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Effects of activator use on the articular disc in Class II adolescent individuals using magnetic resonance imaging

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Abstract

Aim: This study evaluated the effects of activator-type functional appliance therapy on the articular disc of the temporomandibular joint (TMJ) following forward movement of the mandible in individuals with skeletal Class II malocclusion via magnetic resonance imaging (MRI). Specifically, this study compared individuals with normal growth and development to those who had undergone treatment.

Methodology: This study was conducted using a controlled, randomized, crossover design. The study group consisted of 40 individuals with skeletal Class II malocclusion, whereas the control group included 20 individuals with the same anomalies who did not receive treatment. The treatment group underwent therapy with an activator-type functional appliance for a period of six months, during which MRI scans were obtained from participants. The soft- and hard tissue characteristics of the TMJ were assessed using MRI. Data were analyzed using SPSS software, with a statistical significance level of $p<0.05$.

Results: In the treatment group, significant changes were observed in the anterior position of the mandibular condyle and TMJ disc angles. With respect to disc position and configuration, an increase in the biconcave structure and in the anterior angle, and a decrease in the posterior angle, were noted in the treatment group. These changes were not statistically significant in the control group. Additionally, improvement in the TMJ disc position was detected in individuals in the treatment group.

Conclusion: Activator-type functional appliance therapy can have positive effects on the mandibular condyle and TMJ disc position in individuals with Class II malocclusion. MRI has been highlighted as an effective method for evaluating soft and hard tissues of the TMJ. This treatment approach supports orthodontic outcomes by promoting TMJ adaptation.

Keywords: Retrognathia, temporomandibular joint disc, Class II, malocclusion, activator, functional treatment, magnetic resonance imaging

Introduction

Dentofacial problems are significant anomalies that affect the positions of the jaws in various planes and their relationships with each other. Class II malocclusions, which are one of the sagittal anomalies, are among the most frequently encountered conditions, with prevalence rates reported to range between 10% and 40% in studies conducted across different populations. Research conducted in Turkey also supports this observation (1-5).

Class II malocclusions can present various structural abnormalities in three dimensions, such as a narrow maxilla, high palate, and sagittal discrepancies. However, mandibular skeletal retrusion is the most consistent diagnostic finding in this type of malocclusion (3). Therefore, treatment with functional appliances capable of enhancing mandibular growth is indicated for these patients (1-3). The primary goal of functional treatment is to alter the functional environment of teeth to support normal function (1).

Most functional appliances are designed to enhance forward mandibular growth by functionally promoting the downward and forward displacement of the mandibular condyle within the glenoid fossa. This process is balanced by the upward and backward forces exerted by the muscles supporting the mandible. Adaptive remodeling can occur on both surfaces of the temporomandibular joint (TMJ) to improve the position of the mandible relative to the maxilla (1-4).

The TMJ is a complex joint located between the mandibular condyle and the temporal bone. The characteristics of the articular disc play crucial roles in the normal functioning of the TMJ. The articular disc is a flexible structure capable of adapting to shape changes and optimizes stress distribution, which thereby reduces joint loading. However, destructive forces applied to the joint can lead to irreversible structural changes in the disc. Such changes may impair joint function and result in biomechanical problems (6, 7).

Numerous studies have been conducted to evaluate the effects of growth modifications with functional appliances. However, the results of these studies remain inconclusive. Some studies have reported significant effects, while others have not demonstrated consistent changes (8, 9).

The effects of functional appliances on dentofacial structures have been extensively documented through cephalometric studies (8, 9). However, information regarding changes occurring in the TMJ remains limited. There are concerns regarding the adaptive process in the TMJ following repositioning of the mandible through functional appliance therapy in Class II malocclusions (10). Traditional imaging methods are not well-suited for detailed examination of TMJ structures. In contrast, magnetic resonance imaging (MRI) provides a superior approach for evaluating both the soft and hard tissues of the TMJ. However, studies utilizing MRI to assess functional appliance therapy are relatively scarce (11-14).

This study used magnetic resonance imaging (MRI) to comparatively evaluate the effects of forward mandibular movement on the articular disc following activator-type functional appliance therapy in Class II malocclusions. This condition is frequently encountered in clinical practice and is treatable with functional appliances. These findings are compared with those of individuals exhibiting normal growth and development.

Materials and Methods

This study was designed as a single-center, controlled, randomized crossover trial. The experimental design was conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) statement and the extended checklist developed for crossover randomized trials (15).

The study received approval from the local ethics committee of the Dicle University Faculty of Dentistry, decision number 2015/04, and was conducted in accordance with the principles of the Declaration of Helsinki for biomedical research. Written informed consent was obtained from the parents and/or legal guardians of the participating children, in compliance with current legislation regarding the protection of personal data.

Determination of sample size

The sample size for the study was calculated using G*Power 3.1 software (version 3.1.9.2; Heinrich Heine University, Düsseldorf, Germany). A 95% confidence interval and 80% power level were set, resulting in an estimated sample size of 60 participants.

The study material comprised MRI scans of individuals treated at the Department of Orthodontics, Dicle University Faculty of Dentistry, who underwent mandibular advancement therapy. The study group consisted of 40 individuals with skeletal Class II anomalies, while the control group comprised 20 individuals with similar anomalies.

MRI scans were obtained at the Department of Radiology, Dicle University Faculty of Medicine.

Inclusion Criteria:

- Presence of Class II, Division 1 anomaly
- Mandibular retrognathia
- ANB angle > 5°
- Horizontal or normal growth pattern (SN-GoGn ≤ 38°)
- Pubertal growth spurt initiated but had not yet reached its peak
- Overjet distance between +4 mm and +8 mm

Exclusion Criteria:

- High-angle growth pattern (SN-GoGn > 38°)
- Pubertal growth spurt has surpassed the peak
- Transversal orthodontic anomalies or facial asymmetry
- Complaints of palpation or pain in the masticatory muscles
- Presence of clicking, crepitus, pain, or tenderness in the TMJ
- Congenital or acquired jaw-facial deformities
- Any condition that interferes with MRI imaging procedures

Group characteristics

The study group consisted of 40 individuals, 18 of whom were female and 22 were male, with a mean chronological age of 12.8 years. All participants exhibited a Class II molar and canine relationship, with overjet measurements ranging from +4 mm to +8 mm.

The control group consisted of 20 individuals —7 females and 13 males — with a mean chronological age of 13.2 years. Similarly, these participants demonstrated a Class II molar and canine relationship, and their overjet measurements ranged from +2 mm to +8 mm.

Skeletal age determination was based on the hand-wrist criteria of Grave and Brown, in conjunction with the Greulich and Pyle atlas. All participants in the study had entered the pubertal growth spurt, though none had yet reached its peak (16,17).

Participants in the treatment group received functional therapy using an activator appliance, while those in the control group were monitored for six months without orthodontic intervention. Data were collected at two distinct time points as follows: at the initiation of treatment and after an average of six months of active therapy.

Application of the activator appliance

Monoblock-type activators were used for individuals included in the treatment group. After the participants' working models were obtained, wax occlusal records were made using a Projet Bite Wafer (Orthocare (UK) Limited) to ensure standardization. The vertical dimension was increased by 2 mm, and sagittal activation was applied where necessary.

After the appliances were placed, the participants were instructed to wear them for 24 hours a day, with removal permitted only during meals and physical activities. Throughout the treatment period, the patients were monitored at 5-6-week intervals. Once sagittal correction was achieved, adjustments were made to the acrylic portion of the appliance, and the retention phase was initiated after the active treatment period.

Magnetic Resonance Imaging (MRI)

MRI scans were performed at the MRI Unit of the Department of Radiology, Dicle University Faculty of Medicine. Sagittal oblique sections of both TMJ regions were obtained with the mouth closed. Prior to the MRI procedure, the parents of the participants were provided with the necessary explanations, and consent was obtained. Imaging was conducted using a 3 Tesla Picker MRI machine (Phillips Medical Systems, OH) equipped with a 6 × 8 cm surface coil, utilizing a spin-echo T1 sequence technique, which optimally visualized the TMJ. All imaging assessments were conducted by a single specialist.

After the participants were placed in the supine position on the MRI machine, their heads were stabilized using a rubber platform that encircled the head and neck. The marker light of the MRI machine was adjusted to pass through the soft tissue, Frankfurt Horizontal plane, and the mid-occlusal plane. A 3-inch surface coil was placed on the TMJ region, and the participants were instructed to remain still and not be alarmed by the sounds produced by the machine during the examination.

The imaging parameters were as follows: TR = 500 ms, TE = 21 ms, slice thickness = 3 mm, slice gap = 0.5 mm, field of view = 10 cm, number of excitations (NEX) = 4, and matrix = 256×128. The imaging duration was 4.30 minutes.

The axes of the sagittal sections were defined perpendicularly to the long axis of the condylar head, extending from the anteromedial to the posterolateral aspect in the axial plane. To ensure accurate TMJ targeting and correct orientation of the sagittal sections, axial images were initially obtained. Subsequently, sagittal oblique sections were obtained, and post-processing was used to identify the appropriate slices for descriptive point determination.

A total of 120 MR images were obtained with images taken at different times as follows: at the beginning of treatment, during the active treatment phase, and at the end of the observation period. The obtained MR images were transferred to a computer system using an Epson Expression 1680 Professional Film Scanner (Epson America Inc., Long Beach, CA, USA). Measurements were performed using INFINITT software (Infinitt Healthcare, Seoul, Korea) with a precision of 0.01° and 0.01 mm.

The measurement points identified on the sagittal oblique MR images of the TMJ are shown in Figure 1, and the angular measurements indicating the disc position are shown in Figure 2 (14, 18, 19). Figure 3 depicts the regional evaluation of disc position on sagittal oblique MRI images of the TMJ, and Figure 4 illustrates the configurations of the joint discs (20).

Statistical analysis

Statistical analyses in this study were performed with a 95% confidence interval, and the results were analyzed using SPSS 17.0 software (IBM Corp., Armonk, NY, USA).

Statistical significance was set at $p<0.05$. Descriptive statistical values for all parameters were calculated before and after activator treatment, and these values were assessed for significance. The Kolmogorov–Smirnov test was applied to determine whether the data followed a normal distribution.

A paired t-test was used for intragroup comparisons between the treatment and control groups. An independent t-test was used for comparisons between the treatment and control groups, while a paired t-test was used to compare MRI measurements of the right and left joints.

After the evaluation of MRI images and to control for individual drawing and measurement errors, 60 randomly selected MRI images from 240 patients were redrawn by the same researcher after a 1-month period, and all measurements were repeated. Methodological error was assessed using the intraclass correlation coefficient (ICC) and confidence intervals, which statistically validated the reliability and repeatability of the measurements. This method statistically validated both the reliability and repeatability of measurements.

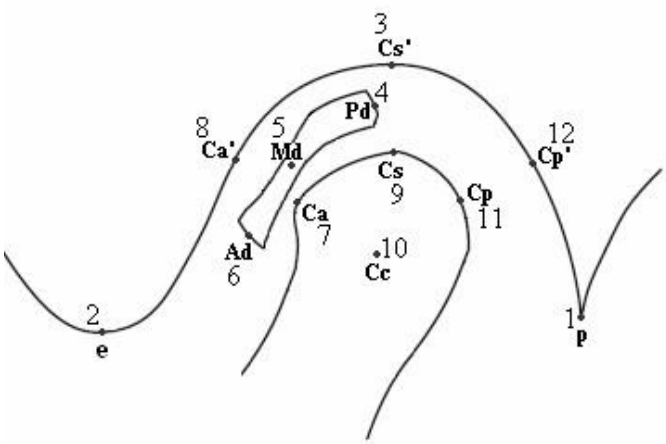

Figure 1. Points identified on sagittal oblique MR images of the TMJ.

p: The inferior extremity of the postglenoid process. e: The inferior extremity of the articular eminence. Cs': The point where a perpendicular drawn from the Cs point intersects the depth of the fossa. Pd: The mid-posterior point of the posterior band of the disc. Md: The midpoint of the intermediate zone of the disc. Ad: The mid-anterior point of the anterior band of the disc. Ca: The point formed on the anterior surface of the condyle by a tangent drawn from the Cs' point to the anterior edge of the condyle. Ca': The projection point where a perpendicular drawn from the Ca point intersects the glenoid fossa surface facing the anterior part of the condyle. Cs: The midpoint of the superior curvature of the condyle. Cc: The central point within the condyle, determined sagittally as half the anteroposterior diameter measured from the condyle's apex. Cp: The point on the posterior surface of the condyle formed by a tangent drawn from the Cs' point to the posterior edge of the condyle. Cp': The projection point where a perpendicular drawn from the Cp point intersects the glenoid fossa surface facing the posterior part of the condyle.

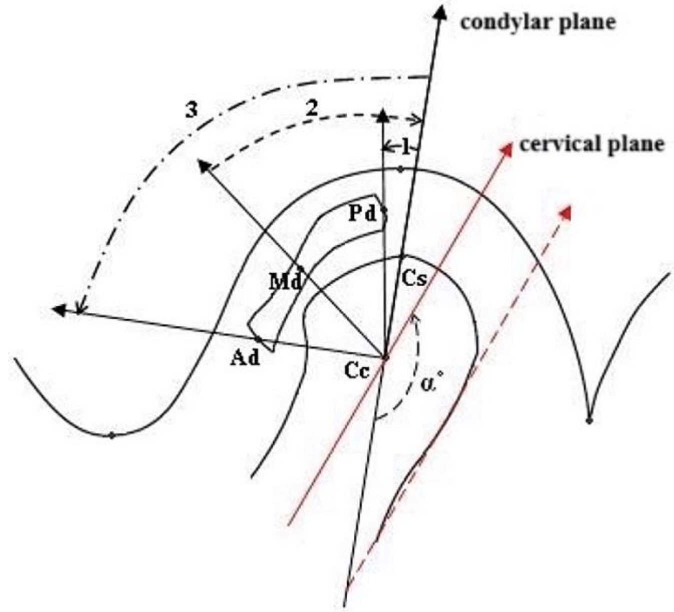

Figure 2. Angular measurements illustrating the disc's position on sagittal oblique MR images.

Posterior Angle (Pd): The angle formed between the points Cs, Cc, and Pd. Medial Angle (Md): The angle formed between the points Cs, Cc, and Md. Anterior Angle (Ad): The angle formed between the points Cs, Cc, and Ad. Alpha Angle: The angle between the condylar plane and the collum plane.

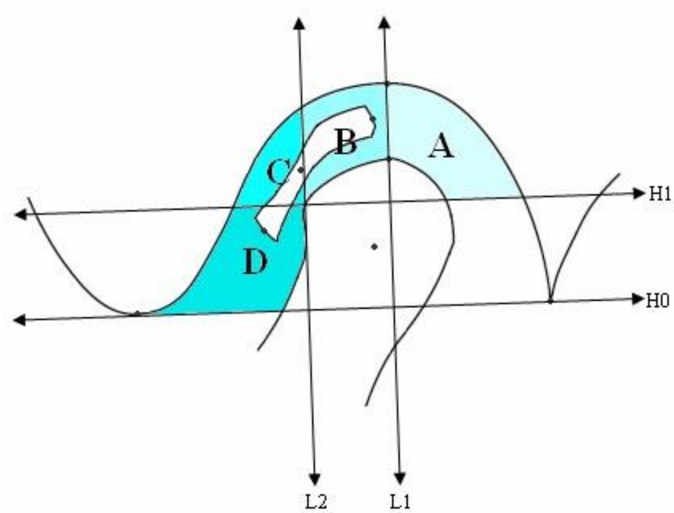

Figure 3. The regional evaluation of the disc position on the sagittal oblique MRI images of the TMJ.

A Region: In the MR image of the TMJ taken with the mouth closed, the disc is positioned at the 12 o'clock position, which is considered normal. B Region: The disc is considered to be in its normal position but slightly displaced anteriorly. C Region: The disc is considered to be displaced anteriorly beyond the normal position. D Region: The disc is considered to be fully displaced anteriorly.

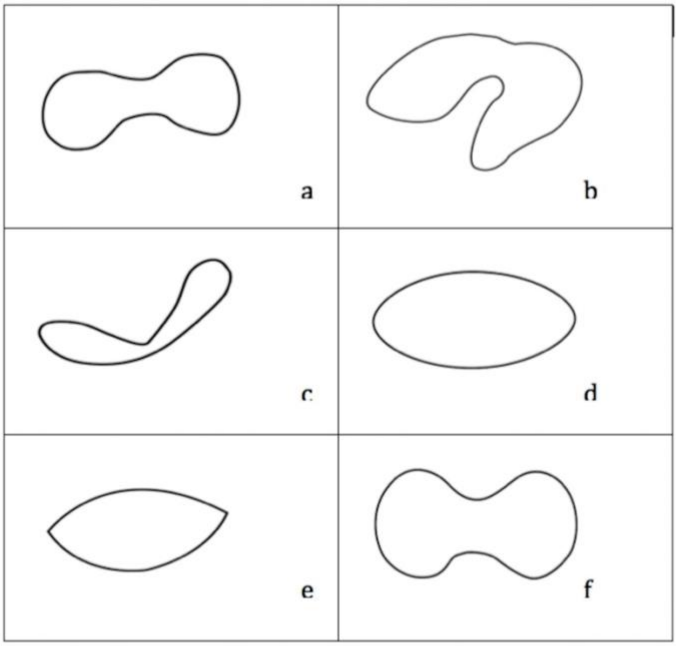

Figure 4. The configurations of the joint disc.

(a) Bicondylar (normal) disc, (b) Folded disc, (c) Biplanar disc, (d) Round disc, (e) Biconvex disc, (f) Hemiconvex disc

Results

Descriptive statistical values for all parameters were calculated before and after treatment. Following evaluation of the treatment and control groups for pre-treatment, post-treatment, and systemic errors, no significant measurement errors were detected ($p>0.05$).

Measurements for each individual were evaluated separately for the right and left joints. The difference between pretreatment and post-treatment measurements for the right and left joints in the treatment and control groups was examined using paired t-tests; no statistically significant difference was found ($p > 0.05$). Therefore, the data obtained from the right and left joints were combined and analyzed without differentiating between the sides. Descriptive statistical data are presented in Table 1.

When the angular measurements determining disc position were compared before and after treatment, statistically significant increases were observed in the anterior, medial, and alpha angles in the treatment group ($p<0.05$). Conversely, a statistically significant decrease in the posterior angle was observed after treatment ($p<0.05$).

In the control group, no statistically significant angular changes were observed before or after the observation period ($p > 0.05$). Descriptive statistical data for the mean values of the angular measurements used to determine disc position are presented in Table 2.

In the treatment group, before treatment, the disc was located in area A in 36.5% of individuals and in area B in 63.8%. However, following treatment, these percentages changed to 72.5% in area A and 27.5% in area B, respectively. These changes in disc position were statistically significant ($p<0.05$).

In the control group and before the observation period, the disc was located in area A in 32.5% of individuals and in area B in 67.5%. After the 6-month observation period, these percentages changed to 47.5% in area A and 52.5% in area B. However, these changes were not statistically significant ($p>0.05$).

Table 1. Descriptive statistics of MRI data.

	Treatment group		Control group	
	X	SD	X	SD
Right Posterior Angle pre-Tx	0.38	2.44	0.48	2.15
Left Posterior Angle pre-Tx	0.37	2.38	0.42	1.92
Right Posterior Angle post-Tx	0.37	2.36	0.39	1.75
Left Posterior Angle post-Tx	0.40	2.57	0.51	2.28
Right Medial Angle pre-Tx	0.32	2.04	0.79	3.56
Left Medial Angle pre-Tx	0.31	2.01	0.85	3.84
Right Medial Angle post-Tx	0.35	2.26	0.73	3.29
Left Medial Angle post-Tx	0.32	2.24	0.98	4.38
Right Anterior Angle pre-Tx	1.00	6.37	0.96	5.14
Left Anterior Angle pre-Tx	1.01	6.34	0.94	5.19
Right Anterior Angle post-Tx	1.03	6.53	0.81	5.46
Left Anterior Angle post-Tx	1.01	6.40	0.93	5.34
Right Alfa Angle pre-Tx	1.01	6.44	1.15	4.31
Left Alfa Angle pre-Tx	1.08	6.86	1.16	4.24
Right Alfa Angle post-Tx	0.84	5.36	1.22	3.66
Left Alfa Angle post-Tx	0.93	5.93	1.19	4.17

x: data; SD: Standard deviation

Table 2. Descriptive statistical values for angular measurement data.

		N	Mean	SD	SE
Anterior Angle pre-Tx	Treatment group	80	89.9375	6.32724	**0.70741**
	Control group	40	86.6750	4.23288	**0.66928**
Anterior Angle post-Tx	Treatment group	80	91.4375	6.43339	**0.71927**
	Control group	40	86.1750	3.90192	**0.61695**
Posterior Angle pre-Tx	Treatment group	80	1.8000	2.40464	**0.26885**
	Control group	40	-0.3000	2.01533	**0.31865**
Posterior Angle post-Tx	Treatment group	80	-1.3125	2.45771	**0.27478**
	Control group	40	-0.5750	2.02405	**0.32003**
Medial Angle pre-Tx	Treatment group	80	54.8250	2.01749	**0.22556**
	Control group	40	55.2000	3.68086	**0.58199**
Medial Angle post-Tx	Treatment group	80	62.5625	5.57957	**0.62381**
	Control group	40	56.5750	3.83565	**0.60647**
Alfa Angle pre-Tx	Treatment group	80	149.8250	6.62518	**0.74072**
	Control group	40	149.6500	5.12185	**0.80984**
Alfa angle post-Tx	Treatment group	80	152.9500	5.74544	**0.64236**
	Control group	40	150.1250	5.35023	0.84595

n: sample size; SD: Standard Deviation; SE: Standard Error

Descriptive statistical data regarding the regional disc position in the treatment and control groups are presented in Table 3.

In terms of disc configuration, before treatment in the treatment group, 61.2% of individuals presented with a bicondylar shape, 31.3% presented with a biplanar shape, and 7.5% presented with a hemiconvex form. After treatment, these proportions changed to 80% bicondylar, 12.5% biplanar, and 7.5% hemiconvex.

In the control group and prior to the observation period, 62.5% of individuals exhibited a bicondylar shape, 27.5% a biplanar shape, and 10% a hemiconvex form. After the observation period, these proportions changed to 80% bicondylar, 12.5% biplanar, and 7.5% hemiconvex. Descriptive statistical data regarding disc configuration in the treatment and control groups are presented in Table 4.

Table 3. Evaluation of the regional position of the disc.

Group		Disc position	
		A	B
Treatment group (n=40)	Pre-treatment	36.5%	63.8%
	Post-treatment	72.5%	27.5%
Control group (n=20)	Pre-treatment	32.5%	67.5%
	Post-treatment	47.5%	52.5%

Table 4. Evaluation of disc configuration.

Group	Time	Disc configuration		
		Bicondylar	Biplanar	Hemiconvex
Treatment group (n=40)	Pre-treatment	61.2%	31.3%	7.5%
	Post-treatment	80.0%	12.5%	7.5%
Control group (n=20)	Pre-treatment	62.5%	27.5%	10.0%
	Post-treatment	62.5%	30.0%	7.5%

Discussion

Skeletal Class II malocclusion is one of the most common orthodontic anomalies in the population. The most frequent cause of this malocclusion is mandibular growth deficiency (21). One of the most used methods in the early treatment of individuals with Class II malocclusion is functional jaw orthopedics. This treatment approach induces changes in the bone, cartilage, soft tissues, and the ramus, gonion, and joint regions of the mandible by increasing muscle stimulation (22).

This study compared changes occurring in the articular disc due to forward movement of the mandible using functional appliances in individuals with skeletal Class II, Division 1 malocclusion with those in individuals demonstrating normal growth and development using MRI.

The inclusion criteria for the treatment group were aligned with the methods specified in similar studies (23, 24). In the literature, the peak period of growth and development is considered the most appropriate time for the orthodontic treatment of Class II malocclusions (17, 24, 25). Therefore, care was taken to include individuals in our study who had entered the pubertal growth spurt but had not yet reached its peak, as determined by wrist film analysis using the Grave and Brown criteria (17).

This study included individuals of both sexes, and no significant sex differences were found between the groups. It has been reported in the literature that there is no statistically significant difference between sexes in terms of the age of the pubertal growth spurt (26, 27).

In the literature regarding functional appliances, various opinions exist regarding the process of obtaining wax bite registrations. Different approaches have been suggested for the sagittal positioning of the mandible during activator fabrication (3, 4, 28, 29). Additionally, the appliance is more easily tolerated when the vertical opening is between 2 and 4 mm (4, 30). This study utilized a blue Projet appliance with a thickness of 2 mm, and both vertical and sagittal activation distances were standardized.

Various techniques have been employed to examine changes in the temporomandibular joint (TMJ). However, the limitations of traditional radiographic methods in soft tissue imaging and monitoring of TMJ adaptation have led to a preference for MRI, which provides noninvasive and repeatable images (21). According to the literature, MRI slices taken in the closed-mouth position yield more objective results in diagnosing the disc position and are therefore recommended for routine use (31, 32). In this study, TMJ evaluations were performed with the mouth in the closed position, and oblique slices were used to consider condylar expansion.

In this study, no significant difference was found between the right and left temporomandibular joints, and the data were combined as per the existing literature (21, 33, 34). Condyle observations indicated that it was positioned more anteriorly post-treatment than pre-treatment. This finding is consistent with other studies in the literature (35, 36).

In terms of disc position and morphological changes, measurements of the medial and anterior angles revealed a statistically significant increase posttreatment. Our findings align with results in the literature reported by Wadhawan et al. (37), Aidar et al. (33), Kinzinger et al. (38), and Gandhi et al. (22).

In our study, post-activator treatment, the disc was positioned in region A in 72.5% of patients and in region B in 27.5%, with a bicondylar disc configuration observed in 80% of patients. These findings suggest that the use of the activator resulted in a positive change in disc morphology. The literature indicates that functional treatments in individuals with anterior disc displacement help the disc return to its physiological position (14, 37-39).

Franco et al. (40), who treated individuals with the Frankel-II appliance, reported positive changes in disc configuration, whereas Arat et al. (14) reported that the initial disc configurations of 73% bicondylar and 27% biplanar changed to 80% bicondylar and 20% biplanar posttreatment. These findings are consistent with the results of our study.

This study has several limitations. As the results immediately following Monobloc treatment were compared with the pretreatment results, these results reflect the short-term effects of the appliance. Functional treatment is typically followed by fixed orthodontic mechanics, and the midterm results are revealed after stable occlusal relationships are achieved through fixed orthodontic treatments. Additionally, a long-term follow-up study is needed to determine whether changes observed are maintained over time

Conclusion

In post-functional treatment, the disc was positioned in region A in 72.5% and region B in 27.5% of patients, with 80% exhibiting a bicondylar configuration. The condyle was located more anteriorly post-treatment, which is consistent with previous studies. No significant difference was observed between the right and left TMJs, but significant increases in the medial and anterior angles were noted. Functional treatment contributed to the return of the disc to its physiological position, and no pathological changes were observed. These findings support the positive effects of functional treatments on the TMJ. Future research should include larger sample sizes, assess sex effects, and involve long-term follow-up with MRI scans before and after retention.

Disclosures

Ethical Approval: Ethics committee approval was received for this study from the Dicle University Faculty of Dentistry Local Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, and with approval number 2015/04

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – N.K.; Design – N.K., G.B.; Supervision – G.B.; Materials – N.K.; Data collection and/or processing – N.K.; Analysis and/or interpretation – N.K.; Literature review – N.K.; Writer – N.K.; Critical review – N.K., G.B.

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