

## THREE-DIMENSIONAL ASSESSMENT OF SKELETAL FROG APPLIANCE OUTCOMES VIA CONE BEAM COMPUTERIZED TOMOGRAPHY

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**Objective:** To assess the three-dimensional effect of the mini-screw supported palatal distalizer the Skeletal Frog appliance via the aid of the cone-beam computed tomography (CBCT) images. **Methods:** This study was conducted on twenty five subjects (9 boys and 16 girls), aged 13 to 15.2 years (average, 14.5 years) who exhibited Angle Class II division 1 malocclusion with the maxillary second molars fully erupted. CBCT were obtained prior treatment and post-distalization for all subjects. CBCT images were used to measure the skeletal, dental, and soft tissue changes. Paired-sample t-test was implemented to compare the mean difference between the pretreatment and post-distalization variables. **Results:** The maxillary first molars were efficaciously distalized, distally tipped, and intruded by 4.14mm, 9.02°, and 2.03mm ( $p \leq 0.05$ ) respectively. The maxillary right and left first molar exhibited significant rotation 4.33° and 4.83° ( $p \leq 0.05$ ) respectively. Whereas the maxillary inter-molar and inter-premolar widths increased by 2.41mm and 0.8mm respectively. Regarding the maxillary first and second premolars they revealed a distalization of 1.89mm and 2.8mm ( $p \leq 0.05$ ) respectively, with insignificant extrusion. The maxillary central incisors showed a statistically insignificant decrease in the anteroposterior position. Whereas the interincisal angle revealed a statistically significant increase by 3.24° ( $p \leq 0.05$ ). **Conclusion:** The Skeletal Frog appliance efficaciously distalizes the maxillary molars with the second molars fully erupted while providing absolute skeletal anchorage.

### Introduction

One of the most frequently encountered orthodontic problems is class II malocclusions.

In growing individuals with class II malocclusions generally there are two main treatment strategies, either extraction or non-extraction. Recently there is a paradigm shift towards non-extraction which is more acceptable for both the patient and the orthodontist<sup>1,2,3</sup>. In class II with mild to moderate crowding in the maxillary arch and normal mandibular arch the possible treatment approaches are, interproximal reduction, expansion, derotation and/or uprightening of posterior teeth, and maxillary molar distalization<sup>4,5</sup>.

Currently there is an increasing trend directed towards distalization mechanics. Distalization allows the correction of; increased overjet, molar and canine relationship, lip profile, as well as facilitating space regaining via various retraction techniques<sup>6,7</sup>. Various noncompliance dependent alternatives for maxillary molar distalization are the fixed intraoral distalizers, which might be positioned either buccally or palatally or both. Among these devices are, Hilgers pendulum appliance, distal jet, Jones Jig, NiTi coil spring, Keles slider, first class appliance, repelling magnets, K-loop, Wilson distalizing arches, and Walde frog appliance<sup>8,9,10</sup>.

Yet, numerous side effects have been associated with these tooth-borne distalizers. Among which are molar tipping and extrusion, anchorage compromise such as, mesial migration of the premolars and flaring of incisors, in addition to the possibility of

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significant molar relapse<sup>4,7,10</sup>. Combining intraoral palatal distalizers with mini-screws (TADs) is gaining more popularity due to the TADs ease of insertion and removal, ability of immediate loading, small size, versatility, reduced invasiveness, variety of placement sites, and low cost<sup>4,10,11</sup>.

When combining mini-screws with a palatal molar distalizer, paramedian placement of TADs is the most suitable region due to the decrease probability of root damage as well as the unnecessary need to reposition the mini-screws during retraction of the premolars and incisors<sup>12,13,14,15,16</sup>.

Ludwig et al.<sup>17</sup>, designed the skeletal frog which is an innovative mini-screw supported maxillary molar distalization appliance which requires neither dental support nor an acrylic palatal button. This appliance is simple, hygienic, easily fabricated, effective in molar distalization, and without undesirable side effects<sup>17</sup>.

Thus, the aim of this study was to assess the three-dimensional effect of the mini-screw supported palatal distalizer the skeletal frog appliance which to the best of our knowledge has not been conducted utilizing the cone-beam computed tomography (CBCT).

## Materials and Methods

### Sample

This study was conducted on twenty five healthy Egyptian subjects selected and treated at the outpatient clinic of the Orthodontic Department, Faculty of Dentistry, Ain Shams University.

Power analysis revealed that a sample of 19 subjects will achieve a statistical power of approximately 80% at a significance level of 0.05. The sample size was increased to involve 25 subjects to compensate for any withdrawals. Therefore, 25 subjects (9 boys and 16 girls), aged 13 to 15.2 years (average, 14.5 years), were included in this study. The inclusion

criteria was as follows: Angle Class II division 1 malocclusion with a bilateral Class II molar relationship, permanent dentition with fully erupted second molars, skeletal class 1 with an ANB angle of ( $0^{\circ}$ – $4^{\circ}$ ), normal or horizontal growth pattern (SN/GoGn,  $32^{\circ} \pm 6^{\circ}$ ), mild to moderate crowding within the maxillary arch (4–6 mm), well aligned to mild crowding within the mandibular arch (0–2 mm), and no history of previous orthodontic treatment. Whereas the exclusion criteria involved; poor oral hygiene, congenitally missing permanent teeth, periodontal disease, and systemic disease or syndromes that might influence orthodontic treatment.

The study protocol was revised, modified, and approved by the local ethics committee, Faculty of Dentistry, Ain Shams University (approval no. FDASU REC ID 031216). Before commencing with treatment all subjects and their guardians signed an informed consent after receiving a detailed explanation of the treatment procedures and protocol.

### Appliance fabrication and activation

All subjects had a full set of pretreatment and post-distalization diagnostic records including; diagnostic sheets, study casts, photographs, and CBCTs. The Skeletal Frog appliance in this study consisted of appropriate size bands on upper first molars with a welded lingual sheath, frog screw, 0.032 inch stainless steel distalizing springs, and hex key screw-driver (Forestadent, Pforzheim, Germany), in addition to two palatal TADs (infinitas, DB Orthodontics, UK).

The TADs were 2mm in diameter, 6mm in length, long neck, and self-drilling. They were positioned antero-posteriorly 6mm posterior to the incisive papillae along the line connecting the mesial contact points of the first premolars. Whereas in the transverse plane they were placed paramedian 3mm from the midpalatal suture. The correct position of the TADs was

guided by a vacuum splint fabricated on a study cast.

Abutments were placed on the TADs followed with an impression with silicon rubber base, these abutments allow direct connection of the TADs to the distalizing screw body. The two transfer TADs were positioned on the abutments which was poured with dental stone to obtain working cast. Then, the fitted abutments on the working cast were soldered to the anterior tabs of the distalizing screw (Figure 1a).

The distalizing screw was positioned according to the following points; horizontally parallel to occlusal plane with a clearance of 10-12 mm

from the cusp tips of the first molars close to their center of resistance, transversally along the midpalatal raphe, and antero-posteriorly the distal end of distalizing screw flushed with the mesial aspect of the lingual sheaths on the first molar bands (Figure 1b).

Finally the end section of the distalizing spring was bent 15° towards the occlusal plane to counteract the molar distal tipping. The distalizing springs were preactivated with a distal force magnitude of 250gm. In the patients mouth, the distalizing springs were tied to the lingual sheaths of the molar bands, and the abutments were tied to the TADs heads with stainless steel ligature wire (Figure 1c).



Figure 1. a) Transfer mini-screws on the working cast, b) Skeletal Frog appliance assembly on the working cast, c) Skeletal Frog appliance intraoral

According to Walde every 360° turn of the screw opens the body by 0.4mm. Therefore, our reactivation protocol was three to five turns of the screw every four to five weeks which

would lead to 1-2mm of molar distalization per month. Reactivation was performed until a full bilateral class I molar relationship was attained (Figure 2).



Figure 2. Intraoral right, frontal, left, and occlusal views post-distalization

**Evaluation**

Assessment of the 3D treatment effects of the Skeletal Frog appliance was performed by using the CBCT scans (SCANORA 3Dx, Soredex, Tuusula, Finland) pretreatment (T1) and post-distalization (T2) for each subject. The CBCT images were then uploaded to the software (Anatomage, version 5.01, San Jose, USA). All linear and angular measurements for the skeletal, dental, and soft

tissue variables were obtained directly from the CBCT 3D volumetric images (Figure 2). The variables details and measurements are listed in (Table 1). All bilateral skeletal, and dental landmarks were digitized for left and right side independently and an average value was taken. The measurements were performed twice by the same practitioner, with an interval of 2 weeks between them.

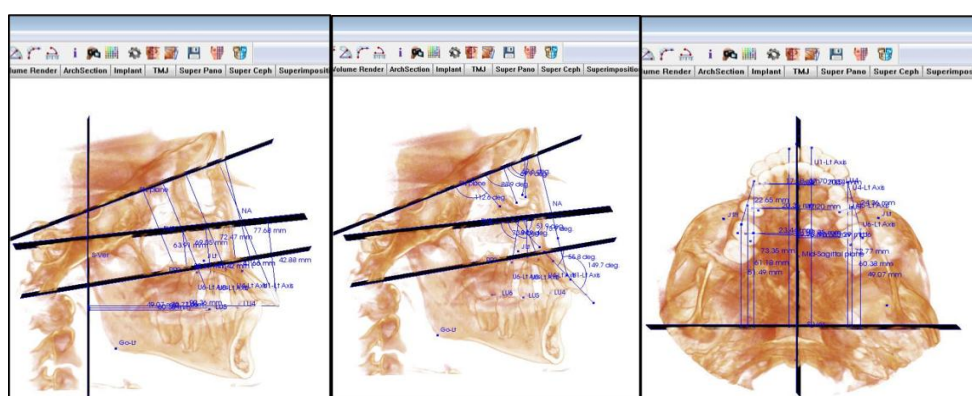


Figure 2. a) Sagittal linear measurements b) Sagittal angular measurements c) Axial linear measurements

Table 1. Variables for skeletal, dental, and soft tissue abbreviations and landmarks

Skeletal	
Sagittal	
SNA(°)	Sella-nasion-A point
SNB(°)	Sella-nasion-B point
ANB(°)	A point-nasion-B point
N-Pog-FHP (°)	Nasion pogonion to Frankfort horizontal plane
Vertical	
ANS-Me (mm)	Lower anterior facial height
MP-PP (°)	Mandibular plane to palatal plane
OP-PP (°)	Occlusal plane to palatal plane
OP-MP (°)	Occlusal plane to mandibular plane
Coronal	
J R-J L (mm)	Linear distance from jugal right to jugal left (maxillary width)
Dental	
Upper first molar	
U6-S Ver (mm)	The distance from mesiobuccal cusp tip of upper right first permanent molar to the S vertical plane

U6-SN (°)	The angle formed between the long axis of maxillary first permanent molar to the SN line
U6-FHP (°)	The angle formed between the long axis of maxillary first permanent molar to the FHP.
IMW (mm)	Distance from center of occlusal surface of right first permanent molar to center of occlusal surface of left first permanent molar
U6-MSP (°)	The anterior angle formed by MBc6-DPc6 line of the maxillary first permanent molar and midsagittal plane.
Upper central incisor	
U1-S Ver (mm)	The distance from incisal edge of upper right central incisor to the S vertical plane
U1-SN (°)	The angle formed between the long axis of the maxillary incisor and the SN plane
U1-FHP (°)	The angle formed between the long axis of the maxillary incisor and the FHP.
U1/L1 (°)	Interincisal angle
Upper first premolar	
U4-S Ver (mm)	The distance from buccal cusp tip of upper right first premolar to the S vertical plane
U4-SN (°)	The angle formed between the long axis of maxillary first premolar to the SN line
U4-FHP (°)	The angle formed between the long axis of maxillary first premolar to the FHP.
IPW4 (mm)	Distance from center of occlusal surface of right first premolar to center of occlusal surface of left first premolar
U4-MSP(°)	The anterior angle formed by Bc4-Pc4 line of the maxillary first premolar and midsagittal plane.
Upper second premolar	
U5-S Ver (mm)	The distance from buccal cusp tip of upper right second premolar to the S vertical plane
U5-SN (°)	The angle formed between the long axis of maxillary second premolar to the SN line
U5-FHP (°)	The angle formed between the long axis of maxillary second premolar to the FHP.
IPW5 (mm)	Distance from center of occlusal surface of right second premolar to center of occlusal surface of left second premolar
U5-MSP (°)	The anterior angle formed by Bc5-Pc5 line of the maxillary second premolar and midsagittal plane.
Soft tissue	
Ls-Eline (mm)	Linear distance from Ls to E-line
Li-Eline (mm)	Linear distance from Li to E-line
NLA(°)	Nasolabial angle

**Statistical analysis**

Statistical analysis was performed by Microsoft Office 2010 (Excel) and Statistical Package for Social Science SPSS version 20 (SPSS Inc, Chicago, III). Numerical data were presented as mean and standard deviation (SD) values. The data was explored for normality using Shapiro-Wilk tests which indicated normal distribution. Thus parametric test was applied for data analysis; Paired sample t-test was used to compare between pretreatment and post-distalization periods. The statistical significance level was set at  $P \leq 0.05$ . Intra-observer reliability (agreement) was measured using Intra-Class correlation coefficient (ICC).

**Results**

The paired sample t-test was used to compare between the pretreatment and the post-distalization treatment effects of the Skeletal

Frog appliance for each variable. Regarding the skeletal measurements in the anteroposterior dimension there was a statistically significant decrease of sella-nasion-B point (SNB), and nasion-pogonion-Frankfort plane (N-Pog-FHP) angles by  $0.89^\circ$  and  $1.26^\circ$  respectively ( $p \leq 0.05$ ). Whereas in the vertical dimension there was a statistically significant increase in lower anterior facial height as indicated by anterior nasal spine to menton (ANS-Me), and mandibular plane to sella-nasion (MP-SN) angles by 1.1mm and  $2.01^\circ$  respectively ( $p \leq 0.05$ ). The transverse skeletal measurements showed a statistically significant decrease of the maxillary base width between JR-JL by 2.17mm ( $p \leq 0.05$ ) (Table 2).

Table 2. Comparison of the skeletal changes induced by Skeletal Frog appliance before (T1) and after distalization (T2)

Variable	Pretreatment (T1) group		Post-distalization (T2) group			P value
	Mean	SD	Mean	SD	Mean difference	
SNA ( $^\circ$ )	82.70	$\pm 0.61$	82.90	$\pm 1.80$	-0.2	0.729
SNB ( $^\circ$ )	79.69	$\pm 0.95$	78.80	$\pm 0.82$	0.89	0.024*
ANB ( $^\circ$ )	3.59	$\pm 1.14$	4.70	$\pm 1.98$	-1.11	0.084
N-Pog-FHP ( $^\circ$ )	88.28	$\pm 1.24$	87.02	$\pm 1.23$	1.26	0.018*
ANS-Me (mm)	60.24	$\pm 1.40$	61.34	$\pm 1.10$	-1.1	0.038*
MP-SN ( $^\circ$ )	34.71	$\pm 1.08$	36.72	$\pm 0.87$	-2.01	0.004*
MP-PP ( $^\circ$ )	23.61	$\pm 1.97$	25.65	$\pm 1.11$	-2.04	0.023*
OP-PP ( $^\circ$ )	7.83	$\pm 1.84$	10.04	$\pm 1.95$	-2.21	0.018*
OP-MP ( $^\circ$ )	8.02	$\pm 2.09$	10.17	$\pm 2.01$	-2.15	0.075
JR-JL (mm)	65.66	$\pm 2.11$	63.49	$\pm 2.42$	2.17	0.048*

Values are presented as mean  $\pm$  standard deviation.

See Table 1 for abbreviations and definitions of each landmark or measurement. Paired-samples t-test was used; statistically significant at  $p < 0.05$ .

Concerning the changes in dental measurements the maxillary first molar (U6) revealed a statistically significant decrease in the anteroposterior position which was displayed by maxillary first molar long axis to the sella-nasion plane (U6-SN) and maxillary first molar long axis to the Frankfort horizontal plane (U6-FHP) angles by  $9.02^\circ$  and  $9.16^\circ$  respectively ( $p \leq 0.05$ ). The distance from mesiobuccal cusp tip of upper first permanent molar to the Sella vertical plane (U6-S Ver)

decreased by 4.14mm. The vertical position of the maxillary first permanent molar to sella-nasion (U6-SN) decreased by 2.03mm. Whereas the maxillary inter-molar width increased by 2.41mm. The maxillary right and left first molar exhibited significant rotation  $4.33^\circ$  and  $4.83^\circ$  respectively as indicated by a line connecting the mesiobuccal cusp tip to distopalatal cusp tip to midsagittal plane (MSP) (Table 3).

Table 3. Comparison of the maxillary first molar and soft tissue changes induced by Skeletal Frog appliance before (T1) and after distalization (T2)

Variable	Pretreatment (T1) group		Post-distalization (T2) group			P value
	Mean	SD	Mean	SD	Mean difference	
	U6-S Ver (mm)	43.95	$\pm 2.12$	39.81	$\pm 2.14$	
U6-SN ( $^\circ$ )	71.05	$\pm 1.82$	62.03	$\pm 2.47$	9.02	<0.001*
U6-FHP ( $^\circ$ )	82.9	$\pm 2.2$	73.74	$\pm 2.52$	9.16	<0.001*
IMW (mm)	44.9	$\pm 4.33$	47.31	$\pm 2.67$	-2.41	0.025*
RU6-MSP ( $^\circ$ )	28.23	$\pm 3.5$	23.9	$\pm 7.1$	4.33	0.026*
LU6-MSP ( $^\circ$ )	26.98	$\pm 4.6$	22.13	$\pm 2.8$	4.85	0.041*
Ls-Eline (mm)	1.25	$\pm 1.60$	1.12	$\pm 2.97$	0.13	0.928
Li-Eline (mm)	3.94	$\pm 1.85$	3.38	$\pm 1.72$	0.56	0.4343
NLA ( $^\circ$ )	115.66	$\pm 2.84$	118.53	$\pm 3.41$	-2.87	0.047*

Values are presented as mean  $\pm$  standard deviation.

See Table 1 for abbreviations and definitions of each landmark or measurement. Paired-samples t-test was used; statistically significant at  $p < 0.05$ .

Regarding the maxillary first and second inter-premolar width increased by 0.8mm and 0.68mm respectively. Whereas insignificant rotation of maxillary right and left first and second premolars were detected. There was a decrease in the anteroposterior position of the maxillary first and second premolars in relation

to Sella vertical line by 1.89mm and 2.8mm respectively, significant decrease in the anteroposterior position in relation to SN and FHP  $5.01^\circ$  and  $5.16^\circ$  respectively ( $p \leq 0.05$ ), and insignificant increase in the vertical positions as well (Table 4).

Table 4. Comparison of the anchorage teeth changes induced by Skeletal Frog appliance before (T1) and after distalization (T2)

Variable	Pretreatment (T1) group		Post-distalization (T2) group			P value
	Mean	SD	Mean	SD	Mean difference	
U1-S Ver (mm)	76.44	±1.33	75.54	±2.83	0.9	0.219
U1-SN (°)	109.6	±3.45	108.43	±4.83	1.17	0.474
U1-FHP (°)	121.45	±3.66	120.14	±4.7	1.31	0.401
U1/L1 (°)	112.65	±2.99	115.89	±2.43	-3.24	0.023*
U4-S Ver (mm)	54.75	±3.06	52.86	±2.45	1.89	0.169
U4-SN (°)	83.1	±1.76	80.37	±2.58	2.73	0.05*
U4-FHP (°)	94.95	±2.72	91.65	±1.98	3.3	0.033*
IPW4 (mm)	39.68	±0.97	40.48	±1.45	-0.8	0.233
RU4-MSP(°)	76.22	±4.1	78.73	±5.4	-2.51	0.65
LU4-MSP(°)	81.95	±2.9	83.87	±6.1	-1.92	0.24
U5-S Ver (mm)	49.58	±2.38	46.78	±1.42	2.8	0.026*
U5-SN (°)	79.31	±1.57	74.3	±2.31	5.01	0.002*
U5-FHP (°)	91.16	±1.92	86	±2.65	5.16	0.003*
IPW5 (mm)	33.85	±1.03	34.53	±1.39	-0.68	0.32
RU5-MSP (°)	76.44	±8.8	80.26	±9.7	-3.82	0.098
LU5-MSP (°)	76.84	±6.8	79.7	±8	-2.86	0.12

Values are presented as mean ± standard deviation.

See Table 1 for abbreviations and definitions of each landmark or measurement. Paired-samples t-test was used; statistically significant at  $p < 0.05$ .

As for maxillary central incisors they showed that there were statistically insignificant decrease in the anteroposterior position for both angular and linear measurements by  $1.17^\circ$  and  $0.9\text{mm}$ . Maxillary central incisors displayed insignificant increase in the vertical position by  $0.64\text{mm}$  (U1-SN). Whereas the interincisal angle which is the angle between the upper central incisor long axis to lower incisor long axis (U1/L1) revealed a

statistically significant increase by  $3.24^\circ$  ( $p < 0.05$ ) (Table 4). The soft tissue measurement showed that, there were statistically significant increase in the nasolabial angle by  $2.87^\circ$  ( $p < 0.05$ ) (Table 3).

### Discussion

Many treatment alternatives have been proposed for the treatment of class II division 1 malocclusions, among which are maxillary



molar distalization that is gaining more popularity. Various methods are implemented for maxillary molar distalization such as headgear which is an effective extraoral appliance yet its drawbacks are patient compliance and esthetic concerns. In an attempt to overcome these disadvantages many fixed intraoral distalizers were introduced. However, these tooth-borne appliances posed problems regarding anchorage loss, increase of overjet, jeopardizing molar stability, and prolongation of treatment duration. Recently the advent of TADs paved the way for researchers to combine them with various tooth-borne distalizing appliances such as the Skeletonized distal jet<sup>20</sup> and the Skeletal Frog<sup>19</sup> to avoid the disadvantages of the conventional intramaxillary distalizers.

In 2011 Ludwig et al.<sup>19</sup> was the first to introduce the Skeletal Frog distalizer. One of the major setbacks of their study was that it was conducted on only two case reports, in addition to the lack of evaluation of the skeletal, dentoalveolar and soft tissue effects. Thus the aim of our study was to assess the effects of the Skeletal Frog on a larger sample size (25 subjects) and the variables were evaluated three dimensionally utilizing the CBCT which to the best of our knowledge was not addressed.

All subjects in this study exhibited bilateral molar relationship since the original assembly of the Skeletal Frog was designed for bilateral distalization<sup>21</sup>, in addition to avoiding the implementation of asymmetric distalizing mechanics which might have an adverse effect on the skeletal, dentoalveolar and soft tissue measurements.

The integration of two TADs placed paramedian 3mm from the midsagittal suture prevented the possible developmental disturbances of the midpalatal sutures. Insertion of TADs 6mm behind the incisive

papillae ensured adequate bone thickness thus providing biomechanical stability of the TADs and a stable four-point support for the appliance<sup>19</sup>. Since the TADs were inserted palatally where there was a reduced possibility of root injury, thus their selected diameters were 2mm which in turn increases stability due to the increase in cortical bone contact. Whereas, the length was 6mm to prevent the possibility of perforation of the nasal cavity.

Skeletal, dental, and soft tissue measurements implemented in this study were performed on 3D volumetric analysis obtained from CBCT scan on a computer software program. The 3D volumetric analysis had an advantage over 2D analysis as a more accurate measurement due to the lack of bilateral structure superimposition and reduced possibility of errors in identification<sup>5,22</sup>.

The associated skeletal changes in the sagittal plane in this study displayed a decrease in SNB angle  $0.89^\circ$  and N-Pog/FHP  $1.26^\circ$  while in the vertical plane the lower anterior facial height showed an insignificant increase which was evident in the posterior rotation of the mandible as indicated by MP/SN, OP/PP, OP/MP, and OP/FH this is concurrent with the findings of Burhan<sup>7</sup>.

The amount of distalization in studies based on bone-borne anchorage appliances, was between 1.3 and 6.4 mm<sup>2,4,14,15</sup>. Whereas, studies that involved tooth-borne appliances such as the dual force distalizers supported by mini-implants or pendulums attributed to a higher degree of molar distalization<sup>16</sup>. In our study, along the sagittal plane, the Skeletal Frog appliance displayed a significant distalization of the maxillary first molar of 4.14mm. The molar distalization was similar to that reported by Mujia et al., (4.25mm),<sup>5</sup> Bayram et al. (4mm)<sup>3</sup>, Nalcaci et al.<sup>4</sup> and Gelgör et al.<sup>2</sup> whom distalized molars via TADs with open coil springs and TADs supported TPAs and

springs by an average of ( $3.95 \pm 1.35$  mm), and ( $3.9 \pm 1.6$  mm) respectively. Yet, the amount of distalization was slightly smaller than the findings of Burhan ( $5.51\text{mm}$ )<sup>7</sup>. These dissimilarities might be due to the differences in appliance designs, longer treatment durations, and sample criteria.

Maxillary molar tipping in this study was  $9.16^\circ$  which is consistent to that obtained by; Kircelli et al.<sup>14</sup> with bone-anchored pendulum appliance ( $10.9^\circ$ ), Bussick and McNamara<sup>23</sup> with the Pendulum appliance ( $10.6^\circ$ ), and Patel et al.<sup>24</sup> with Jones jig ( $9.54^\circ$ ). However, less values for molar tipping were shown by; Burhan<sup>7</sup> when combining the frog appliance with/without headgear ( $4.96^\circ$  and  $1.25^\circ$  respectively), Chiu et al.<sup>25</sup> with the distal jet ( $5^\circ$ ), Kinzinger et al.<sup>26</sup> with the pendulum K ( $4.65^\circ$ ), and Bayram et al.<sup>3</sup> with the Frog appliance ( $3^\circ$ ). These dissimilarities might be the result of the amount of molar distalization, differences in appliance designs, and the full eruption of the maxillary second molar which has been reported in the literature to contribute to a significant amount of molar tipping<sup>5</sup>. Furthermore, tipping in our research can be due to the position of the Skeletal Frog screw which was 10-12mm below the occlusal plane close to the center of resistance of the maxillary first molar rather than being placed close to the center of resistance of the second molar which is at 9mm below the occlusal plane<sup>5</sup>.

Numerous authors displayed molar intrusion in their studies with bone-borne distalizers<sup>14,16,27</sup>. Regarding the vertical plane the maxillary molar showed intrusion of 2.46mm that might be due to the low position of the double-bend of the stainless steel spring in relation to the level of the band sheath which in turn causes the line of action of the force to pass apical to the molar center of resistance thus, intruding the molars. Molar distalization is associated

with their divergence along the arch form natural shape as suggested by Bolla et al.<sup>6</sup> The transverse changes in the intermolar width in the present study unveiled an increase of 2.41mm which is consistent with the findings of Mujia et al.<sup>5</sup> (2.87mm) and Miresmaeili et al.<sup>12</sup> (2.9mm).

Presented in the current study is the distobuccal rotation of the maxillary first molar by  $4.3^\circ$  and  $4.85^\circ$  for the right and left sides, molar rotation could not be prevented since the point of force application is palatal, farther from the molar center of resistance. Buffering measures such as toe-in was not enforced in this study as it creates a complicated multi-couple system that is strenuous to control in addition to friction<sup>18</sup>. These findings are in agreement with Uzuner et al.<sup>28</sup> where the maxillary molar exhibited a distobuccal rotation of  $5.9^\circ$  and  $4.4^\circ$  for the right and left sides with the Frog appliance.

One of the most characteristic aspects of Skeletal Frog in this research is the simultaneous distal movement and distal tipping of the premolars by 1.9mm and  $2.7^\circ$  for the first premolar and 2.8mm and  $5^\circ$  for the second premolar respectively. In addition to extrusion of the first and second premolar by 0.56mm and 0.8mm respectively. This is due to the Skeletal Frog design where the premolars are not included in the anchor unite therefore, they are free to drift. This is advantageous in two aspects; First the new molar position would not be jeopardized since the unnecessary round tripping of the premolars has been avoided through the phenomena of driftodontics. Secondly the first and second interpremolar widths increased by 0.8mm and 0.68mm respectively, this could be attributed to their freedom to drift distally which is in agreement with Uzuner et al.<sup>28</sup> whom recorded significant expansion in premolar region with the Karads integrated distalizing system.

Fudalej and Antoszewska<sup>29</sup> in a systematic review suggested that implementation of temporary skeletal anchorage devices during molar distalization could help avoid labial movement of the maxillary incisors. The findings in current study presented retroclination of the maxillary incisors by 1.3° (U1/FH) and retrusion by 0.9mm (U1-SVer) in addition to increase in the interincisal angle by 3.24°. This might be accredited to the freedom of the incisors therefore, causing the anterior crowding to spontaneously solve out by the stretched trans-septal fibers and the effect of the upper lip. As a consequence, the nasolabial angle showed an increase by 2.87° indicating retrusion of the upper lip which is in harmony with Papadopoulos et al.<sup>30</sup> thus improving facial profile.

### Conclusion

The Skeletal Frog appliance is a fixed skeletal palatal intraoral appliance that has revealed substantial agreement as a means for treating Class II division 1 malocclusions via efficacious distalization of the maxillary molars with the second molars fully erupted. The Skeletal Frog appliance is a simple and hygienic distalizer. It produces maxillary molar distalization without any undesirable side effects on the premolars and incisors. It is associated with spontaneous distal drift of the premolars via driftodontics, in addition to unraveling of the anterior crowding through stretching of the trans-septal fibers thus, permitting leveling and alignment of the maxillary arch to occur simultaneously during the molar distalization. Moreover, the CBCT images demonstrated exactly and veraciously the three-dimensional structures. Therefore, creating a reliable and accurate method for three-dimensional analysis.

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