RESEARCH ARTICLE

Correlation between temporomandibular joint morphology and disc displacement by MRI

¹J F G de Farias, ²S L S Melo, ¹P M Bento, ³L S A F Oliveira, ⁴P S F Campos and ¹D P de Melo

¹Division of Oral Radiology, Department of Oral Diagnosis, State University of Paraíba, Campina Grande, Paraíba, Brazil; ²Department of Oral Pathology, Radiology & Medicine, University of Iowa College of Dentistry, Iowa, IA, USA; ³Department of Health Technology and Biology, Division of Radiology, Federal Institute of Bahia, Salvador, Brazil; ⁴Division of Oral Radiology, Department of Oral Diagnosis, Federal University of Bahia, Salvador, Brazil

Objectives: The aim was to evaluate the morphology of the temporomandibular joint's (TMJs) disc and condyle as well as its correlation with disc displacement, using MRI.

Methods: 190 TMJs were retrospectively analysed. The condyle morphology of each TMJ was evaluated by two observers using both axial and coronal views, as were their disc morphology and displacement, using sagittal view. Condyle morphology was classified as flat, convex, angled or rounded in the coronal sections and as anterior side flat/posterior side convex, biconvex, anterior side concave/posterior side convex, flat or biconcave in the axial view. Disc morphology was determined as biconcave, biplanar, biconvex, hemiconvex or folded. χ^2 , Fisher exact and Bonferroni correction tests were used to evaluate the data. ANOVA followed by *post hoc* Tukey's test was used to evaluate the interaction between age and disc displacement.

Results: Anterior disc displacement with reduction; convex condyle morphology in the coronal view; anterior side concave/posterior side convex morphology in the axial view; and biconcave discs were found to be the most prevalent findings. An association was observed between disc morphology and disc displacement ($p < 0.001$). No correlation between condyle morphology and TMJ disc displacement was found ($p = 0.291$ for axial and $p = 0.14$ for coronal views).

Conclusions: The results of this study suggest that TMJ disc morphology is associated with disc displacement.

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Introduction

The temporomandibular joint (TMJ) is the articulation between the condyle head and the squamous portion of the temporal bone in the skull base. Interposed between the bone surfaces is the articular disc,^{1–5} a fibrocartilaginous plate that is typically described as having a biconcave morphology. It is divided into three parts: the

anterior band, posterior band and intermediate zone.^{1,3} In a healthy joint, the disc is perfectly placed between the articular surfaces throughout the mandibular movement.^{1,6} When the disc is normally positioned, the intermediate zone lies interposed between the condyle and the articular eminence, and the posterior band above the head of the mandible.⁷

Despite the TMJ disc's clinical relevance, little is known about its aetiopathogenesis.⁸ It is necessary to

Correspondence to: Dr Saulo L Sousa Melo. E-mail: sauloleonardo-sousamelo@uiowa.edu

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Figure 1 Classification of condyle morphology in the coronal view: (a) flat, (b) convex, (c) angled and (d) round.

understand the natural course of disc displacement to develop an effective therapy for this disorder.⁹ As there is an intimate relationship between form and function, many authors have suggested that the TMJ's morphology is related to functional changes that result in the displacement of the articular disc.¹⁰ Therefore, several authors have evaluated the morphologies of the condyle and articular disc and investigated the correlation between their morphology and disc displacement.^{2,7,9–17}

MRI is considered the gold standard imaging modality for evaluating TMJ discs, as it produces images of excellent soft-tissue contrast.^{10,18–20} Moreover, it is a non-invasive examination that is free of ionizing radiation.^{16,20,21}

Therefore, the aim of this study was to evaluate the morphology of the articular disc and condyle in the coronal and axial views and to correlate these findings with the position of the articular disc, using MRI.

Methods and materials

This retrospective cross-sectional study protocol was approved by the institutional review board of the State University of Paraíba, Brazil, and is in compliance with the Helsinki Declaration. All subjects provided written informed consent.

The study was conducted on all of the MRIs performed between 2009 and 2012 in a private practice. To be included in the study, the subject had to present at least one of the following signs and symptoms: pain in joints and/or muscles, joint sounds, limitation of movement, history of headaches and otologic complaints. The following exclusion criteria were used: patients with previous surgeries in their TMJ; systemic, inflammatory joint disease; facial growth disorders; history of direct trauma or facial bone fracture; hypoplasia, hyperplasia or tumours of the TMJ; and syndromes. After applying the exclusion criteria, the sample was composed of

114 subjects. However, another 19 examinations were excluded from the sample: 10 for poor image quality and 9 for lack of some data in the patient file. The final sample was therefore 95 subjects (15 males and 80 females), aged 16–81 years (mean age, 39 years), totalling 190 joints.

Prior to the MRI scan, an oral and maxillofacial radiologist (PSFC) with special training in TMJ evaluation and 15 years' experience performed a clinical examination on all of the subjects. Sex and the presence of joint pain, as reported by the subject, were registered accordingly.

The MRI studies were performed using a 1.5-T GE Signa[®] scanner (General Electric, Milwaukee, WI) and a bilateral TMJ dual-phased array coil (Signa; General Electric Medical Systems). The subjects were positioned in the supine position, with the sagittal plane perpendicular to the horizontal plane and the Frankfort plane parallel to the scanner gantry. The protocol consisted of a 256×256 pixel matrix, 145-mm field of view and a pixel size of 0.60×0.57 mm. Based on an axial localizer [repetition time (TR), 400 ms; echo time (TE), 13 ms; number of excitations (NEX), one; scan time, 58 s; slice thickness, 4 mm], oblique parasagittal slices were obtained and corrected by the horizontal angulation of the condyle, in both open- and closed-mouth positions. 10 slices, 2-mm thick, were obtained for each TMJ using spin echo T_1 weighted (TR, 400 ms; TE, 26 ms; NEX, four; scan time, 3 min 44 s) and spin echo T_2 weighted (TR, 3200 ms; TE, 85 ms; NEX, four; scan time, 5 min 12 s) sequences. For the acquisition of images in the open-mouth position, a Burnett TMJ device (TMJ-200s/n 0650; Medrad Inc., Pittsburgh, PA) was used to stabilize the maximal opened-mouth position and minimize motion artefacts. Sequential sagittal images for the open- and closed-mouth positions, as well as coronal and axial images for the closed-mouth position, were obtained. During the MRI examination, if one of the radiologists thought that proton density was needed to evaluate

Figure 2 Classification of condyle morphology in the axial view: (a) flat/convex, (b) biconvex, (c) concave/convex, (d) flat and (e) biconcave.

Figure 3 Classification of disc morphology: (a) biconcave, (b) biplanar, (c) biconvex, (d) hemiconvex and (e) folded.

a specific case, then such images were also acquired (proton density fast spin echo: TR, 1584 ms; TE, 24 ms; NEX, three; scan time, 3 min 28 s).

The position of the disc in closed-mouth images was evaluated and classified as normal (N) or displaced, using the classification of Tasaki *et al.*²² In our study, cases of partial anterior disc displacement in the lateral part of the joint, partial anterior disc displacement in the medial part of the joint, rotational anterolateral disc displacement and rotational anteromedial disc displacement were grouped together with the ones of anterior disc displacement for purposes of statistical analysis. For this reason, discs were categorized into the following groups: normal position (N); anterior displacement with reduction; anterior displacement without reduction (ADWOR); posterior displacement; and medial or lateral displacement.

Axial and coronal sequences were used to assess the condyle morphology. The slices in which the largest latero-lateral size of the condyle was observed were chosen for the morphology analysis. The classification used was the one suggested by Yale *et al.*,²³ modified by Alomar *et al.*¹ (Figures 1 and 2). In both the coronal and axial views, the “other” category was added for those condyles that did not correspond to any of the proposed categories.

Table 1 Absolute and relative frequencies for each studied variable

Variable	F (%)
Disc position	
Anterior disc displacement with reduction	56 (29.5)
Anterior disc displacement without reduction	37 (19.5)
Medial or lateral displacement	20 (10.5)
Posterior displacement	2 (1.1)
Normal position	75 (39.5)
Condyle morphology in axial section	
Anterior side flat/posterior side convex	52 (27.4)
Biconvex	32 (16.8)
Anterior side concave/posterior side convex	73 (38.4)
Flat	21 (11.1)
Biconcave	8 (4.2)
Others	4 (2.1)
Condyle morphology in coronal section	
Flat	46 (24.2)
Convex	66 (34.7)
Angled	55 (28.9)
Round	18 (9.5)
Others	5 (2.6)
Disc morphology	
Biconcave	142 (74.7)
Biconvex	7 (3.7)
Biplanar	5 (2.6)
Folded	19 (10)
Hemiconvex	15 (7.9)
Others	2 (1.1)

F, absolute frequency.

Using Microsoft® PowerPoint® Office 2013 (Microsoft, Redmond, WA) and Adobe® Photoshop® Elements (Adobe Systems, San Francisco, CA) software, the outline of all of the morphological categories that were pre-established for condyle MRI evaluation was designed and printed, for superimposition onto images when the observer was unsure of which category the condyle would fit in, thus assisting the diagnosis.

The image sequences in the sagittal closed-mouth position were used to evaluate the disc's morphology, and the chosen slices were those in which the disc was represented at its largest. Murakami *et al.*²⁴ classification was used for this evaluation, as follows: biconcave, both upper and lower surfaces are concave; biplanar, even thickness; biconvex, both upper and lower surfaces are convex; hemiconvex, upper surface is concave and lower is convex; and folded, the disc is folded at the centre (Figure 3).

Two experienced radiologists evaluated all of the MRI images in a consensus approach, without consulting any clinical information. The data analysis was performed using R software v. 3.15.127 (R Foundation for Statistical Computing, Vienna, Austria). χ^2 test, Fisher exact test and χ^2 partition were used when necessary and in addition to the descriptive statistics of central tendency (mean), dispersion (standard deviation) and absolute and relative frequencies. In the event of p -values ≤ 0.05 , Bonferroni correction was applied to compare the proportions between the columns of the contingency tables. For the intersection between age and disc position, one-way ANOVA followed by a *post hoc* Tukey's test were used.

Results

190 TMJs were analysed. The frequencies of the observed disc positions and morphologies, as well as the condyle morphologies in the coronal and axial views, are listed in Table 1.

There was no statistical correlation between disc displacement and condyle morphology in both the axial and coronal views ($p = 0.29$ and 0.14 , respectively) (Table 2). There was a statistically significant association between the disc position and disc morphology variables ($p < 0.001$). The *post hoc* test revealed that the co-occurrence of ADWOR and a biconcave disc was significantly less frequent than with the other disc positions. Furthermore, the intersection between displacement without reduction and a folded disc appeared with higher frequency than the crossover between normally positioned discs and folded discs (Table 2).

Table 2 Association between disc position and the independent variables [n (%)]

Variable	Disc position					Total	p-value
	Anterior disc displacement with reduction	Anterior disc displacement without reduction	Medial or lateral displacement	Posterior displacement	Normal position		
Condyle morphology in axial section							
Anterior side flat/posterior side convex	20 (36.4%)	8 (23.5%)	1 (5.3%)	—	23 (30.7%)	52 (28.1%)	0.291 ^a
Biconvex	9 (16.4%)	3 (8.8%)	5 (26.3%)	2 (100%)	13 (17.3%)	32 (17.3%)	
Anterior side concave/posterior side convex	21 (38.2%)	17 (50%)	8 (42.2%)	—	26 (34.7%)	73 (38.9%)	
Flat	3 (5.5%)	4 (11.8%)	3 (15.8%)	—	11 (14.7%)	21 (11.4%)	
Biconcave	2 (3.6%)	2 (5.9%)	2 (10.5%)	—	2 (2.7%)	8 (4.3%)	
Condyle morphology in coronal section							
Flat	12 (22.2%)	8 (22.2%)	2 (10%)	—	24 (32%)	46 (24.6%)	0.14 ^a
Convex	22 (40.7%)	11 (30.6%)	9 (45%)	—	24 (32%)	66 (35.3%)	
Angled	17 (31.5%)	11 (30.6%)	4 (20%)	1 (50%)	22 (29.3%)	55 (29.4%)	
Round	3 (5.6%)	6 (16.7%)	5 (25%)	1 (50%)	5 (6.7%)	20 (10.7%)	
Disc morphology							
Biconcave	47 ^A (85.5%)	10 ^B (27.8%)	17 ^A (85%)	—	68 ^A (90.7%)	142 (75.5%)	<0.001 ^a
Biconvex	—	3 ^{A,B} (8.3%)	2 ^B (10%)	2 (100%)	—	7 (3.7%)	
Biplanar	1 ^A (1.8%)	2 ^A (5.6%)	—	—	2 ^A (2.7%)	5 (2.7%)	
Folded	—	18 ^B (20%)	—	—	1 ^A (1.3%)	19 (10.1%)	
Hemiconvex	7 ^A (12.7%)	3 ^A (8.3%)	1 ^A (5%)	—	4 ^A (5.3%)	15 (8%)	
Total	55 (100%)	36 (100%)	20 (100%)	2 (100%)	75 (100%)	188 (100%)	

^aFisher's exact test. Different uppercase letters in table data indicate statistical differences.

Sex had a significant correlation with the position of the disc: 66.7% of the male subjects were classified with normally positioned discs against 34.4% of the female subjects (Table 3).

When intersecting the variables with age, some of the groups differed from each other. The ADWOR had a higher average age than that found in normally positioned discs (Table 4).

Discussion

The predominance of female subjects, as observed in this study, was already reported in a series of studies on TMJ dysfunction.^{7,21,22,25} Although there is no consensus on why this occurs, some theories have been proposed. The first states that this difference is related to an increased demand for treatment from females and not to their greater

Table 3 Association between gender and the other variables [n (%)]

Variable	Male	Female	Total	p-value
Disc position				
Anterior disc displacement with reduction	6 ^A (20%)	50 ^A (31.3%)	56 (29.5%)	<0.01 ^a
Anterior disc displacement without reduction	2 ^A (6.7%)	35 ^A (21.9%)	37 (19.5%)	
Medial or lateral displacement	2 ^A (6.7%)	18 ^A (11.3%)	20 (10.5%)	
Posterior displacement	—	2 (1.3%)	2 (1.1%)	
Normal position	20 ^A (66.7%)	55 ^B (34.4%)	75 (39.5%)	
Condyle morphology in axial section				
Anterior side flat/posterior side convex	6 (20.7%)	46 (29.5%)	52 (28.1%)	0.49 ^a
Biconvex	5 (17.2%)	27 (17.3%)	32 (17.3%)	
Anterior side concave/posterior side convex	11 (37.9%)	61 (39.1%)	72 (38.9%)	
Flat	6 (20.7%)	15 (9.6%)	21 (11.4%)	
Biconcave	1 (3.4%)	7 (4.5%)	8 (4.3%)	
Condyle morphology in coronal section				
Flat	10 (35.7%)	36 (22.6%)	46 (24.6%)	0.48 ^a
Convex	8 (28.6%)	58 (36.5%)	66 (35.3%)	
Angled	8 (28.6%)	47 (29.6%)	55 (29.4%)	
Round	2 (7.1%)	18 (11.3%)	20 (10.7%)	
Disc morphology				
Biconcave	27 (90%)	115 (72.8%)	142 (75.5%)	0.32 ^a
Biconvex	—	7 (4.4%)	7 (3.7%)	
Biplanar	—	5 (3.2%)	5 (2.7%)	
Folded	2 (6.7%)	17 (10.8%)	19 (10.1%)	
Hemiconvex	1 (3.3%)	14 (8.9%)	15 (8%)	

^aFisher's exact test. Different uppercase letters in table data indicate statistical differences.

Table 4 Age distribution among the disc position groups (years)

Disc position	Mean value	Range	Confidence interval (95%)		Minimum	Maximum
			Inferior	Superior		
Anterior disc displacement with reduction	41.21 ^{A,C}	14.64	37.29	45.14	22	81
Anterior disc displacement without reduction	43.62 ^A	18.02	37.61	49.63	22	76
Medial or lateral displacement	33.40 ^{B,C}	10.74	28.37	38.43	16	60
Posterior displacement	41.00	0	41.00	41.00	41	41
Normal position	37.33 ^C	12.29	34.50	40.16	16	81
Total	39.33	14.32	37.28	41.38	16	81

ANOVA *post hoc* Tukey's test. Different uppercase letters in table indicate statistical differences ($p < 0.05$).

predisposition towards TMJ degenerative diseases.²⁶ Another suggests that the difference is owing to a change in collagen metabolism associated with joint laxity of genetic origin.²⁷ Some studies also suggest that oestradiol—the female sexual hormone—induces pro-inflammatory cytokines, aggravating TMJ inflammation.²⁸

There was a significant association between sex and the position of the articular disc, with female subjects presenting a smaller number of discs in the normal position. This difference, however, can be owing to the small number of male subjects in the study's sample.

Most of the discs were in the normal position, and the most frequent type of displacement was anterior displacement with reduction, occurring in 29.5% of the cases. The rarest type of displacement was the posterior displacement, found in only 1.1% of the cases. The rarity of the posterior displacement was reported earlier.²⁹ However, there is no consensus among authors when it comes to anterior disc displacement. Some point out that anterior displacement with reduction is the most frequent type of disc displacement, as found in our study,^{7,15,21,30} whereas others observed higher prevalence of ADWOR.^{9,30,31} These differences must be related to the sample's characteristics (age and symptoms, for example), since disc displacement is a chronic disease.³¹

The most prevalent morphology of the condyle in the axial view was anterior side concave/posterior side convex (37.9%), while the most unusual was biconcave (4.2%). These findings diverge from those of Yale *et al*²³ and Sülün *et al*,¹⁶ who observed a higher prevalence of condyles with a convex anterior surface (biconvex). No association was observed between axial morphology and the position of the disc, in agreement with Raustia and Pyhtinen³² and Solberg *et al*.³³ Sülün *et al*¹⁶ found an association between these variables, probably because they used a different sample (composed exclusively by symptomatic subjects) and a classification with a fewer number of categories, thus increasing the possibilities of statistical association.

Regarding the condyle morphology in the coronal section, our findings are in agreement with Yale *et al*,²³ who also found the convex type to be the most prevalent and the rounded type the most unusual. Cholitgul *et al*²¹ observed a greater number of rounded condyles; however, they used a classification with only three categories: round, flat and concave. Thus, condyles that would be classified as convex in our study may have been included in the rounded type, explaining the different

results. Matsumoto *et al*³⁴ also used only three classifications: convex, angled and flat, with the convex type being the most prevalent in patients with both affected and unaffected sides, in accordance with our findings.

Our findings also diverge from Santos *et al*,¹⁵ who observed a higher prevalence of flattened condyles. These authors claim that condyle morphology is associated with the stage of disc displacement. Therefore, differences in the sample's composition could explain the dissonance in the results, given that there were a considerably lower number of patients with disc displacement without reduction in our sample, when compared with theirs.

It has been hypothesized that form and function are closely linked; thus, in the presence of condylar morphology changes, disc position should also change.¹¹ Although expected, the association between condyle morphology and TMJ disc displacement was not observed in the present study. A different theory may explain our results, as other factors may affect condyle morphology (*e.g.* excessive occlusal force), condyle morphology may be interpreted as a normal variation and not a pathology itself, and may not be related to disc position.³⁴ Disc displacement, as in the mediolateral position, may also have a further association with jaw function movement, rather than the morphology of the TMJ's components.³⁴

Nonetheless, some studies found a higher prevalence of anterior disc displacement in convex and rounded condyles,¹⁵ and angled condyles.¹⁶ Another study applied a more accurate method, in which condyle dimensions were defined by measures and found an association between narrower condyles in the anteroposterior and transverse directions with disc displacement.³⁵ Discrepancies in the results may be associated with different methodologies of evaluating condylar morphology.

Biconcavity is considered to be the normal form of TMJ disc. Changes in disc morphology are a characteristic factor of internal TMJ derangement.^{1,3} The prevalence of discs with normal morphology in our sample may indicate that this is a sample in the early stages of internal derangement. The results showed an association between disc displacement and changes in the morphology of the articular disc, in agreement with the literature.^{7,15,24,36–38} Most of the normally positioned discs showed a biconcave shape, while none of them had a folded shape. Additionally, all of the folded discs were found in patients in advanced stages of internal derangement (ADWOR). Similar results were

found by Murakami *et al*²⁴ and Hirata *et al*.¹⁰ These findings indicate that the articular disc tends to become deformed with the advancement of disc displacement. We cannot, however, assert a relationship of cause and effect because of this study's design; a longitudinal study would be more appropriate for that.

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Conclusion

In conclusion, no correlation was found between the morphology of the condyle and TMJ disc displacement. However, an association between the shape of the articular disc and disc displacement was observed.

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