Clin Oral Invest (2013) 17:1243–1250
DOI 10.1007/s00784-012-0803-4

ORIGINAL ARTICLE

Disk and joint morphology variations on coronal and sagittal MRI in temporomandibular joint disorders

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Received: 29 March 2012 / Accepted: 19 July 2012 / Published online: 7 August 2012

Abstract
Objectives This study aims to assess the disk morphology and the condyle position in subjects with temporomandibular (TMJ) disk displacements on sagittal and coronal magnetic resonance imaging (MRI).
Materials and methods Seventy-four TMJs (from 37 patients) with positive clinical TMD symptoms according to the RDC/TMD axis I protocol were evaluated by 1.5 T MRI. Disk position, disk morphology, sagittal and coronal condyle position, joint effusion, joint space, and coronal condyle angulation were evaluated. Multivariate logistic regression was used to explore the relationship between disk displacement and MRI variables.
Results Disk displacement with reduction (DDR) was found in 36.48 % and without reduction (DDwR), in 21.62 % of the joints. Disk displacement was anterior in 35.1 %, anterior-medial in 13.5 %, and anterior-lateral in 9.45 % of cases. The thickened posterior band (94.48 OR, $p=0.001$) and the posterior condyle position (4.57 OR, $p=0.03$) were more likely found on sagittal MRI in disk displacements. On coronal slices, the disk displacement was significantly associated with the distance from the most medial condyle point to the midplane ($p<0.05$).
Conclusions Disk displacement is associated with changes of disk shape, disk dimension, and condyle position on sagittal MRI. A significant variation of the distance from the most medial condyle point to the midplane in disk displacement was found on coronal MRI.
Clinical relevance Our study highlights the existence of changes on coronal MRI in TMD patients which should be assessed for better understanding of the clinical evolution of temporomandibular disorders.

Keywords Temporomandibular joint · Magnetic resonance imaging · Temporomandibular joint disorders · Mandibular condyle · Temporomandibular articular disk

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Introduction

A growing demand in using three-dimensional imaging techniques in diagnosing TMJ pathology has been reported [1]. Magnetic resonance imaging (MRI) is considered the prime imaging of choice for assessing soft tissue components of the temporomandibular joint (TMJ) [2] due to its excellent soft tissue contrast resolution [3]. Magnetic resonance imaging has the advantage of being noninvasive and having a minimal risk potential when compared to other imaging techniques [4]. Lately, MRI has added substantial contributions to understanding TMJ pathology [5, 6], and it is known that MRI is the gold standard for diagnosing TMJ disk displacement [7].

There are several studies in the literature that showed a strong association between clinical examinations of the TMJ and disk displacement [8, 9]. Most of the previous studies highlighted the morphological changes of TMJ on lateral view.

Schmitter et al. [10] showed that in the closed and open mouth, a medially shifted disk is more likely found, while Brooks et al. [11] suggest that a combined antero-lateral or antero-medial disk displacement is more frequently encountered than pure anterior disk displacement. There is still not enough description of the morphology of the TMJ on coronal view in case of disk displacement. A possible displacement of the condyle could be found in antero-medial or antero-lateral disk displacement.

The purpose of this study was to assess the disk morphology in cases of TMJ disk displacement on sagittal as well as on coronal MRI. The objectives of this study were to reveal relationship between TMJ disk shape, disk position, disk dimensions, joint space, and condyle position in TMD subjects based on sagittal and coronal MRI findings.

Subjects and methods

We investigated 74 joints from 37 subjects selected through a prospective study for MRI evaluation of the temporomandibular joint from October 2010 to February 2012. All patients included in the study were clinically investigated according to the RDC/TMD axis I protocol [12]. This protocol included the assessment of the mandibular range of motion, opening pattern, joint pain, muscle pain, joint sounds during lateral excursions or protrusion, and joint or muscle pain at palpation. Patients who had at least two positive clinical TMD symptoms underwent MRI examinations for objective assessment of the TMJs included in the study. Patients with deformities, TMJ ankylosis, TMJ fractures, osteocondrosis, or rheumatoid arthritis were not included in the study.

Out of the subjects, 29 (78.4 %) were women (mean age 31.9 years, range 16–60 years) and eight (21.6 %) were men (mean age 30.8 years, range 16–46 years). Informed consent was obtained from each of the subjects before performing the study. The procedures and protocol were approved by the institutional review board at the University and by the Ethics Committee, certificate number 173/2010.

MRI examination

All MRI images were obtained using a 1.5 T system (General Electric, Signa Excite HD) with a split head coil. All subjects were placed into the standard head coil with fixation devices on both sides.

The MRI protocol included T1-weighted coronal plane images (repetition time (TR), 1,500 ms; echo time (TE), 24 ms; field of view (FOV), 140×140 mm; number of signs acquired, 11; and matrix, 256/3/224); proton density fast spin echo sagittal oblique images with the closed and open mouth position (TR, 1,500 ms; TE, 24 ms; FOV, 140×140 mm; number of signs acquired, 11; and matrix, 256/3/224); and T2 fast spin echo sagittal oblique images with closed mouth position (TR, 3,960 ms; TE, 90 ms; FOV, 140×140 mm; number of signs acquired, 11; and matrix, 256/4/224). In all sagittal oblique images, the thickness/increment was 3.0/0.5 mm, and in the coronal oblique images, the thickness/increment was 5/1 mm. Coronal oblique slices were placed parallel to the long axis of the mandibular condyles. Sagittal oblique slices were placed perpendicular to the long axis of the mandibular condyles.

Image assessment

All MRI images were evaluated independently by two observers with experience in maxillofacial diagnosis on the same monitor and under equal examining conditions after mutual calibration. The acquired images were used to determine the following qualitative data on sagittal slices: disk position, disk shape, joint effusion, and condyle position. If there were differences between qualitative data, the observers read the images once again, and agreement was established.

The disk position was assessed according to the MRI imaging criteria for TMD [13]. The encountered disk positions were normal disk position (N), anterior disk displacement with reduction (DDR), and anterior disk displacement without reduction (DDwR). The following possibilities for the disk shape were assessed [14]: (1) biconcave disk shape with clearly identifiable posterior and anterior bands and tapered intermediate zone; (2) lengthened disk with equal thickness of the anterior, intermediate, and posterior band; (3) thickened posterior band with the posterior band thicker and longer anteroposteriorly; (4) folded with an atypical elongated anterior band and thickened and shortened posterior band; and (5) rounded or oval disk shape.

The condyle position as being concentric, anterior, or posterior was evaluated in the sagittal images of the closed mouth position, according to the method described by Robinson de Senna et al. [15].

The quantitative data assessed on sagittal slices in closed and open mouth position were the disk dimension (length and size of the anterior, intermediate and posterior band), joint space (anterior, superior and posterior), and fossa depth.

For the disk dimension, the maximal thickness of the anterior, posterior bands, and intermediate zone were measured (Fig. 1). Condyle–fossa relationship was evaluated on sagittal images by measuring the depth of the condylar fossa and the closest superior, anterior, and posterior joint space. The depth of the condylar fossa was measured from the most superior point of the fossa to the plane formed by the most inferior point of the auditory meatus, and the most inferior point of the articular tubercle (Fig. 2). The closest anterior joint space was measured from the most anterior point of the condyle (assessed by drawing a tangent from the most superior point of the mandibular fossa to the most anterior condyle point) to the mandibular fossa. The closest superior joint space was measured from the most superior point of the mandibular fossa to the most superior point of the condyle. The closest posterior joint space was measured from the most posterior point of the condyle (assessed by drawing a tangent from the most superior point of the mandibular fossa) to the mandibular fossa (Fig. 3). On coronal images, we determined condyle angulation (the angle between the medio-lateral condyle diameters to the midplane) and condyle position (the distance from the condyle to the median plane). The angle between the transversal (medio-lateral) condyle diameter to the midplane and the distance from the most medial condyle point to the midplane was measured (Fig. 4).

Statistical analysis

Quantitative data were presented by mean and standard deviation for normally distributed data and median along with interquartile range otherwise. Normality of the data was checked with quantile–quantile plot and Shapiro–Wilk test. To check for differences between three or more independent groups of quantitative data, for nonnormally distributed data, the Kruskal–Wallis test and Tukey–Kramer posthoc tests were used. Interrater reliability for quantitative data was assessed with interclass correlation coefficient (ICC) and the associated test of significance.

Qualitative data were analyzed by descriptive statistics, and the association between qualitative variables was tested using Fisher exact test, if more than 20 % of expected frequencies were less than 5. Bonferroni correction was used for subgroup analyses. The associations between disk displacement in closed mouth position, disk shape, condyle position, and coronal parameters were analyzed using multivariate logistic regression analysis.

For all statistical tests used, the significance level alpha chosen was 0.05, and the two tailed (where possible) *p* value was computed. The statistical analysis was made in R environment for statistical computing and graphics, version 1.12.1 [16, 17]. The IRR package version 0.83 was used for interrater reliability.

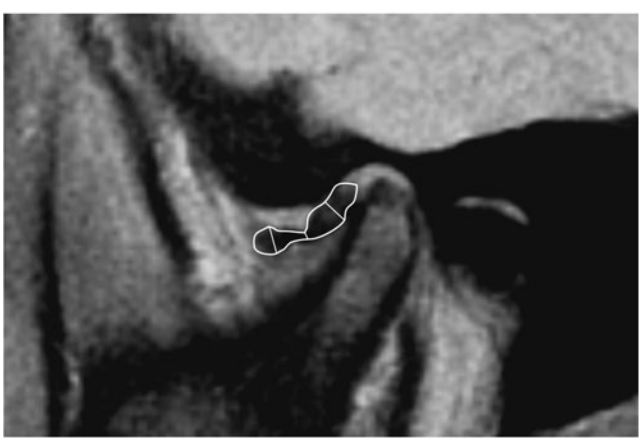

Fig. 1 Sagittal section: the largest disk thickness of anterior band, intermediate zone, and posterior band

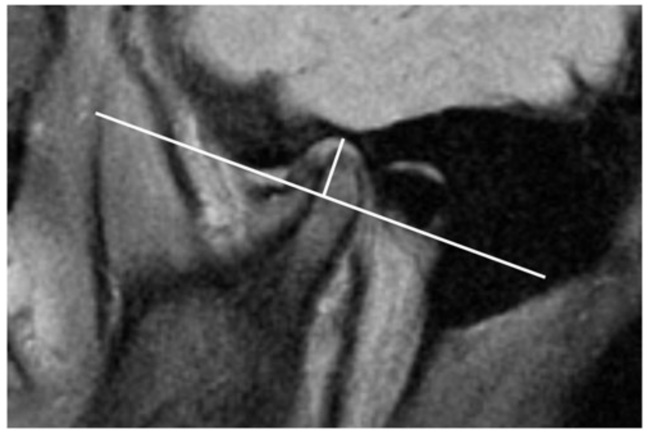

Fig. 2 Sagittal section: the depth of the condylar fossa measured from the most superior point of the glenoid fossa to the plane formed by the most inferior point of the auditory meatus and the most inferior point of the articular tubercle

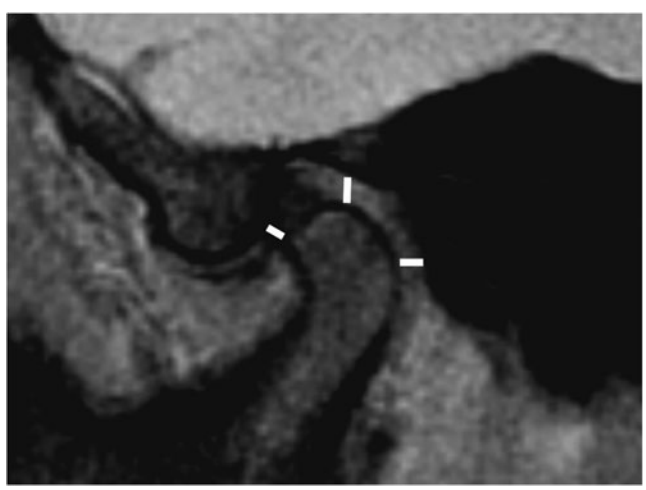

Fig. 3 Sagittal section: the closest anterior, superior, and posterior joint space

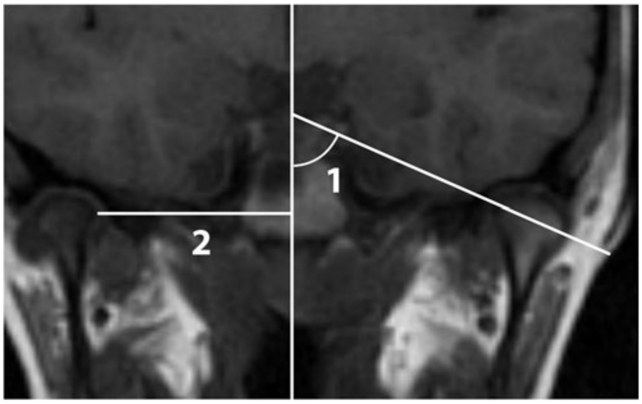

Fig. 4 Coronal section: the position and the orientation of the condyle. *1* angle between the transversal condyle diameter and the midplane; *2* distance from the most medial condyle point to the midplane

Results

From the total 74 joints, a number of 43 joints (58.1 %) with disk displacement were identified on MRI: 27 joints (36.5 %) with DDR; and 16 joints (21.6 %) with DDwR. The disk displacement assessed in sagittal and coronal images was anterior in 26 cases (35.1 %), anterior-medial in ten cases (13.5 %), and anterior-lateral in seven cases (9.45 %). No pure medial, lateral, or posterior disk displacements were found. A significant association was found between disk displacement and disk shape, condyle position, and joint effusion ($p<0.001$, Table 1).

Disk shape

The biconvex normal disk shape was found in 15 joints (48.3 %) with normal disk position and only for 1 joint (2.3 %) with disk displacement. The posterior thickened band was the most common disk shape in joints with DDR (40.7 %) as well in those with DDwR (50 %). The lengthened disk shape was encountered in 11 joints (32.5 %) with normal disk position and in 14 joints (35.4 %) with disk displacement. All laterally displaced disks and 84 % of medial displaced disks had modified disk shape, the most frequent disk shape being lengthened and thickened posterior band.

Joint effusion

Joint effusion was found in joints with internal derangements of the TMJ as well in those with normal disk position (1/31, 3.2 %), being most frequent in joints with DDwR (10/16, 62.5 %) compared with DDR (8/27, 29.6 %). The joint effusion was significantly associated with the thickened posterior band and lengthened disk shape ($p<0.005$). The detailed data regarding the disk shape, condyle position, and disk effusion according to disk position are shown in Table 1.

Disk dimension

No significant differences of the disk dimensions could be found between patients with disk displacement compared to those with normal disk position, in closed mouth position, except for the anterior band. However, in case of mouth opening, we found significant differences of disk length, anterior, intermediate, and posterior band in cases with DDwR compared with DDR and normal group ($p<0.01$, Table 2).

Condyle position

The condyle was situated posteriorly in 27 joints with disk displacement (62.7 %, $p<0.0001$). The posthoc comparisons (Tukey–Kramer method) showed significant diferences of the superior and posterior joint space between normal disk position and DDwR (Table 3). Unlike, the glenoid fossa, depth was not associated with the disk displacement.

On coronal slices, the disk displacement was significantly associated with the distance from the most medial condyle point to the midplane ($p<0.05$), but not with the condyle angulation (Table 4).

Relationship between disk position, condyle position, and disk shape

A multivariate logistic regression model for assessing the relationship between disk position and the independent

Table 1 Disk shape, condyle position, and joint effusion in disk displacements ($n=74$ temporomandibular joints)

MRI disk position	Disk shape (*n*)				Condyle position (*n*)			Effusion (*n*)	
	Folded	Lenghtened	Normal	Thickened posterior band	Anterior	Concentric	Posterior	No	Yes
DDR	7	8	1	11	0	9	18	19	8
DDwR	2	6	0	8	1	6	9	6	10
Normal	2	11	15	3	5	20	6	30	1
Total number (*n*)	11	25	16	22	6	35	33	55	19
p value (Fisher Exact test)	<0.0001				<0.0001			<0.0001	

Table 2 Disk dimensions in open and closed mouth positions in subjects with disk displacements of the temporomandibular joint

MRI disk position	Anterior band (mm) median (interquartile range)		Intermediate band (mm) median (interquartile range)		Posterior band (mm) median (interquartile range)		Disk length (mm) median (interquartile range)	
	Closed mouth*	Open mouth**	Closed mouth	Open mouth***	Closed mouth	Open mouth	Closed mouth	Open mouth****
DDR	2.5 (1.9–3.2)	2.8 (2.0–3.6)	1.2 (1.08–1.4)	1.4 (1.15–2.0)	2.4 (1.7–3.0)	3.5 (2.8–4.0)	11.2 (9.7–12.5)	12.1 (11.3–13.1)
DDwR	1.8 (1.5–2.0)	1.7 (1.5–1.8)	1.2 (1.03–1.6)	1.0 (0.65–1.5)	2.0 (1.2–2.4)	2.3 (1.9–3.6)	11.5 (10.5–12.2)	10.7 (9.3–12.3)
Normal	1.9 (1.2–2.9)	2.5 (1.8–3.4)	1.0 (0.78–1.4)	1.3 (1.20–1.6)	1.7 (1.2–2.8)	3.4 (3.0–4.2)	11.1 (10.4–11.6)	11.5 (10.4–12.3)
p value (Kruskal–Wallis test)	0.05	0.0008	0.24	0.04	0.44	0.06	0.76	0.01

Posthoc comparisons between DDwR–DDR (Tukey–Kramer method)

DDR disk displacement with reduction, *DDwR* disk displacement without reduction

*$p=0.03$; **$p=0.001$; *** $p=0.04$; **** $p=0.01$

variables, namely distance from the most medial condyle point to the midplane, condyle angulation, sagittal condyle position, and disk shape, are shown in Table 5. The disk displacement was more likely found for nonnormal disk shapes: for folded disk shape (91.07 OR, $p=0.002$), for lengthened disk shape (23.24 OR, $p=0.01$), and for thickened posterior band (94.48 OR, $p=0.001$). The disk displacement was more likely found for the posterior condyle position (4.57 OR, $p=0.03$). The disk displacement was less likely found as the distance from the condyle to the midplane increased (0.77 OR, $p<0.05$), implying that each millimeter increase of the distance reduced the odds of disk displacement by 23 % (Table 5).

The interrater reliability for quantitative data ranged from 0.832 to 0.984 (interclass correlation coefficient (ICC) and the associated F test, $p<0.0001$). These results implied outstanding inter- and intraexaminer reliability for the determination of quantitative data assessment.

There was a 95.9 % (71 of 74 joints) agreement between the two observers in the first interpretation of the qualitative data. For three joints, a final diagnosis was made by consensus after a second interpretation.

Discussion

Our study reveals that disk displacement is significantly associated with changes of disk shape, condyle position, and joint effusion. Significant variations of condyle position were encountered on sagittal as well on coronal MRI in disk displacements. The high values of interrater reliability obtained in our study showed that MRI is a reliable method for the assessment of TMJ disk morphology and joint space dimensions.

In subjects with internal derangements of the TMJ, we found a mostly modified disk shape, the normal biconcave shape occurring in only 2.3 % of these. The posterior thickened band was the most common disk shape in subjects with disk displacement, being in accordance with the results of other authors [14, 18, 19] who found the thick posterior band as being the most frequent disk deformation in internal derangements. Heffez and Jordan [20] showed that changes of disk shape are an important feature in internal derangements of the TMJ. Miller et al. [21] reported that all DDwR cases had thickened and deformed disks.

By contrast, in our study, there was a similar rate of lengthened disk shape in subjects with normal disk position as well as in those with disk displacements regardless of DDR or DDwR. Furthermore, multivariate logistic regression showed that the patients with disk displacement have a higher odds ratio for thickened posterior band or folded disk than for lengthened disk shape compared with subjects with normal disk position. Slight differences of disk shape were

Table 3 The mean values of glenoid fossa depth and the closest anterior, superior and posterior joint space in subjects with disk displacement

MRI disk position	Glenoid fossa depth median (interquartile range)	Closest anterior joint space median (interquartile range)*	Closest superior joint space median (interquartile range)**	Closest posterior joint space median (interquartile range)***
DDR	9.6 (8.8–11)	2.7 (2.4–3.0)	2.4 (2.0–2.7)	1.9 (1.2–2.4)
DDwR	10.2 (9.0–11)	2.6 (1.6–3.8)	1.9 (1.1–2.4)	1.8 (1.3–2.0)
Normal	9.7 (8.9–10)	2.1 (1.9–2.5)	2.4 (2.0–3.2)	2.0 (1.8–2.6)
p value (Kruskal–Wallis test)	0.74	0.05	0.009	0.04

Posthoc comparisons (Tukey–Kramer method)

DDR disk displacement with reduction, *DDwR* disk displacement without reduction

*p=0.05 (normal–DDR); **p=0.007 (normal–DDwR); ***p=0.04 (normal–DDwR)

reported by Taşkaya-Yýlmaz and Oğütcen-Toller [22] who showed that 32 % of anterior DDR had a lengthened disk, whereas DDwR had either a rounded or folded disk shape.

Regarding the disk dimension, our study reveals no significant differences in closed mouth position, except for the anterior band. After mouth opening, in subjects with DDwR, the disk became smaller in all its areas, unlike in subjects with DDR, in which the disk length, as well as its anterior, intermediate, and posterior band increased. These dynamic variations of the disk dimension suggest that the disk morphology is strongly related to the mandibular biomechanics.

Wang et al. [23] also found a variation of the anterior band disk dimension in open mouth associated with disk displacement. The authors explained the morphological changes in the disk due to decreased compressive load by the condyle during function, the increased thickness of the anterior band, and the intermediate zone in the TMD group, suggesting a decreased compressive load from the condyle. This mechanism could explain also the influence of the condyle position and joint space on the disk morphology.

In respect of the condyle position, we found in our study a positive association between internal derangements and posterior condyle position. We consider that a posterior-located condyle may alter the condyle–fossa relationship, and this could have a response on the disk shape and dimension as well. Rammelsberg et al. [24] demonstrated also that in patients with bilateral disk displacements, the condyle position is more posteriorly situated than in patients with unilateral disk displacement, and the posterior joint space is more compressed. However, Pereira et al. demonstrated that posterior condyle position cannot predict TMD [25].

Unlike previous studies, our study assesses condyle angulation and distance from the most medial condyle point to the midplane on coronal slices in disk displacements. Our results suggest that the disk displacement could generate changes of the condyle orientation in the coronal plane. To our knowledge, the assessment of condyle position on coronal view was not yet described in the literature. The displacement in the frontal plane can generate changes of the condyle orientation. Therefore, the coronal view is important to be assessed together with the sagittal one because the anterior disk displacement is frequently associated with lateral or medial disk displacement.

Table 4 Variation of condyle angulation and the distance from the most medial condyle point to the midplane on coronal MRI in disk displacement

Disk position	Condyle angulation (deg) median (interquartile range)	Distance to the midplane (mm) median (interquartile range)
Normal	84.8 (79.1–88.7)	40.4 (37.9–42.8)
Anterior displacement	85.9 (79.1–88.3)	38.6 (36.9–40.2)
Antero-lateral displacement	77.2 (75.6–86.9)	40.8 (38.8–42.9)
Antero-medial displacement	81.6 (79.4–87.1)	39.5 (38.0–41.2)
p value (Kruskal–Wallis test)	0.5	0.04

Table 5 Odds ratios for the multivariate logistic regression model for assessing the relationship between disk position (with displacement vs. normal) and the independent variables: distance from the most medial condyle point to the midplane, condyle angulation, sagittal condyle position, and disk shape

	Odds ratio	Beta	Standard error	*p* value
Distance to the midplane	0.77	−0.25	0.12	0.03
Condyle angulation	0.97	−0.02	0.06	0.66
Sagittal condyle position				
Anterior vs. centered	1.19	0.17	1.42	0.90
Posterior vs. centered	4.57	1.51	0.72	0.03
Disk shape				
Folded vs. normal	91.07	4.51	1.48	0.002
Lengthened vs. normal	23.34	3.14	1.24	0.01
Thickened posterior band vs. normal	94.48	4.54	1.36	0.001

The relationship between disk morphology, disk position, and condyle position is still controversial. In our study, we found an increase of the anterior joint space and a decrease of the posterior joint space associated with DDR and DDwR. The posterior joint space was compressed regardless of disk shape, whereas the changes of anterior joint space were more often encountered in subjects with folded and thickened posterior band disk shapes. The glenoid fossa depth was not found to be changed in our patients with DDR and DDwR, suggesting that disk displacement might be associated with changes only in disk shape, joint space, and condyle position.

The relationship between condyle and glenoid fossa in patients with internal derangements of the TMJ can explain the changes of the disk dimensions and shape. The posterior position of the condyle could be associated with the deterioration of the disk ligaments or the disk position, as suggested by Robinson de Senna et al. [15].

Joint effusion was significantly associated with internal derangements of the TMJ for both types of disk displacement, DDR and DDwR. These results are in accordance with the results of other authors [26–29] who demonstrated that joint effusion is associated with DDwR and with degenerative changes of the bone structure. In our study, we found that joint effusion is also associated with the thickened posterior band and folded disk shape. We consider that this result supports the hypothesis that a chronically not reduced displaced disk could induce changes in disk shape and also in the condyle relationship with the glenoid fossa, creating the condition for joint fluid accumulation. This mechanism was also suggested by Manfredini et al. [27], who explained the fluid effusion by the change of the flexibility of the posterior attachment.

Conclusions

Disk displacements induce changes of disk shape, disk dimensions condyle position, and joint space in TMJ dynamics. A significant variation of the distance from the most medial condyle point to the midplane in disk displacement was found on coronal MRI.

Acknowledgments This study is supported by funding from a POSDRU/107/1.5/S/78702 project from the University of Medicine and Pharmacy "Iuliu Hațieganu" Cluj-Napoca, Romania.

Conflict of interest The authors declare that they have no conflicts of interests.

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