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POSITIONAL AND DIMENSIONAL TMJ CHANGES FOLLOWING THE USE OF DIFFERENT CLASS II CORRECTORS IN A SAMPLE OF ERBIL CITY [RANDOMIZED CLINICAL TRIAL]

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Abstract
Background: Due to the retrognathic mandible, an orthodontist frequently observes skeletal class II malocclusion in growing patients. The preferred technique for analyzing and monitoring the temporomandibular joint alterations caused by the functional device is magnetic resonance imaging [MRI]. The study aimed to assess and compare changes in the articular disc's dimension and location before and following the use of various class II correctors to correct the class II molar relation using MRI technology. Methods: 39 adolescent patients aged 15-23 years old [24 girls and 15 boys] who were diagnosed with skeletal Class II division 1 malocclusion based on clearly defined criteria underwent treatment with either the power scope II [PS], Sabbagh Advanced Repositioning Appliance [SARA] and or Dynaflex [DF] with fixed appliances. For fixed functional treatment, the average length of treatment was 5-7 months. The changes in the articular disc dimension and position and condylar position were assessed. The study was done at the Department of Orthodontics at the College of Dentistry, Hawler Medical University in Erbil City.
Results: Group DF has a significant effect on the condylar position index and posterior joint space on the closed mouth and disc length on both open and close mouth techniques, and in the group SARA, disc position, and condylar position index on closed mouth technique have shown that significant differences were observed.
Conclusion: Class II malocclusions can be effectively corrected by fixed functional appliances. The statistical significance forward movement of the condyle in the glenoid fossa and the posterior movement of the articular disc concerning the condylar head was observed. The mechanism of action of functional appliances appears to include the forward migration of the C-GF complex.

Keywords: fixed functional appliance, MRI, Class II, articular disc, Tmj

INTRODUCTION
Skeletal class II malocclusion is one of the most common orthodontic problems, affecting about 30% of the population [1,2]. Class II development can occur from a variety of skeletal and dental factors,

although mandibular retrognathism is considered to be the primary cause [3,4]. Functional appliances are often utilized to treat class II malocclusion caused by mandibular retrognathism [5,6,7]. Class II elastics or removable functional appliances are typically recommended for class II malocclusion in growing populations. However, using these therapeutic methods increases serious concerns about patient compliance. Fixed functional appliances [FFAs] are an effective treatment option for Class II malocclusion in post-adolescent patients whose growth has mostly finished [8]. A functional orthodontic treatment consists of repositioning the mandible to generate force through the contraction of the corresponding muscles; this force is subsequently transmitted to the teeth, skeletal system, and temporomandibular joint [TMJ] [9]. Thus, it is important to assess the TMJ modifications brought on by functional orthodontic treatment [10]. Magnetic resonance imaging [MRI] is the preferred modality for assessing the soft tissue anatomical structures within the TMJ, particularly in determining the disk's position and shape [11].
Numerous research has been conducted on the changes in the skeletal, dental, and condyles after class II correction [12,13,14,15,16]. Few studies compared the various available tools for class II treatment and their impact on the articular disc. This study aimed to assess and compare the positional and dimensions changes in the Temporomandibular Joint disc resulting from various class II correctors before and after correcting the class II molar relation using MRI.

Subjects and methods

Study design

A prospective parallel randomized clinical trial was conducted.

Study Setting

A total of 39 patients, 14 boys, and 25 girls, between the ages of 15 and 23 who had mandibular retrognathism and angle Class II division 1 malocclusion were chosen sequentially for treatment.
Inclusion criteria were patients with clinical manifestation of a retrognathic mandible, as determined by cephalometric study, with an ANB angle larger than 4°, due to the retrognathic mandible [SNB angle < 78◦], Permanent dentition with angle Class II division 1 malocclusion with no missing or history of extraction. Patients without history of TMJ dislocation or pain. No history of orthodontic treatment. Complete treatment records [cephalometric and panoramic X-ray, photography, and digital study models]. Absence of transverse pre-treatment discrepancy. Non-extraction treatment strategy and Class I occlusal relationship following treatment. Cervical vertebrae maturation stages 4,5, and/or 6 in healthy pro-pubertal patients [17]. Patients having a history of trauma or TMJ operations, severe TMDs, systemic issues such as pregnancy, former orthodontic treatment, claustrophobia, or dental appliances or restorations that could have compromised patient safety during an MRI scan were not included in the study.

Sample size calculation:

The calculation of the sample size was performed utilizing the power analysis assessment tool G*power, version 3.1.9.7 [Franz Faul Universität, Kiel, Germany]. Considering an effect size of 0.649 and a significance level of 0.05, an 80% statistical power could be generated to identify significant differences with a sample size of 39 patients divided into three groups [18].

Groups randomization

The study participants were randomly assigned to different groups using an online randomization strategy developed by online software available on the website. https://www.graphpad.com/quickcalcs/. The allocation ratio was determined as 1:1:1. The researchers involved in the study were unaware of the group assignment. Following the initial clinical and radiological assessment, the patients were allocated into three groups of 13 individuals each: Power scope 2[American Orthodontics], SARA-Sabagh Advanced Repositioning Appliance [Forestadent, Germany], CS-2000® Niti spring class II corrector [Dyna flex]. The study was authorized by the

Local Research Ethics Committee of Hawler Medical University (HMU D.22). Every participant who is a part of this research has provided written informed consent that details every stage of treatment.

Starting fixed orthodontic treatment
All patients were treated with MBT 0.022" bracket [Dentaurum GmbH & Co. KG, discovery] collected from private orthodontic practices in Erbil city. After initial leveling and alignment, and one month after the insertion of the 0.019"x 0.025" Niti archwire, patients were sent to take an MRI of the TMJs. The duration of fixed functional appliance treatment was about 5-7 months.

MRI evaluation
Magnetic resonance imaging [MRI] scans of the right and left temporomandibular joints [TMJs] were conducted at two specific time intervals during treatment: immediately before the placement of the fixed functional device [T1], and after attaining class I molar relation [T2]. The MRIs were performed with the mandible closed [MC] and opened [MO] at the Erbil International Hospital using a 3.0 T Magnetom Trio [Siemens Medical, Germany] with a 32-channel head coil. T Turbo spin echo T2-weighted coronal images [repetition time, 5400 ms; echo time, 71 ms; flip angle: 90°; slice thickness, 3 mm; interslice gap, 1 mm; field of view [FoV], 200; regional FoV, 64] as closed mouth, and parasagittal proton density spin-echo images [repetition time, 2850 ms; echo time, 66 ms; flip angle, 90; slice thickness, 3 mm; interslice gap, 0.3 mm; m; FoV, 150; regional FoV, 90] with the mouth closed and open were obtained. The images were measured twice by a general radiologist [10 years of experience] who was blinded to the patient's clinical condition. The observer repeated the trial 15 days apart to measure intra-observer variability. The statistical analysis includes all measurement mean values. All the measurements were done using Radiant DICOM viewer 2023.1 software and those sections were chosen that displayed the maximum width of the condyle and disc.

Statistical Analysis
The data was organized and presented in a tabular format using Microsoft Excel. GraphPad Prism 10.2.2.397 Windows was utilized for data analysis. The explanatory and outcome factors were analyzed using descriptive statistics, specifically the mean and standard deviation for quantitative data, and frequency and percentage for qualitative variables.
To evaluate the data for normality, the Shapiro-Wilk test was employed. Using a paired t-test, the means of numerous parameters at baseline and after the intervention were compared. By utilizing one-way ANOVA, the means of the three groups were compared. A p-value of less than 0.05 was deemed statistically significant for all two-tailed analyses. The assessment of intra-examiner reliability was conducted by calculating the intraclass correlation coefficient [ICC] and 95% confidence intervals at a significance level of 5% [$p \leq 0.050$]. When the degree of agreement between measures was less than 5° and 95% of the subjects' measures fell within the upper and lower limits of agreement, then the measures were considered to agree.

Results
The gender and age distribution of the groups has been illustrated in Table 1. The current study shows that group DF has a significant effect on the forward position of condyle and retrusion of the disc, increased posterior joint space, and decreased disc length in the closed-mouth technique and a decrease in the disc length and increased width of the disc in the open-mouth technique [Table 2,3]. In the closed mouth technique, the number of non-biconcave discs was 10 on the right side before treatment while one patient had improved the shape of the disc. While on the left side, 8 patients had no biconcave form which decreased to 7 after treatment. In the open mouth technique, the number of discs was non-biconcave was 8 on the right side before treatment while three patients have improved the shape of the disc. While on the left side, 10 patients had no biconcave form which decreased to 7 after treatment. 23 % of joints were interiorly displaced before treatment and remained in the same position after FFA treatment.

In the PS group, a significant difference was observed in the superior joint space on the closed-mouth technique [Table 4,5]. In the closed mouth technique, the number of non-biconcave discs was 10 on the right side before treatment while three patients improved the shape of the disc. While on the left side, 8 patients had no biconcave form which decreased to 6 after treatment. In the open mouth technique, the number of non-biconcave discs was 7 on the right side before treatment while two patients improved the shape of the disc. While on the left side, 9 patients had no biconcave form which decreased to 6 after treatment. 15 % of joints were interiorly displaced before treatment and remained in the same position after FFA treatment.
In the SARA group, retrusion of the articular disc with protrusion of condyle has shown significant differences in the closed-mouth technique [table 6,7]. In the closed mouth technique, the number of non-biconcave discs was 8 on the right and left side before treatment while two patients improved the shape of the disc. In the open mouth technique, the number of discs was non-biconcave was 6 on the right side before treatment while two patients improved the shape of the disc. While on the left side 6 patients have no biconcave form which decreased to 4 after treatment. 23 % of joints were interiorly displaced before treatment and decreased to 15% after FFA treatment. When comparing between groups, there were statistically significant differences in CPI, among all groups in closed mouth technique right side, noticeably between DF and PS, and DF and SARA. Also, Disc length has been significantly changed when comparing PS with SARA and DF with SARA. There is no significant difference among groups regarding Tmj change in the left side of the closed mouth [Table 8,9], however significant differences in condyle position were noticed among all groups, especially group DF and PS, group DF and SARA in the sight side [Table 10,11]. Regarding open mouth technique, there was no significant difference among groups [Table 12-14], while disc decreased significantly when comparing group SARA with PS and DF [Table 15].

Table 1. Baseline demographic and clinical characteristics of each group

Characteristic	Group 1 (PS)	Group 2 (SARA)	Group 3 (DF)
Number of patients recruited	13	13	13
Number of patients completed trial	13	13	13
Age (years)	19.23±3.15	21.2±2.56	20.54±62
Gender (frequency) (%)			
Male	8(61.53)	6 (46.15)	6 (46.15)
Female	5(38.47)	7 (53.85)	7 (53.85)

Table 2. Comparison of temporomandibular joint change in group DF (Open mouth technique)

Variables	Left side				Right side			
	Mean± SEM				Mean± SEM			
	Before	After	Mean Difference	p-value	Before	After	Mean Difference	p-value
DL	8.13±0.26	7.1±0.26	-1.03±0.19	0.02*	8.24±0.42	6.72±0.44	-1.52±0.16	0.024*
DW	1.35±0.16	1.45±0.09	0.09±0.16	0.57	1.18±0.12	1.45±0.1	0.25±0.06	0.005**

DL: disc length, DW: disc width. *: significant. **: highly significant.

Table 3: Comparison of temporomandibular joint change in group DF (closed mouth technique)

Left side					Right side			
Variables	Mean± SEM				Mean± SEM			
	Before	After	Mean Difference	p-value	Before	After	Mean Difference	p-value
PJS	1.36±0.16	1.9±0.25	0.54±0.21	0.035*	1.22±0.15	1.52±0.15	0.3±0.073	0.003**
SJS	1.88±0.17	1.96±0.22	0.08±0.26	0.766	1.63±0.12	1.66±0.15	0.03±0.17	0.86
AJS	1.63±0.20	1.48±0.13	-0.14±0.13	0.294	1.54±0.15	1.28±0.18	-0.25±0.15	0.12
CPI	-9.04±7.55	10.76±4.37	19.8±5.59	0.007**	-12.83±5.8	14.04±10.57	26.86±13.59	0.008**
DL	8.71±0.62	8.05±0.61	-0.66±35	0.012*	8.81±0.41	8.24±0.46	-0.56±0.24	0.006**
PDA	14.24±3.93	11.4±3.73	-2.84±3.1	0.387	11.16±5.72	8.37±6.51	-2.78±5.02	0.59
DW	1.46±0.195	1.54±0.22	0.08±0.09	0.422	1.50±0.185	1.59±0.12	0.09±0.11	0.43

PJS: posterior joint space, SJS; Superior joint space, AJS: anterior joint space, CPI, Condylar position index, DL: disc length, PDA: posterior disc angle, DW: disc width. *: significant. **: highly significant.

Table 4: Comparison of temporomandibular joint change in group PS (Open mouth technique)

Left side					Right side			
Variables	Mean± SEM				Mean± SEM			
	Before	After	Mean Difference	p-value	Before	After	Mean Difference	p-value
DL	7.77±0.57	7.67±0.46	-0.10±0. 39	0.70	8.57±0.62	7.71±0.48	-0.88±0.49	0.109
DW	1.65±0.18	1.68±0.25	0.026±0.19	0.89	1.46±0.13	1.49±0.12	0.03±0.11	0.76

DL: disc length, DW: disc width. *: significant. **: highly significant.

Table 5: Comparison of temporomandibular joint change in group PS [Closed mouth technique]

Right side					Left side			
Variables	Mean± SEM			p-value	Mean± SEM			
	Before	After	Mean Difference		Before	After	Mean Difference	p-value
PJS	1.33±0.1	1.35±0.12	0.02±0.05	0.7	1.38±0.12	1.52±0.13	0.14±0.13	0.32
SJS	1.57±0.09	1.69±0.08	0.12±0.08	0.06	0.96±0.59	1.37±0.79	0.40±0.43	0.37
AJS	1.25±0.15	1.23±0.09	-0.02±0.16	0.93	1.84±0.13	1.68±0.08	-0.16±0.11	0.18
CPI	4.22±6.34	4.93±5.57	0.7±7.31	0.92	-11.03±4.8	-9.52±5.17	1.50±5.99	0.80
DL	9.55±0.58	8.92±0.57	-0.63±0.33	0.09	9.09±0.41	8.53±0.37	-0.56±0.41	0.21
PDA	14.57±3.98	11.84±3.82	-2.73±3.11	0.40	14.81±4.04	11.87±3.82	-2.94±3.1	0.37
DW	1.3±0.17	1.37±0.19	0.04±0.09	0.65	1.32±0.17	1.39±0.18	0.07±0.09	0.45

PJS: posterior joint space, SJS; Superior joint space, AJS: anterior joint space, CPI, Condylar position index, DL: disc length, PDA: posterior disc angle, DW: disc width. *: significant. **: highly significant.

Table 6: Comparison of effect of disc and condyle change in group SARA [Open mouth technique]

Left side					Right Side			
Variables	Mean± SEM				Mean± SEM			
	Before	After	Mean Difference	p-value	Before	After	Mean Difference	p-value
DL	7.61±0.43	7.57±0.74	-0.03±0.48	0.94	7.71±0.61	7.46±0.78	0.24±0.27-	0.39
DW	1.22±0.1	1.32±0.08	0.09±0.13	0.50	1.26±0.12	1.38±0.13	0.12±0.07	0.15

DL: disc length, DW: disc width. *: significant. **: highly significant.

Table 7: Comparison of effect of disc and condyle change in group SARA (closed mouth technique)

Right side					left side			
Variables	Mean± SEM			p-value	Mean± SEM			
	Before	After	Mean Difference		Before	After	Mean Difference	p-value
PJS	1.97±0.39	2.11±0.23	0.13±0.28	0.65	1.78±0.46	1.84±0.11	0.05±0.45	0.90
SJS	2.14±0.24	2.32±0.37	0.18±0.13	0.22	2.08±0.26	2.11±0.24	0.02±0.14	0.85
AJS	2.13±0.30	1.85±0.28	-0.27±0.16	0.14	1.88±0.20	1.53±0.17	-0.35±0.23	0.18
CPI	4.89±4.59	11.26±6.20	6.36±2.49	0.04*	-6.86±10.06	10.08±5.87	16.94±4.98	0.019*
DL	9.58±0.47	9.35±0.56	-0.22±0.49	0.66	8.83±0.77	8.19±0.77	-0.64±0.34	0.11
PDA	22.08±8.83	14.6±9.39	-7.47±2.83	0.04*	7.46±4.86	1.1±4.81	-6.36±1.92	0.021*
DW	1.38±0.11	1.64±0.16	0.25±0.17	0.19	1.25±0.21	1.55±0.24	0.29±0.17	0.15

PJS: posterior joint space, SJS; Superior joint space, AJS: anterior joint space, CPI, Condylar position index, DL: disc length, PDA: posterior disc angle, DW: disc width. *: significant. **: highly significant.

Table 8: Intergroup comparison of Tmj changes (T2-T1) of groups in the left side of the Closed mouth technique.

Variables	Mean difference ±SD			*p*-value (One way ANOVA)
	G1	G2	G3	
PJS	0.54±0.64	0.14±0.41	0.05±1.10	0.36
SJS	0.08±0.80	0.40±1.29	0.02±0.34	0.69
AJS	-0.14±0.39	-0.16±0.33	-0.35±0.56	0.0804
CPI	19.8±16.77	1.5±18	16.94±12.2	0.06
DL	-0.66±0.42	-0.56±1.25	-0.64±0.29	0.96
PDA	-2.84±9.32	-2.94±3.1	-6.368±4.72	0.24
DW	-0.08±0.29	-0.08±0.45	-0.29±0.43	0.20

PJS: posterior joint space, SJS; Superior joint space, AJS: anterior joint space, CPI, Condylar position index, DL: disc length, PDA: posterior disc angle, DW: disc width. *: significant. **: highly significant.

Table 9: Intergroup comparison of Tmj changes (T2-T1) of each two groups in the left side of the Closed mouth technique.

Variables	Mean difference ±SD			*p*-value		
	G1	G2	G3	G1 vs G2	G1 vs G3	G2 vs G3
PJS	0.54±0.64	0.14±0.41	0.05±1.10	0.4779	0.41	0.97
SJS	0.08±0.80	0.40±1.29	0.02±0.34	0.7573	0.99	0.73
AJS	-0.14±0.39	-0.16±0.33	-0.35±0.56	0.2876	0.6298	0.0755
CPI	19.8±16.77	1.5±18	16.94±12.2	0.0665	0.94	0.19
DL	-0.66±0.42	-0.56±1.25	-0.64±0.29	0.817	0.97	0.87
PDA	-2.84±9.32	-2.94±3.1	-6.368±4.72	0.84	0.47	0.42
DW	-0.08±0.29	-0.08±0.45	-0.29±0.43	0.64	0.56	0.17

Table 10: Intergroup comparison of Tmj changes (T2-T1) of all groups in the right side of the Closed mouth technique.

Variables	Mean± SD			*p*-value
	G1	G2	G3	
PJS	0.3±0.07	0.021±0.05	0.13±0.28	0.31
SJS	0.03±0.17	0.12±0.08	0.18±0.13	0.15
AJS	-0.25±0.15	-0.02±0.16	-0.27.14	0.36
CPI	26.86±13.59	0.70±7.31	6.36±2.49	0.01*
DL	-0.56±0.24	-0.63±0.33	-0.22±0.49	0.67
PDA	-2.78±5.02	-2.73±3.11	-7.47±2.83	0.32
DW	0.09±0.11	0.04±0.09	0.25±0.17	0.68

PJS: posterior joint space, SJS; Superior joint space, AJS: anterior joint space, CPI, Condylar position index, DL: disc length, PDA: posterior disc angle, DW: disc width. *: significant. **: highly significant.
Group 1:DF, Group 2:PS, Group 3: SARA.

Table 11: Intergroup comparison of Tmj changes (T2-T1) of each two groups in the right side of the Closed mouth technique.

Variables	Mean± SD			*p*-value		
	G1	G2	G3	G1 vs G2	G1 vs G3	G2 vs G3
PJS	0.3±0.07	0.021±0.05	0.13±0.28	0.1855	0.6771	0.7168
SJS	0.03±0.17	0.12±0.08	0.18±0.13	0.3836	0.7362	0.147
AJS	-0.25±0.15	-0.02±0.16	-0.27.14	0.4323	0.9948	0.452
CPI	26.86±13.59	0.70±7.31	6.36±2.49	0.015*	0.038*	0.0926
DL	-0.56±0.24	-0.63±0.33	-0.22±0.49	0.85	0.45	0.49
PDA	-2.78±5.02	-2.73±3.11	-7.47±2.83	0.5783	0.319	0.8329
DW	0.09±0.11	0.04±0.09	0.25±0.17	0.9953	0.696	0.7452

PJS: posterior joint space, SJS; Superior joint space, AJS: anterior joint space, CPI, Condylar position index, DL: disc length, PDA: posterior disc angle, DW: disc width. *: significant. **: highly significant.
Group 1:DF, Group 2:PS, Group 3: SARA.

Table 12: Intergroup comparison of Tmj changes [T2-T1] of all groups on the left side of open mouth technique

Variables	Mean± SD			*p*-value
	G1	G2	G3	
DL	-1.03±0.19	-0.1±0.39	-0.03±0.48	0.10
DW	0.09±0.16	-0.02±0.19	-0.09±0.13	0.747

DL: Disc Length, DW: Disc Width
Group 1:DF, Group 2:PS, Group 3: SARA.

Table 13: Intergroup comparison of Tmj changes [T2-T1] of each two groups in left side of open mouth technique

Variables	Mean± SD			*p*-value	*p*-value		
	G1	G2	G3		G1 vs G2	G1 vs G3	G2 vs G3
DL	-1.03±0.19	-0.1±0.39	-0.03±0.48	0.10	0.058	0.12	0.88
DW	0.09±0.16	-0.02±0.19	-0.09±0.13	0.747	0.861	0.744	0.960

DL: Disc Length, DW: Disc Width
Group 1:DF, Group 2:PS, Group 3: SARA.

Table 14: Intergroup comparison of Tmj changes [T2-T1] of all groups on the right side of the open-mouth technique

Variables	Mean± SD			*p*-value
	G1	G2	G3	
DL	-1.52±0.16	-0.88±0.49	-0.24±0.27	0.56
DW	-0.03±0.11	0.03±0.11	-0.12±0.07	0.080

DL: Disc Length, DW: Disc Width
Group 1:DF, Group 2:PS, Group 3: SARA.

Table 15: Intergroup comparison of Tmj changes [T2-T1] of each two groups on the right side of the open-mouth technique

Variables	Mean± SD			*p*-value		
	G1	G2	G3	G1 vs G2	G1 vs G3	G2 vs G3
DL	-1.52±0.16	-0.88±0.49	-0.24±0.27	0.76	0.04*	0.02*
DW	-0.03±0.11	0.03±0.11	-0.12±0.07	0.065	0.601	0.489

DL: Disc Length, DW: Disc Width
Group 1:DF, Group 2:PS, Group 3: SARA.

Discussion

The present study was done to evaluate the dimensional and positional changes in the articular discs with different class II correctors by using Magnetic Resonance Imaging.

Assessment of Condylar Position [Condylar Concentricity] and Joint Spaces

According to Vargas-Pereira's proposal, the anterior joint space [AJS] is the shortest path connecting the eminence and the head of the condyle. Similarly, the posterior joint space [PJS] is defined as the smallest distance between the condylar head and the post-glenoidal fossa [19] [Figure 1]. After measuring the AJS and PJS, the resulting values were inputted into the following formula: JSI= [[P – A]/ [P + A]]x100, where A is the AJS, P is the PJS, and JSI is the joint space index. The physiologic limit for the condylar position ranged from –32.5% to 21.1%. The condyle's anterior position relative to the glenoid fossa is represented by a positive number, whereas a negative value suggests a posterior location of the condyle. A value of zero is referred to as concentric [20].

In the current study, results show all groups have a protrusive effect on condyle in both the right and left sides. Among study groups, the SARA and DF appliances showed significant anterior positioning of the condyle on both sides. There was no significant difference between all groups and between each two groups. A study revealed that 75% of the patients exhibited a more anterior condyle position following treatment compared to the control group. Additionally, the condyle displayed varying degrees of forward movement about the articular fossa [20]. In the present study, it was 78% in DF, 67% in PS, and SARA 84% found forward positioning of the condyle. The result of the current study is compatible with studies done by [14,19,21,22,23,24]**.** According to Parvathy's study, the utilization of a functional appliance in the mandibular advancement method led to the stimulation of condylar growth in a posterior direction and remodeling of the glenoid fossa. Consequently, this process resulted in the anterior movement of the condyle to the skull [14]. According to research, the condyle exhibited a notable increase in anterior positioning in the MRIs obtained immediately after treatment. However, after a period of one year, the condyle had reverted to its initial position. The potential cause for the return to the initial position may be attributed to the displacement of the condyle within the fossa or the successful completion of the condyle-fossa remodeling process [25,26].
Several investigations have reported that there are no notable alterations in the location of the condyles inside the TMJ space after therapy [20; 25, 27, 28, *29*]. They used different methods for the treatment of class II malocclusion. Nindra et al. discovered that adaptive restoration of the condyle and articular fossa occurred following functional orthodontic therapy, but their relative positions did not alter [30]. Arici et al and Zhang et al, in their studies, have found more posterior movement of the condyle. They used different methods of analysis and removable types of functional appliances [10,31].

Joint spaces
Results of the current study revealed that posterior joint space has increased while anterior joint space was decreased in all study groups but only was significant in group DF. Also, SJS has been increased which indicates forward and downward movement of the condyle. The same result was found in studies done by Elfeky et al. [23], On the other hand, Cacho et al and Kinzinger et al studying the Herbst appliance and functional mandibular advancer, respectively, found no significant changes in the joint space [27,32].

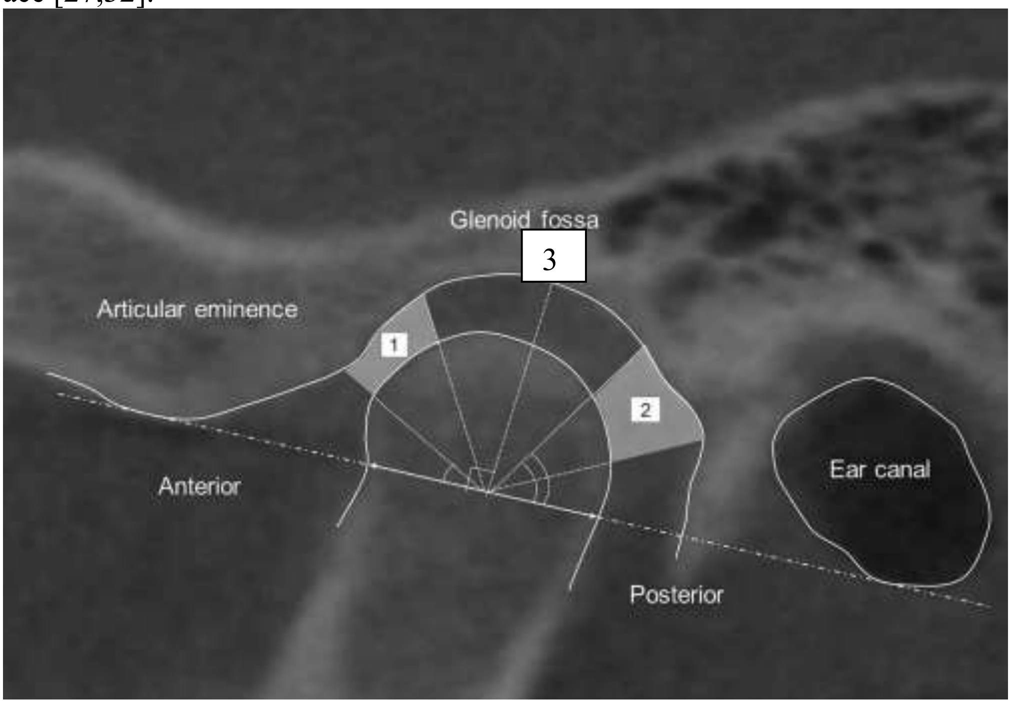

Figure 1. Evaluation method for condylar position and joint spaces [33].

Disc morphology.
T2 oblique sagittal images were evaluated and classed for disc morphology using mouth close and mouth open. Based on band abnormalities, Ribeiro classified the disc as non-biconcave [abnormal morphology] or biconcave [34]. The internal derangements of the temporomandibular joints [TMJs] are influenced by changes in the morphology of the disc, in addition to its position [35]. The disc's morphology and interarticular pressure determine its translation with the condyle. Indeed, disc shape is crucial for maintaining the correct location throughout the function [36]. In the present study around 85% of discs remain stable in morphology. Aidar et al in their study found that 93.75% of subjects have no alterations to disc morphology which is comparable with the current result [37].
In 6 joints, disc morphology was improved to biconcave form with the mouth closed while in the mouth open, 8 joints were modified to biconcave. Franco et al. found that Frankel II functional regulators improved disc shape in treated subjects [38].

Disc Length
In a study conducted by Shen et al, it was shown that the utilization of the anterior repositioning appliance resulted in an increase in disc length within the anterior disk displacement with reduction [ADDwR] group, but it led to a decrease in the anterior disk displacement without reduction [ADDwoR] group. This may be because the disc was extruded when anteriorly displaced and worsened after moving the mandible forward in the ADDWoR group. Conversely, the disk returned to its original length upon repositioning in the ADDWR group [39].
Zhang et al conducted a study that found a significant relationship between the displacement distance and quantitative parameters such as disc length, width, and L/W. The disks demonstrated reduced lengths, increased widths, and decreased L/W as the displacement distance increased [9].

Sagittal disc position
Silverstein et al. reported a normal range of 25.7° to −18.7°, while Vargas-Pereira reported 33° to −21° [40,41]. Displaced disks had the thickest posterior band previous or posterior to this point. The posterior band was used to determine the disc limit, maybe because the posterior ligament has more fat and water than the darker disc tissue and is easier to identify [42].
In the present study, pretreatment MRIs in all three groups showed nine cases of anterior disk displacement [three DF, four PS, two SARA] whereas the remaining patients were within the normal range. In comparison between pre- and post-functional treatment, disk position showed non-significant posterior movement from its initial pretreatment position among all groups but was within the physiologic range. These findings were in accordance with the Ruf and Pancherz study [25]. Also [Chintakanon et al, Arat *et al*; Kinzinger *et al* ; Wadhawan *et al*] showed no statistically significant changes in disk position [20, 26,32,43].
Pretreatment disc displacement determines repositioning prognosis. A partially displaced disc can be repositioned and remain stable until final inspection [25].
On the other hand, the current result was contrary to those of Foucart et al who reported that 3 of 10 previously healthy patients who used the Herbst appliance developed disc displacement after treatment. Those authors evaluated results from removable appliances, rather than those from a fixed functional appliance as in the present study [44]. They also used sagittal MRI and in the current study, oblique sagittal images [parasagittal] were used.
The biomechanism of the temporomandibular joints [TMJs] is influenced by several parameters, including condyle shape, articular fossa, and articular tubercle. Additionally, an abnormally large eminence may also act as a contributing factor in the development of disc displacement [45,46].
Aidar et al suggest that an increased overjet may be a reason leading to disk displacement [47]. According to Patti, increasing overbite keeps the mandible and condyles in a retrieve position and may promote articular disc anterior displacement [48]. One of the limitations of the current study was the small sample size, However, the results are readily apparent and hold considerable importance. It is recommended that future investigations with a larger sample size validate these findings. The lack

of a control group in the study can be regarded as another limitation that has not been enrolled due to ethical considerations. Future research on functional appliances should prioritize the examination of the glenoid fossa and temporomandibular joint remodeling, with a particular focus on the positional alteration of the glenoid fossa. The study also emphasizes the necessity of establishing accurate techniques for assessing the magnetic resonance imaging (MRI) of the temporomandibular joint (TMJ).

Conclusion

Class II malocclusions can be effectively corrected by fixed functional appliances. The results of the study suggested that the forward condylar position within the glenoid fossa and articular disc retrusion with respect to the condylar head was statistically significant after fixed functional therapy. This study showed that arthroscopic disc repositioning significantly increases the widths of posterior and superior spaces of the joint, pushing the condyle downward and forward. The statistical significance of the position of the condyle in the glenoid fossa and the retrusion of the articular disc with respect to the condylar head was observed. The mechanism of action of functional appliances appears to include the forward migration of the C-GF complex.

Conflict of Interest

The authors declare no conflict of interest.

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