Occlusal Splint Therapy and Magnetic Resonance Imaging

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Aims: *To investigate the efficacy of the anterior repositioning splint and the canine-protected splint in relieving the signs and symptoms of anterior disc displacement with reduction, and to evaluate the effects of both splints on disc position using a standardized magnetic resonance imaging measurement technique.* ***Material and Methods:*** *A sample of 18 adult subjects was studied. The joint disorder was dually diagnosed via pretreatment clinical examination and magnetic resonance imaging. The sample was randomly divided into two groups. In the first group, each subject received an anterior repositioning splint; in the second group, each subject received a canine-protected splint. The treatment lasted 3 months. A standardized magnetic resonance imaging 10-step procedure was developed. Posttreatment clinical examinations and magnetic resonance imagings were done. Pretreatment and posttreatment records were statistically compared.* ***Results and Conclusions:*** *Both types of splints were effective in eliminating pain and clicking. All magnetic resonance imaging measurements showed that the canine-protected splint was superior to the anterior repositioning splint, as it allowed the articular disc to resume its normal length and shape while moving in a posterior direction toward recapture. Disc recapture was demonstrated via magnetic resonance imaging in 25% of the subjects from the anterior repositioning splint group, in 40% of the subjects from the canine-protected splint group, and in 33.3% of the subjects from both groups. Thus, noninvasive treatment techniques (such as occlusal splint therapy) might be the treatment of choice for anterior disc displacement with reduction.* World J Orthod 2004;5:133–140.

Temporomandibular disorders (TMD) are traced back to the written hieroglyphic records of the ancient Egyptians. By definition, they are upsets of normal temporomandibular functions, resulting from a group of musculoskeletal disorders. TMD is not just a single disorder, but a group of disorders. One of the most common of these disorders is anterior disc displacement with reduction (ADDR).

Occlusal splint therapy is a popular, simple, and conservative modality in the treatment of ADDR. However, the mechanism by which occlusal splints work in alleviating the signs and symptoms of such a disorder is still controversial. The field is replete with clinical opinions that lack scientific foundations.

A wide variety of occlusal splint designs is currently available, two of which are more commonly used than the rest. These are the anterior repositioning splint (ARS) and the canine-protected splint (CPS). The use of an ARS, for 3 to 6 months, results in disc recapture.[1] The CPS tends to establish a mutually protected occlusion, which prevents mandibular displacement in maximum intercuspation and may be responsible for the displacement of the condyle-disc assembly.[2]

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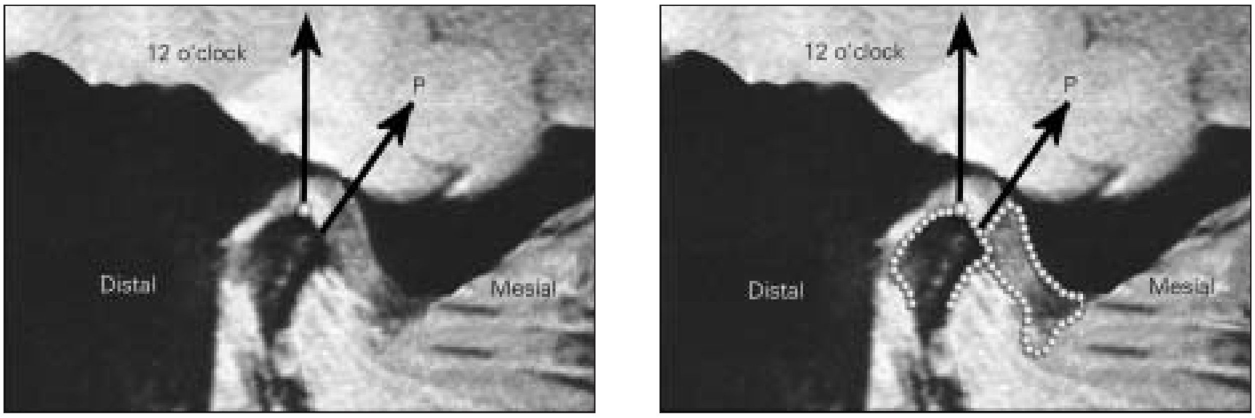


Fig 1 MRI of pretreatment disc displacement during maximum intercuspation. The P ray represents the posterior band of the disc. Note that the posterior band of the symptomatic disc is abnormally displaced mesial to the normal 12 o'clock position. This MRI diagnostic criterion indicates the presence of anterior disc displacement. In the figure on the right, the mandibular condyle and the articular disc are traced for better orientation.

The majority of the comparative studies that evaluated different splint designs relied only on the case history and clinical examination for diagnosing disc displacement.[3–6] Today, magnetic resonance imaging (MRI) has emerged as a prime diagnostic imaging technique for TMD. Westesson[7] has demonstrated its superiority to both arthrography and computerized tomography for the evaluation of the soft tissues of the joint.

The purpose of this study was to *(1)* examine the effects of anterior repositioning and canine-protected splints in relieving the signs and symptoms of anterior disc displacement with reduction, and *(2)* evaluate their effects on disc position using a standardized MRI measurement technique. The hypothesis was that both the ARS and the CPS can recapture the displaced disc. Specifically, the following three questions could be raised: *(1)* Are both types of splints equally effective in eliminating pain and clicking? *(2)* Which splint is superior to the other? *(3)* Can disc recapture be demonstrated?

MATERIAL AND METHODS

Sample

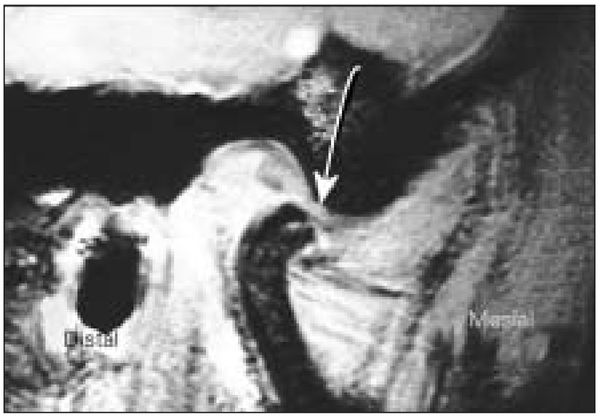
Informed consents were obtained and the rights of human subjects were protected. The sample initially consisted of 18 adult subjects clinically diagnosed as having anterior disc displacement with reduction. All subjects underwent MRI to confirm the clinical diagnosis. MRIs of 4 subjects demonstrated normal TMJ anatomy. Therefore, these 4 subjects were excluded from the study. The remaining 14 subjects were randomly divided into two equal groups. The first group received ARS, while the second group received CPS.

Criteria for selection of subjects were as follows:

1. Adult subjects with an age range of 18 to 30 years of age.
2. Negative history of previous orthodontic treatment.
3. Absence of osseous pathosis on the panoral radiographs.
4. Presence of anterior disc displacement with reduction dually diagnosed through pretreatment clinical examinations and MRIs. Clinically, the following two essential diagnostic criteria manifested themselves: *(a)* reciprocal clicking (a click sound during both mouth opening and mouth closing) was present; and *(b)* these clicks could be eliminated when starting the opening movement from a protruded position.[8] For the MRI diagnosis, the posterior band attachment of the disc was mesial to the normal 12 o'clock position during maximum intercuspation (Fig 1).

Experimental procedures

The history form included the history of trauma, dysfunction, and psychological stress. For the clinical examination, the chief complaint, pain location, pain type, degree of pain, and date of onset of TMD problem were recorded. A thorough pretreatment static and functional clinical examination of the TMJs was performed. This included examination of the muscles of mastication, and the head and neck muscles through palpation. Detection of joint noises via auscultation was done. The click type and its timing during mouth opening and closure were noted. The pain level was recorded on an ascending pain scale from 0 to 3 (0, no pain; 1, slight discomfort; 2, moderate pain; and 3, severe pain), according to Okeson.[9]



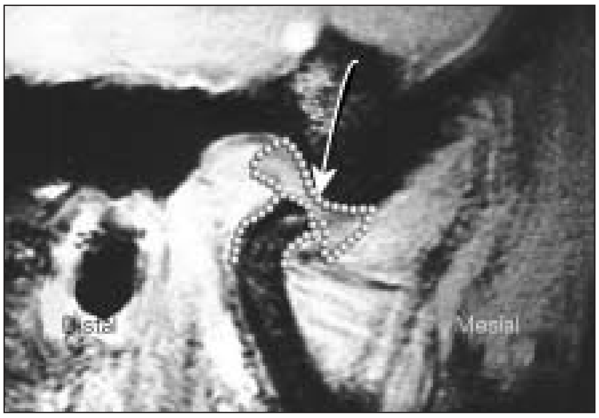


Fig 2 MRI of pretreatment disc reduction in the open-mouth position. The arrow points to the disc, which is interposed between the articular eminence and the condylar head. In the open-mouth position, the posterior band of the symptomatic disc assumes a seemingly normal location above the condylar head. In the figure on the right, the mandibular condyle and the articular disc are traced.

Pretreatment MRIs of the joint area were taken in both closed-mouth and open-mouth positions. MRI was performed using a Signa 1.0 Tesla machine (General Electric, Milwaukee, WI, USA). Unilateral sagittal oblique gradient echo images were taken perpendicular to the long axis of the condyle, with the subject supine, and the head stabilized in a head positioner. The subject's head was positioned in a standardized manner, according to the machine's alignment light lines. The orbital-meatal line was perpendicular to the table. The sagittal light coincided with the midline of the head. The axial light passed through both the outer canthii of the eyes.

The surface coil was then placed on the affected TMJ, with the condyle in its middle. The subject's head was secured in this position with stabilizing tapes on the forehead and chin. An axial image was then taken to locate the condyle and orient the sagittal cuts to be perpendicular to the long axis of the condyle.

The disc was considered anteriorly displaced when the posterior band attachment was mesial to the normal 12 o'clock position[8,10] during maximum intercuspation (see Fig 1). Reduction of the disc to its normal position[8,10] was ensured by the posterior band in its normal aspect in the open-mouth position (Fig 2).

According to the technique recommended by Okeson,[9] two types of splints were constructed: the anterior repositioning splint (ARS) and the canine-protected splint (CPS). The anterior ramp of the ARS was developed into a smooth sliding surface (see Fig 3). The ARS was adjusted to allow contacts on all the teeth, evenly and simultaneously, in the established advanced position (Fig 3). The CPS (Fig 4) was adjusted to permit even centric occlusion contacts. In lateral excursions, the CPS provided canine rise.

All subjects were instructed to wear the splints on a full-time basis (except during meals and toothbrushing) for a period of 3 months. The subjects were clinically examined every 2 weeks. During each visit, the examinations of the TMJs and muscles of mastication were repeated.

Posttreatment MRIs of the joint area were done in the closed-mouth position. By employing a standardized technique, the pretreatment and posttreatment MRIs were evaluated. This standardized MRI technique was achieved by the following 10-step procedure:

1. The MRIs were made while the splints were out of the mouth.
2. A reference millimeter ruler was printed on the edge of each MRI film.
3. The pretreatment and posttreatment MRIs were compared in the same plane, for each subject, by using identical cuts.
4. A double-blind experimental design was used for MRI tracings and measurements. During tracings and measurements of the MRIs, the examiner was unaware of the treatment groups.
5. Using a matte acetate paper and a sharp lead pencil, the outline of the condyle and the disc were traced for each MRI film.
6. Selected landmarks (Table 1) were identified.
7. Reference planes (Table 1) were drawn either parallel or perpendicular to the reference ruler.
8. Five millimetric measurements (Table 1 and Fig 5) indicating disc length, as well as horizontal and vertical disc positions, were made on the reference planes.
9. The posttreatment tracing for each subject was superimposed on the pretreatment tracing by registering on condylion.
10. All MRIs were retraced and the same measurements repeated 1 week later.

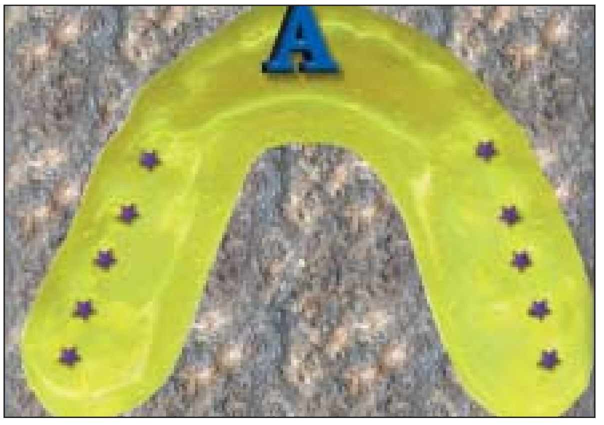


Fig 3 Occlusal view of the maxillary anterior repositioning splint (ARS). Note that the bottom of the "A" points to the anterior repositioning ramp which was developed into a smooth sliding surface. The stars represent even occlusal contacts of the mandibular premolars and molars in the established advanced anterior position.

Fig 4 Occlusal view of the maxillary canine-protected splint (CPS). Note that the bottom of the pencil rests on the canine-protected ramp. The horizontal slash of the "X" indicates the lateral excursion guidance, which provides canine rise. The stars represent even centric occlusion contacts of the mandibular premolars and molars.

Table 1 MRI TMJ landmarks, reference planes, and measurements

	Definitions
Landmarks	
Condylion (C point)	Highest point on the condylar head; it is the intersection point (zero) of the Cartesian coordinates x-axis and y-axis
Anterior discal band (A point)	Most anterior point on the anterior band of the disc
Posterior discal band (P point)	Most posterior point on the posterior band of the disc
Reference planes	
X-axis	Straight horizontal line passing through condylion, and parallel to the printed reference millimeter ruler; it is the horizontal Cartesian coordinate
Y-axis	Straight vertical line passing through condylion, and perpendicular to the printed reference millimeter ruler; it is the vertical Cartesian coordinate and superimposes on the 12 o'clock reference plane
12 o'clock	Straight vertical ray passing through condylion, and perpendicular to the printed reference millimeter ruler; it superimposes on the Y-axis reference plane
Linear millimetric measurements	
Disc length (A'-P')	Horizontal distance between the anterior and posterior discal bands
Condylion to anterior band H space (C-A')	Horizontal distance between condylion and the abscissa of the anterior discal band as measured along the x-axis; it was considered positive when A point was anterior to C point and negative when vice versa
Condylion to posterior band H space (C-P')	Horizontal distance between condylion and the abscissa of the posterior discal band as measured along the x-axis; it was considered positive when P point was anterior to C point and negative when vice versa
Condylion to anterior band V space (C-A")	Vertical distance between condylion and the ordinate of the anterior discal band as measured along the y-axis; it was considered positive when A point was higher than C point and negative when vice versa
Condylion to posterior band V space (C-P")	Vertical distance between condylion and the ordinate of the posterior discal band as measured along the y-axis; it was considered positive when P point was higher than C point and negative when vice versa

Statistical analyses

Statistical analyses were done for the clinical data, MRI measurements, and possible errors of measurements. Specifically, for the clinical data, analysis of variance was used to compare the pain scores (in the TMJ, muscles of mastication, and the head and neck muscles) and extent of mandibular movements for each subject before, during (after 1 month and after 2 months), and after treatment. This was followed by both Student *t* test and Wilcoxon Ranksome test to compare the changes between the two groups.

For the MRI, paired *t* tests were used to compare the difference in the mean of each MRI measurement before and after treatment for each group of subjects. Unpaired *t* tests were employed to compare the mean change of each MRI measurement between the two treatment groups.

Further, all MRIs were retraced and the same measurements repeated 1 week later. For the errors of measurements, paired *t* tests were used to compare between the two sets of measurements.

RESULTS

Five subjects did not return for the final clinical and MRI evaluations. Therefore, nine subjects comprised the final sample: four subjects (two females and two males) in the ARS group, and five subjects (one female and four males) in the CPS group. The mean age of the subjects was 24 years.

The closed-mouth and open-mouth pretreatment MRIs are shown in Figs 1 and 2. The MRI of the posttreatment disc recapture is shown in Fig 6, and the results are summarized in Tables 2 through 6.

DISCUSSION

In a meta-analysis, Kim et al[11] stated that: "It is apparent that a reliable and valid diagnostic classification system for TMD is needed for future research." Despite its high cost, the MRI is an excellent diagnostic procedure for TMD. MRI allows visualization of disc position relative to the condylar head, and hence a proper diagnosis of internal derangement. Six methodologic aspects of the present research study will be discussed. First, the sample was limited to subjects having anterior disc displacement with reduction, as diagnosed by both clinical examinations and MRIs. Most of the previous studies, which evaluated the efficacy of occlusal splints in treating TMD, relied only on the improvement of the subjects' clinical signs and symptoms.[3–6] This has shown itself to be insufficient because the presence of a joint click is not confirmation of an anterior disc displacement, nor does the disappearance of the click confirm disc recapture.[8]

Second, the average age of the subjects was 24 years, to avoid false significant clinical results in children and to exclude the aging effects on TMJ structures in older age groups. Third, pretreatment panoral radiographs were examined to rule out any arthritic or degenerative osseous pathosis in the TMJ region. Fourth, the ARS and the CPS appliances were compared because they are two of the most commonly used and misunderstood types of occlusal splints. To avoid false significant results, the following three procedures were done: *(1)* the sample was randomly divided; *(2)* MRIs were made while the splints were out of the mouth; and *(3)* a double-blind experimental design was used during MRI tracings and measurements. This was the fifth methodologic aspect.

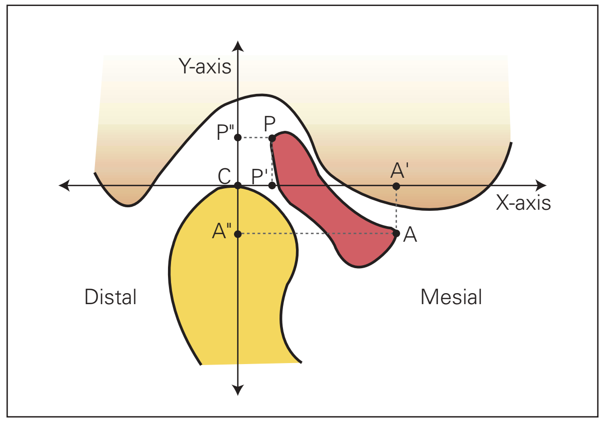


Fig 5 Diagram of MRI-TMJ measurements. The landmarks (C, A, and P points) are identified in Table 1. In the same table, the reference planes (x-axis and y-axis) are explained and the measurements (A'-P', C-A', C-P', C-A", C-P") are defined.

Finally, a standardized MRI 10-step procedure was developed for reliability and validity reasons. Reliability refers to the degree of consistency, precision, stability, and/or dependability. Validity is the conformity to accepted biologic principles. El-Mangoury[12] has indicated that reliability is a prerequisite for validity.

In the present investigation, an attempt was made to accurately measure changes in disc position, both in the sagittal and vertical directions, in relation to the condylar head. By examining Table 2, it is clear that the ARS resulted in a significant reduction of condylion to anterior band H space (C-A'). Further (see Table 2), the CPS caused a significant increase in disc length (A'-P'), as well as a significant decrease in condylion to posterior band H space (C-P'). Thus, the CPS caused an increase in disc length (see Table 2) allowing the disc to decompress and to return to its original biconcave lens shape with a thin central portion and thick anterior and posterior bands (see Fig 6). This finding could be attributed to mandibular repositioning. This is in agreement with Kovaleski and De Boever,[13] who indicated that the corrections resulted from mandibular repositioning that eliminated dental interferences. Furthermore (see Table 2), significant differences existed between the ARS and CPS for both the disc length (A'-P') and the condylion to posterior

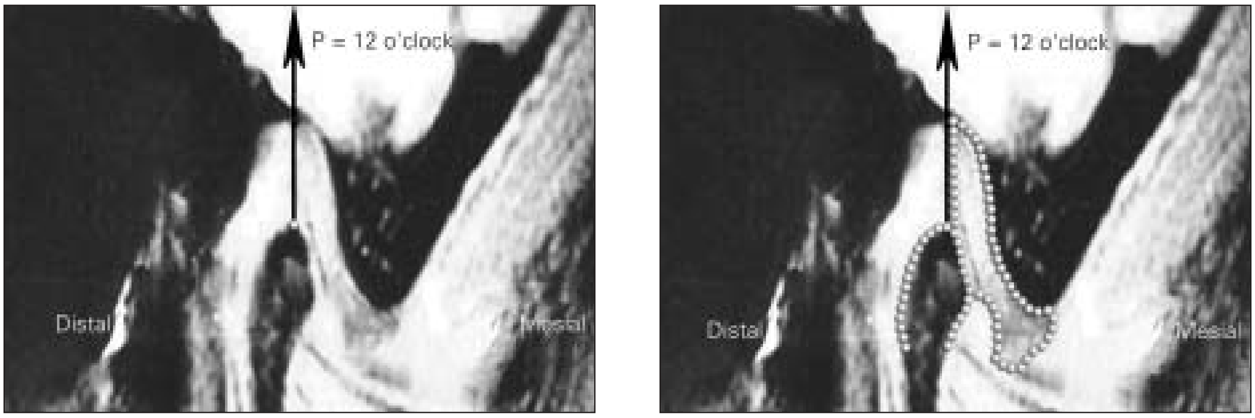


Fig 6 MRI of posttreatment disc recapture. The P ray represents the posterior band of the disc and is superimposed on the 12 o'clock reference plane. In other words, the disc was recaptured to the normal 12 o'clock position; ie, the disc was recaptured above the condylar head. Note the increase in disc length after occlusal splint therapy. In the figure on the right, the outline of mandibular condyle and the articular disc is marked.

band H space (C-P'). Thus, these findings indicate a more favorable response in disc size and position in the CPS group, as the previously distorted disc moved posteriorly toward recapture. Note that all vertical measurements of disc position were nonsignificant (see Table 2). This means that the disc moved straight back with negligent vertical translation, despite the expectation that the disc would move upward as it moved posteriorly over the condylar head.

Disc recapture was identified by the return of the posterior attachment to the 12 o'clock position superior to the condylar head (see Fig 6). Specifically, as shown in Table 3, disc recapture was demonstrated via MRIs in 25% of the subjects from the ARS group, in 40% of the subjects from the CPS group, and in 33.3% of the subjects from both groups. These results are in conflict with those of Chen et al[14] who could not detect any change in disc position following CPS use. However, they are in agreement with those of Simmons and Gibbs,[1] who found disc recapture in 96% of the subjects. In their study,[1] it is important to note that the MRIs were made with the splints intraorally, which could bias the indication of true disc recapture. In the present research, MRIs were done while the splints were out of the mouth to avoid false significant results.

For the method errors, no significant differences were found between the measurements made at the 1-week interval (see Table 4). By looking at Table 5, it is evident that the TMJ pain level was significantly reduced, at a probability level of less than 1% for the ARS. This is in agreement with Lundh et al[3] and Zamburlini and Austin.[15] In the present research study, the ARS caused TMJ pain relief (see Table 5) that might be attributed to the reduction of the horizontal anterior attachment space (condylion to anterior band H space (C-A') (see Table 2). This is just a speculation and is in disagreement with Lundh et al,[3] who ascribed the pain relief to the healing of the elongated posterior attachment (ie, retrodistal pad). Additional studies are suggested.

In the present investigation, the TMJ pain level was significantly decreased, at a probability level of less than 5% for the CPS (see Table 5). This is in agreement with Clark,[16] Fitins and Sheikholeslam,[17] Levandoski,[18] Tsuga and colleagues,[2] and Zamburlini and Austin.[15] The present researchers speculate that the CPS resulted in TMJ pain relief (see Table 5) that might be attributed to discal elongation (increase in disc length (A'P'); see Table 2), and to the horizontal decompression of the posterior attachment space (decrease in condylion to posterior band H space (C-P'; as evidenced in Table 2). This speculation is in agreement with Levandoski,[18] who also credited pain relief to the decompression of the posterior band. Further, this pain relief could be due to dental stabilization and force redistribution,[16] and to reduced activation of the jaw muscles by the canine rise built into the splint design.[17]

No significant differences were found for any mandibular movements (see Table 5). On one hand, pretreatment TMJ clicking was present in five joints in the ARS group, and in eight joints in the CPS group (see Table 6). On the other hand, posttreatment TMJ clicking existed in one joint in the ARS group and in one joint in the CPS group (see Table 6). In other words, TMJ clicking disappeared from four out of five pretreatment symptomatic joints in the ARS group, compared to seven out of eight pretreatment symptomatic joints in the CPS group. Thus, occlusal splint therapy reduced TMJ clicking. This agrees with Simmons and Gibbs,[1] and Zamburlini and Austin.[15] The

Table 2 Occlusal splint therapy and MRI

MRI-TMJ measurements	ARS	CPS	Significance
Disc length (A'-P')	−1.60^{NS}	2.33*	*
Condylion to anterior band H space (C-A')	−1.85*	−0.77^{NS}	NS
Condylion to posterior band H space (C-P')	−0.25^{NS}	−2.84*	*
Condylion to anterior band V space (C-A")	0.52^{NS}	0.56^{NS}	NS
Condylion to posterior band V space (C-P")	−0.43^{NS}	1.06^{NS}	NS

MRI-TMJ = Magnetic resonance imaging of the temporomandibular joint; ARS = anterior repositioning splint posttreatment minus pretreatment mean difference; CPS = canine-protected splint posttreatment minus pretreatment mean difference. Significance = significance level between ARS and CPS; NS, not significant; $*P < .05$.

Table 3 MRI-TMJ disc recapture and occlusal splint therapy

MRI-TMJ disc recapture	ARS	CPS	Total
Yes (recaptured)	25%	40%	33.3%
No (not recaptured)	75%	60%	66.7%

MRI-TMJ = magnetic resonance imaging of the temporomandibular joint; ARS = anterior repositioning splint; CPS = canine-protected splint.

Table 4 MRI-TMJ methodologic errors and occlusal splint therapy

MRI-TMJ	Mean difference	Standard error	Significance
Disc length (A'-P')	−0.13	0.18	NS
Condylion to anterior band H space (C-A')	−0.22	0.15	NS
Condylion to posterior band H space (C-P')	0.05	0.07	NS
Condylion to anterior band V space (C-A")	−0.13	0.15	NS
Condylion to posterior band V space (C-P")	−0.10	0.13	NS

MRI-TMJ = repeated measurements of MRI of the TMJ.

Table 5 Changes in TMJ pain levels and mandibular movements because of occlusal splint therapy

TMJ pain and mandibular movements	ARS	CPS
TMJ pain level	−3.00**	−2.00*
Widest interincisal opening	−2.25^{NS}	2.40^{NS}
Right lateral excursion	1.50^{NS}	−0.60^{NS}
Left lateral excursion	−0.25^{NS}	0.40^{NS}
Protrusion	1.50^{NS}	0.80^{NS}

ARS = anterior repositioning splint posttreatment minus pretreatment mean difference; CPS = canine-protected splint posttreatment minus pretreatment mean difference. **Significant at $P < .01$; *significant at $P < .05$; NS, not significant.

Table 6 TMJ clicking and occlusal splint therapy

TMJ clicking	ARS	CPS	Total
Pretreatment right joint clicking	3	5	8
Pretreatment left joint clicking	2	3	5
Pretreatment total joint clicking	5	8	13
Posttreatment right joint clicking	0	0	0
Posttreatment left joint clicking	1	1	2
Posttreatment total joint clicking	1	1	2

ARS = anterior repositioning splint; CPS = canine-protected splint.

present researchers conjecture that the absence of clicking might be an indication for the development of a harmonious relationship between the condylar head, articular disc, and glenoid fossa.

Clinical implications

Many TMD treatment plans are not supported by research. To serve our orthodontic patients in the best possible manner, the clinician should search for evidence-based research. A detailed clinical examination of the parts of the TMJ can be carried out by means of MRI. The present authors recommend the use of MRI as a supplemental diagnostic procedure in orthodontics, especially in TMD cases.

It is known that TMD complicates orthodontic treatment planning. Further, most children and young subjects with TMD respond rapidly to simple conservative methods, such as counseling, jaw exercises, and interocclusal appliances[19]; disc displacement during growth is associated with facial asymmetry in adulthood.[20] On the basis of this study, noninvasive treatment techniques (such as occlusal splint therapy) might well be the treatment of choice of anterior disc displacement with reduction. Orthognathic surgery should be limited to specific situations.

Research limitations

Although the results of the present study indicate the superiority of the CPS over the ARS in the ability to recapture the disc in cases of anterior disc displacement with reduction, a conclusive statement cannot be made due to the small sample size.

Suggestions for future studies

Establishing reliable guidelines for diagnosing TMD is important. With the use of the precise quantitative MRI analysis and the 10-step procedure developed in this research, additional studies on larger samples utilizing various splint designs and/or treatment modalities are suggested.

CONCLUSIONS

1. ARS and CPS appliances were effective in eliminating pain and clicking.
2. All MRI measurements showed that the CPS was superior to the ARS; it allowed the disc to resume its normal length and shape while moving in a posterior direction toward recapture.
3. Disc recapture was demonstrated via MRI in 25% of the subjects from the ARS group, in 40% of the subjects from the CPS group, and in 33.3% of the subjects from both groups.
4. Noninvasive treatment techniques (such as occlusal splint therapy) might be the treatment of choice for anterior disc displacement with reduction.

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