.001	<0.001
S-Ar/Ar-Go (%)	83.2±2.1	81.7±2.1	78.5±2.1	0.08	<0.001	<0.001
Co-Gn (mm)	100.9±1.5	101.6±1.5	103.5±1.5	0.25	0.03	0.002
Co-A (mm)	79.6±1.3	79.2±1.3	79.5±1.3	0.46	0.51	0.93
y-axsis°	69.1±1	69.1±1	69.1±1	1.0	1.0	1.0
N-A-Pog°	171.7±11.1	172.5±11.1	174.4±11.1	0.92	0.74	0.82
PNS-RL1 (mm)	39.2±0.8	39.6±0.8	39.8±0.8	0.28	0.4	0.06
U1/SN°	86.9±2.2	108.2±2.32	104.7±2.2	<0.001	0.2	<0.001
U1/NA°	7.9±2.2	27.6±2.2	24.7±2.2	<0.001	0.06	<0.001
U1-NA (mm)	(−1.1)±0.6	3±0.6	2.4±0.6	<0.001	0.31	<0.001
U1/RL1°	96.8±2	117.3±2	114.9±2	<0.001	0.19	<0.001
U1-RL1 (mm)	50.2±1.4	50.5±1.4	51.5±1.4	0.59	0.01	0.003
L1-RL2 (mm)	59.7±1.1	61.3±1.1	63.7±1.1	0.001	<0.001	<0.001
L1-NB (mm)	2.2±0.6	3.6±0.6	5.1±0.6	<0.001	<0.001	<0.001
L1/NB°	21.4±1.5	26.1±1.5	31.6±1.5	<0.001	<0.001	<0.001
U6-RL1 (mm)	53.6±1.1	54±1.1	54.1±1.1	0.41	0.83	0.31
U6-RL2 (mm)	41.4±1	42±1	40.9±1	0.2	0.008	0.17
Interincisal angle°	145.2±2.4	120.9±2.4	119.2±2.4	<0.001	0.5	<0.001
IMPA°	93.9±1.5	98.9±1.5	104.9±1.5	<0.001	<0.001	<0.001
Overjet (mm)	3.3±0.3	5.6±0.3	2.3±0.3	<0.001	<0.001	0.007
Overbite (mm)	6.2±0.4	4.5±0.4	2.6±0.4	<0.001	<0.001	<0.001

Definitions of parameters and landmarks are explained in the Methods section

increase. Hanandeh and El-Bialy[8] found the same result and attributed it to forward positioning of the mandible and increased facial height. Changes in the afore-mentioned skeletal indices may be attributed to the conformity of growth and development with treatment[8,21] or growth stimulation by the functional appliance.[12,21,22] However, this topic is still a matter of debate, and a definite judgment cannot be easily reached since such studies cannot have a control group for ethical reasons.[23-25]

Regarding dental indices, U6-RL2 was decreased in this study, which was in agreement with the findings of Ruf and Pancherz[10] and McNamara *et al*.[17] However, Hanandeh and El-Bialy[8] did not report a reduction in this variable, probably due to heavy distal cinch back of the maxillary wire. However, this justification is not acceptable because cinch back was performed in all relevant studies including ours. In general, the main reason for distal movement of the maxillary molar teeth may be due to the headgear effect of functional appliances.[10,26]

A significant increase was noted in IMPA, L1-RL2, and L1-NB in our study, which was in agreement with the results of Henriques *et al*.,[19] Oztoprak *et al*.,[9] Ruf and Pancherz,[10] and Hanandeh and El-Bialy.[8] However, increases in these variables may also be attributed to the mesial component of load exerted by the appliance. Due to fixed orthodontic treatment, the dentition of the mandibular arch is united and the spring force is applied to dental crowns at a

Table 3: Mean±standard errors of changes in cephalometric indices between the two groups (and their statistical comparison) at the three time points

Parameter	T1-T0			T2-T1			T2-T0		
	Division 1	Division 2	*P*	Division 1	Division 2	*P*	Division 1	Division 2	*P*
SNA°	0±0.12	(-0.19)±0.18	0.39	0.17±0.11	0±0.1	0.27	0.17±0.17	(-0.19)±0.24	0.24
SNB°	0.17±0.16	0.15±0.09	0.94	0.63±0.23	0.89±0.24	0.44	0.79±0.33	1.04±0.31	0.59
ANB°	(−0.17)±0.16	(−0.35)±0.2	0.49	(−0.46)±0.2	(−0.89)±0.18	0.13	(−0.63)±0.27	(−1.23)±0.31	0.16
SN/MP°	(−0.27)±0.13	(−0.31)±0.33	0.91	(−0.25)±0.47	(−0.73)±0.41	0.44	(−0.52)±0.57	(−104)±0.65	0.5
SN/OP°	(−0.17)±0.3	(−0.54)±0.34	0.42	3.42±0.52	2.23±0.58	0.14	3.25±0.53	1.69±0.58	0.06
Pog-NB (mm)	0.2±0.12	0.06±0.05	0.27	0.18±0.09	(−0.13)±0.15	0.1	0.38±0.14	(−0.07)±0.15	0.04
Ar-Pog (mm)	2.33±0.78	0.89±0.16	0.07	2.32±0.8	1.65±0.39	0.46	4.64±1.29	2.54±0.53	0.13
A-RL2 (mm)	0.8±0.41	0.12±0.16	0.12	0.36±0.23	0.21±0.22	0.64	1.16±0.46	0.32±0.36	0.16
B-RL1 (mm)	1.91±0.73	0.75±0.18	0.12	1.56±0.38	1.72±0.42	0.79	3.47±0.7	2.46±0.54	0.27
B-RL2 (mm)	1.14±0.58	0.39±0.21	0.22	0.88±0.58	1.34±0.31	0.49	2.03±1.03	1.72±0.51	0.79
ANS-Me/N-Me (%)	(−0.15)±0.29	0.18±0.17	0.33	(−0.1)±0.25	(−0.25)±0.24	0.66	(−0.25)±0.39	(−0.08) 0.35	0.74
Jarabak Ratio (%)	0.13±0.15	0.38±021	0.34	0.27±0.29	1.05±0.22	0.04	0.42±0.38	1.43±0.39	0.08
S-Ar/Ar-Go (%)	(−1.63)±0.84	(−1.58)±0.6	0.96	(−2.63)±0.56	(−3.12)±0.76	0.61	(−4.25)±1.24	(−4.69)±1.22	0.8
Co-Gn (mm)	2.63±0.93	0.75±0.18	0.05	1.82±0.55	1.36±0.41	0.51	4.44±1.02	2.11±0.56	0.05
y-axsis°	0.71±0.42	0±0.13	0.11	0.29±0.33	0±0.22	0.47	1±0.6	0±0.31	0.14
N-A-Pog°	0.54±0.18	0.85±0.48	0.57	(−14.58)±15.3	1.89±0.44	0.28	(−14.04)±15.3	2.73±0.84	0.27
PNS-RL1 (mm)	1.37±0.47	0.34±0.09	0.04	0.56±0.15	0.26±0.1	0.1	1.93±0.6	0.6±0.18	0.04
U1/SN°	4.21±1.4	20.35±3.09	0.0001	(−5.33)±3.67	(−2.53)±3.52	0.0008	(−1.13)±1.85	17.81±2.53	<0.0001
U1/NA°	4.42+1.49	19.73±2.26	<0.0001	(−4.04)±0.59	(−2.92)±0.42	0.13	0.38±1.69	16.81+2.08	<0.0001
U1-NA (mm)	0.2±0.34	4.08±0.86	0.0005	(−1.9)±0.22	(−0.59)±0.6	0.06	(−1.7)+0.36	3.49+0.76	<0.0001
U1/RL1°	4.29±1.44	20.46±2.88	0.0001	(−4.17)±0.7	(−2.42)±0.97	0.17	0.13±1.55	18.0.4±2.47	<0.0001
U1-RL1 (mm)	1.18±0.65	0.23±0.24	0.17	1.48±0.34	1.06±0 – 18	0.27	2.66±0.69	1.29±0.36	0.08
L1-RL2 (mm)	1.05±0.55	1.69±0.27	0.31	1.77±0.55	2.38±0.36	0.36	2.82±0.89	4.06±0.44	0.21
L1-NB (mm)	0.28±0.27	1.38±0.33	0.02	1.3±0.32	1.55±0.31	0.57	1.58±0.54	2.93±0.48	0.07
L1/NB°	2.17±0.98	4.77±1.13	0.1	5.13±1.13	5.46±0.99	0.82	7.29±1.83	10.23±1.79	0.26
U6-RL1 (mm)	1.74±0.73	0.4±0.23	0.08	0.21±0.34	0.11±0.22	0.8	1.95±0.84	0.51±0.34	0.12
U6-RL2 (mm)	1.13±0.51	0.53±0.16	0.26	(−1.25)±0.38	(−1.09)±0.35	0.76	(−0.13)±0.65	(−0.56)±0.36	0.55
Interincisal angle°	(−5.42)±2.53	(−24.35)±3.25	0.0001	(−1.42)±0.95	(−1.73)±0.96	0.82	(−6.83)±2.93	(−26.08)±3.62	0.0004
IMPA°	2.25±0.99	5.08±1.12	0.07	4.83±1.05	6±1.03	0.44	7.08±1.72	11.08±1.53	0.09
Overjet (mm)	0±0.17	2.29±0.5	0.0003	(−3.88)±0.3	(−3.33)±0.41	0.3	(−3.88)±0.3	(−1.04)+0.52	0.0001
Overbite (mm)	(−1.64)±0.28	(−1.72)±0.78	0.93	(−1.23)±0.4	(−1.82)±0.35	0.27	(−2.87)+0.3	(−3.55)+0.57	0.31

Definitions of parameters and landmarks are explained in the Methods section

point higher than the center of resistance, causing protrusion of the mandibular incisors.[8] In Class II div 2 patients, the value of these indices is primarily low and therefore in line with our therapeutic goals. However, in Class II div 1 patients, these values are basically high and therefore act as a side effect. This is noteworthy in selection of patients for the treatment with this appliance and highlights the suitability of this appliance for treatment of Class II div 2 patients.

Overjet decreased in our study, which was similar to the findings of others such as Henriques *et al*.,[19] Bock and Pancherz,[11] and Darda.[20] Correction of overjet can be explained by the retroclination of the maxillary teeth (confirmed by the reductions in U1/SN, U1/NA, U1-NA, and U1/RL1) and proclination of mandibular incisors (confirmed by increases in L1/NB, L1-NB, and IMPA). Moreover, reduced overjet can be attributed to forward growth of the mandible in addition to dental alterations.[9,19]

Our study also showed a significant increase in SN/OP, which was in line with the findings of Li *et al*.,[27] Oztoprak *et al*.,[9] and Hanandeh and El-Bialy.[8] The clockwise rotation of this plane may be due to the intrusion of maxillary molars or intrusion of mandibular incisors; extrusion of mandibular posterior teeth can also cause steepening of OP.[27] Since no significant reduction was noted in U6-RL1, it may be concluded that this change was due to the intrusion of mandibular anterior teeth.[9] Thus, it may be concluded that SUS2 can correct the anterior bite of Class II patients especially the div 2 group. In our study, U1-RL1 showed a significant increase, which was in accordance with the findings of Oztoprak *et al*.,[9] Henriques *et al*.,[19] McNamara

et al.,[17] and Schaefer *et al*.[16] The extrusion of maxillary central incisors may be due to the fact that the distal force applied by the appliance is more toward the occlusal than the center of resistance of the entire maxillary arch, and the resultant torque has a clockwise direction and causes backward and downward movement of the maxillary incisors.[9]

Overbite showed a significant reduction in our study, which was in line with the findings of Hanandeh and El-Bialy,[8] Henriques *et al*.,[19] Franchi *et al*.,[14] and Siara-Olds *et al*.[28] The reason may be the intrusion and protrusion of mandibular incisors or even extrusion of mandibular molars. In addition, these changes may be related to load application by the appliance, causing forward movement of the mandible along the lingual inclination of the maxillary incisors.[9,26,28] This was in agreement with another study on Class II/1 malocclusion of patients in the postpubertal growth period, in which SUS2 was successful in advancing the mandible as well as increasing the facial height, inhibiting the maxilla's forward growth, decreasing the nasolabial and interincisal angles, proclining the incisors, and causing a clockwise rotation of the OP.[29]

During T0–T2, significant changes were noted in Co-Gn, B-RL2, B-RL1, Ar-Pog, ANB, SNB, SN/MP, SN/OP, Pog-NB, A-RL2, Co-A, PNS-RL1, Jarabak ratio, and S-Ar/Ar-Go skeletal indices. Part of these changes may be attributed to the natural growth while part of them can be due to the effect of appliance. Significant changes were noted in U1-RL1, U1-NA, L1-NB, L1/NB, interincisal angle, IMPA, U1/SN, U1/NA, U1/RL1, U6-RL, overjet, and overbite, which may be due to effects of SUS2 and fixed orthodontic treatment.

Comparison of Class II div 1 and div 2 patients between T0 and T1 showed significant differences between the two groups in terms of interincisal angle, overjet, U1-NA, U1/RL1, U1/Na, and U1/SN; this difference may be attributed to the proclination of teeth in leveling and aligning to obtain a correct dental relationship for the placement of appliance. This difference was logical considering the natural difference in inclination of the incisor teeth in the two groups at baseline and retroclination of teeth in div 2 compared to div 1 group.[9,21] Change in A-RL2 and Co-A skeletal indices may be due to the change in the position of point A in the sagittal plane due to the great change in the longitudinal axis of the maxillary incisors in this phase.[28] Difference in PNS-RL1 might be partially explained by the small sample size and measurement errors.

Significant changes were noted in U1/SN index. In div 2 group compared to div 1, significant changes occurred in the longitudinal axis of teeth in the leveling and aligning phase. Immediately after placement of the appliance, the longitudinal axis of the maxillary incisor teeth was more affected by the distal force applied by the appliance.

Comparison of Class II div 1 and div 2 patients between T1 and T2 showed that the changes in the Jarabak ratio were statistically significant. These changes were probably attributed to the increased posterior facial height in div 2 compared to div 1 group and more horizontal growth pattern in this group with aging. Comparison of Class II div 1 and div 2 patients between T0 and T2 showed significant changes in A-RL1 skeletal index, which was probably due to the change in the position of point A in the sagittal plane due to the significant change in the longitudinal axis of the maxillary incisors during this time period. Perhaps, significant changes in Pog-NB might be due in part to the difference in chin remodeling. The significant change in PNS-RL1 may be due to small sample size and error in measurements. Significant changes in U1/SN, U1/NA, U1/RL1, U1-NA, overjet, and interincisal angle at this time point may be due to fixed orthodontic treatment, effect of using the appliance, and different baseline values of these variables in div 1 and div 2 groups. Although controversies exist over results, it seems that overall, functional appliances are proper for correction of Class II patients, and these include SUS and SUS2 although studies on the latter are a few.[30-35] Future studies with larger samples and longer follow-ups are required to better elucidate this topic.

This preliminary study had some limitations. First, most patients were females, and this can limit the generalizability of results. Moreover, the sample size should have been determined based on pilot studies. However, this study itself was a preliminary research. Furthermore, the operator who traced the cephalographs was not blinded. However, it was not possible to blind the operator, because the cephalographs being assessed by the operator would easily reveal the grouping.

CONCLUSION

Within the limitations of this preliminary study, the results showed that SUS2 had positive therapeutic

efficacy in both Class II div 1 and div 2 groups and caused reduction in overjet and overbite and correction of molar relationship, although the nature of these changes was mainly dentoalveolar. The significant difference in the Jarabak ratio between the two groups may be due to better long-term growth pattern of div 2 patients and conformity of this property with camouflage orthodontic treatment. Considering the dentoalveolar changes caused by this appliance, it is indicated for use in mild skeletal Class II or skeletal Class I patients with dental Class II relationship (mainly seen in div 2 patients).

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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