*Int. J. Oral Maxillofac. Surg. 2013; 42: 765–770*
http://dx.doi.org/10.1016/j.ijom.2013.01.004, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
TMJ Disorders

# Biometric parameters of the temporomandibular joint and association with disc displacement and pain: a magnetic resonance imaging study

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*I. Vieira-Queiroz, M. G. Gomes Torres, C. de Oliveira-Santos, P. S. Flores Campos, I. M. Crusoé-Rebello: Biometric parameters of the temporomandibular joint and association with disc displacement and pain: a magnetic resonance imaging study. Int. J. Oral Maxillofac. Surg. 2013; 42: 765–770.* 

*Abstract.* The aim of this study was to evaluate the relationship between biometric parameters of the components of the temporomandibular joint (TMJ), articular disc displacement, and TMJ pain. Magnetic resonance imaging (MRI) examinations of 185 patients were assessed (39 males and 146 females (370 TMJs), mean age 41.3 years, range 18–79 years). The antero-posterior length of the condyle was measured in its medial and lateral regions, as well as the transverse length of the condyle. Possible associations between linear measurements of the condyle, presence of disc displacement, and joint pain were tested. Although pain was more commonly reported among patients with disc displacements, this association was not statistically significant. We found statistically significant associations showing that the antero-posterior length of the condyle at the lateral pole (D1L), the antero-posterior length of the condyle at the medial pole (D1M), and the transverse length of the condyle (D2) were higher among patients without disc displacements when compared to those with unilateral or bilateral displacements. This study showed that disc displacement was associated with smaller condyles in the antero-posterior and transverse dimensions when compared to condyles in subjects with normal disc position.

Key words: temporomandibular joint; temporomandibular joint disorders; temporomandibular joint disc; magnetic resonance imaging.

Accepted for publication 9 January 2013
Available online 9 March 2013

Temporomandibular joint (TMJ) disorders may show non-specific clinical presentations, and diverse conditions may be responsible for the patient's symptoms.[1] The conditions affecting the TMJ can be classified into three groups: (1) muscle disorders, (2) disc displacements and (3) joint pain, arthritis, and arthosis.[2] TMJ disc displacement has been defined as an abnormal relationship between the articular disc and the mandibular condyle, articular fossa, and eminence.[3] Signs and symptoms associated with TMJ disorders affect between 4% and 28% of the adult population and tend to occur more often in women.[4–7]

Classification of the disc location in the closed mouth position (CMP) may be based on a clock-hands analogy. The disk is considered to be in its normal position when the thicker portion of its posterior band lies on the uppermost portion of the condyle, i.e. between 11 and 1 o'clock in relation to the condyle. Discs in a position between 9 and 11 o'clock are considered displaced.[5,8]

Magnetic resonance imaging (MRI) is currently the best imaging modality for the evaluation of disc position.[9–11] With this method, it is possible to visualize soft tissue and joint structures, allowing better understanding of sources of pain and eventual discrepancies between other imaging findings and clinical symptoms.[9,12] MRI has been considered the gold standard for the study and diagnosis of soft tissue components of TMJ.[13–16]

The position and morphology of the components of the TMJ are of great importance in the diagnosis of TMJ disorders. Several parameters can be used to evaluate the relationship between the mandibular condyle, articular fossa, and disc. These parameters include subjective criteria for articular spaces,[17] the position of the condyle in the articular fossa,[18,19] the horizontal angle of the condyle,[20,21] and the slope of the articular eminence.[22]

This study assessed the correlation between biometric parameters of anatomic structures of the TMJ not fully explored previously and articular disc displacement, using MRI, in patients with and without joint pain.

## Materials and methods

The study was approved by the Human Research Ethics Committee of the Federal University of Bahia, Brazil (reference No. 0022036800010). Two hundred consecutive exams from patients referred to a private diagnostic imaging clinic for bilateral MRI of the TMJ during the period from May to September 2011 were included in the sample. Exclusion criteria included the presence of TMJ bony pathologies and patients aged less than 18 years. Gender and the presence of joint pain, i.e. as reported by the patient, were registered according to information in the patient records. Oblique parasagittal sections were obtained and corrected by the horizontal angulation of the condyle, in both the open mouth position (OMP) and the CMP. A Signa MR system (General Electric, Milwaukee, WI, USA) was used, operating at 1.5 T with a $6 \times 8$-cm bilateral surface coil, in the supine position, with the sagittal plane perpendicular to the horizontal plane, and the Frankfort plane parallel to the opening of the scanner. A $256 \times 256$ matrix was used, 145-mm field of view, and pixel size of 0.60 mm $\times$ 0.57 mm. Ten slices, 2-mm thick, were obtained for each TMJ using a T1 sequence. For the acquisition of OMP images, a device (Burnett TMJ device, TMJ-200s/n 0650; Medrad, Pittsburgh, PA, USA) was used to keep the mouth open during the examination.

The examinations were assessed by an oral and maxillofacial radiologist with over 10 years' experience in MRI for TMJs. Criteria described by Katzberg and Westesson[21] and adapted by Milano et al.[23] were followed. Joints were then grouped, according to their diagnosis, as in a normal position or as disc displacement (Fig. 1). Patients were grouped according to the presence of disc displacement: no disc displacement, unilateral displacement, and bilateral displacement. Furthermore, in the OMP, normal or abnormal disc position was registered.

The images were then submitted to two previously calibrated independent observers who performed linear measurements of the condyles using a computer program (Centricity DICOM Viewer, version 2.2, 2004, GE Medical Systems). Measurements were performed in optimal environmental conditions in three different sessions. The right and left TMJs of each patient were assessed sequentially, in the same sessions. All measurements were then repeated, with at least a 2-week interval between each measurement session. Inter-rater agreement was measured according to Lin's concordance correlation coefficient.

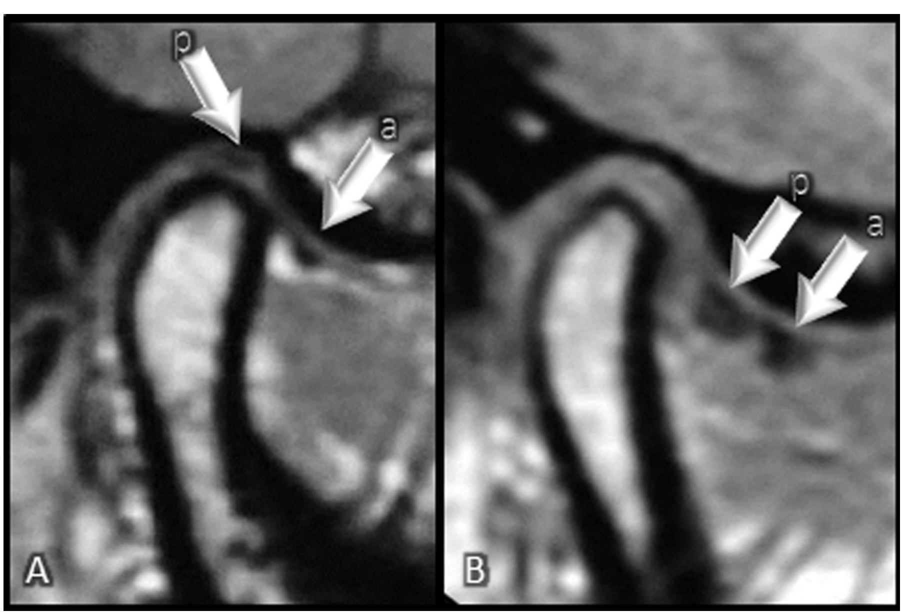


*Fig. 1.* MRI sagittal images of TMJs displaying the hyposignal areas (arrows) corresponding to the anterior (a) and posterior (p) bands of the articular discs. The disc is in its normal position in A, and disc displacement is observed in B. Note that cortical bone is seen as dark areas (hyposignal) in MRI T1 images.

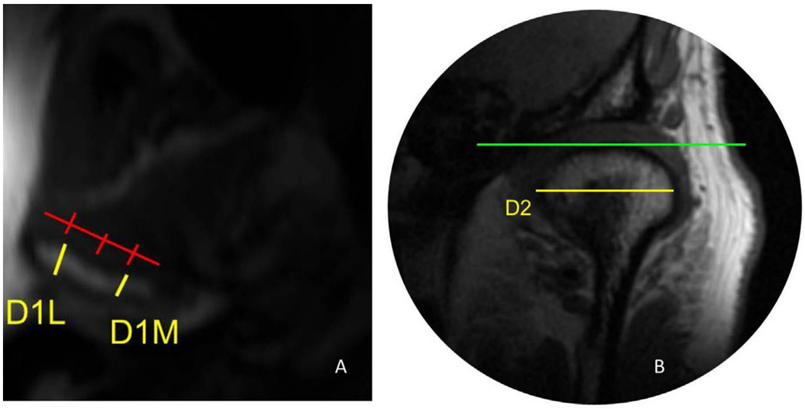


*Fig. 2*. (A) MRI axial image of the right mandibular condyle, identifying the medial and lateral regions where D1L and D1M were measured. (B) MRI coronal image of the TMJ, showing the extent of D2 in the left mandibular condyle.

The most central area of the mandibular condyle was selected to assess the biometric parameters of the structures. The antero-posterior lengths of the condyle at the lateral pole (D1L) and medial pole (D1M) were measured in the axial plane. The transverse length of the condyle (D2) was measured in the coronal plane (Fig. 2).

Statistical analyses were used to assess potential differences in measurements among TMJ diagnoses and patient groups, i.e. disc displacement (*t*-test and ANOVA, respectively), disc position in the OMP (*t*-test), and gender (*t*-test). Additionally, the $\chi^2$ test was used to compare the presence of pain among groups. The significance level was set at 0.05.

*Table 1*. Mean linear measurements (D1L, D1M and D2; in mm) of the condyles according to patient group with regard to the presence of disc displacement. Standard deviations are in parenthesis. Statistically significant differences between groups were found (ANOVA).

| | No displacement | Unilateral displacement | Bilateral displacement | *P*-value |
|---|---|---|---|---|
| D1L | 6.77 (1.26) | 6.92 (1.29) | 6.19 (1.27) | 0.003 |
| D1M | 6.51 (1.51) | 6.72 (1.36) | 5.96 (1.47) | 0.011 |
| D2 | 19.89 (1.89) | 18.86 (2.71) | 18.20 (2.86) | 0.036 |

D1L, antero-posterior length of the condyle at the lateral pole; D1M, antero-posterior length of the condyle at the medial pole; D2, transverse length of the condyle; ANOVA, analysis of variance.

*Table 2*. Mean linear measurements (D1L, D1M and D2; in mm) of the condyles according to TMJ diagnosis with regard to the presence of disc displacement. Standard deviations are in parenthesis. Statistically significant differences were found (Student's *t*-test).

| | No displacement | Disc displacement | *P*-value |
|---|---|---|---|
| D1L | 6.81 (1.27) | 6.26 (1.30) | <0.0001 |
| D1M | 6.57 (1.47) | 6.03 (1.44) | 0.0005 |
| D2 | 19.63 (2.21) | 18.21 (2.80) | <0.0001 |

D1L, antero-posterior length of the condyle at the lateral pole; D1M, antero-posterior length of the condyle at the medial pole; D2, transverse length of the condyle; TMJ, temporomandibular joint.

*Table 3*. Mean linear measurements (D1L, D1M and D2; in mm) of the condyles according to TMJ diagnosis with regard to disc location in OMP. Standard deviations are in parenthesis. Statistically significant differences were found (Student's *t*-test).

| | Normal position | Abnormal position | *P*-value |
|---|---|---|---|
| D1L | 6.63 (1.28) | 5.80 (1.30) | <0.0001 |
| D1M | 6.36 (1.46) | 5.73 (1.58) | 0.0042 |
| D2 | 18.98 (2.51) | 17.95 (3.20) | 0.0089 |

D1L, antero-posterior length of the condyle at the lateral pole; D1M, antero-posterior length of the condyle at the medial pole; D2, transverse length of the condyle; TMJ, temporomandibular joint; OMP, open mouth position.

## Results

After the exclusion of patients under the age of 18 years ($n = 15$), the sample comprised 185 patients, 146 (78.9%) female and 39 (21.1%) male. The patients ranged in age from 18 to 79 years; the average age was 41.3 years. Nearly a third (32.5%) of the patients did not present disc displacement, whereas those with disc displacement (67.5%) presented this condition bilaterally in most of the cases (66.4%). Of the 370 TMJs studied, 57.02% (i.e. 211/370, or 57%) had disc displacement (71.5% with reduction and 28.5% without reduction). Of the 185 patients studied, 51.4% did not present joint pain, 27.5% had unilateral pain, and 21.1% had bilateral pain.

The articular disc presented in a normal position in the OMP in 85.4% of the TMJs analyzed, and 78.4% of the patients had the disc in normal position bilaterally. The median linear measurements were as follows: D1L 6.52 mm (6.42 mm and 6.6 mm for the right and left sides, respectively), D1M 6.27 mm (6.19 mm and 6.31 mm for the right and left sides, respectively), and D2 18.81 mm (18.77 mm and 18.84 mm for the right and left sides, respectively). Medians of D1L and D2 were significantly higher in males ($P < 0.001$). Statistically significant differences between D1L and D1M were also observed, with D1L relatively higher than D1M ($P < 0.001$), showing that the lateral pole is statistically larger than the medial pole.

Lin's concordance correlation coefficient ($R_c$) showed inter-rater agreement for linear measurements as follows: for the right side, D1M 0.6198, D1L 0.8248, and D2 0.9566; for the left side, D1M 0.7855, D1L 0.7489, and D2 0.9634.

Table 1 shows the mean linear measurements of the condyles according to the patient group with regard to the presence of disc displacement. Statistically significant differences between groups were observed ($P < 0.05$). In the evaluation of patients with unilateral disc displacements, D2 was higher for the TMJs without displacement compared with the contralateral TMJs with disc displacement ($P = 0.018$ and $P = 0.022$ for disc displacements on the right and left sides, respectively). Table 2 shows that the mean linear measurements were higher for the TMJs without disc displacement compared with

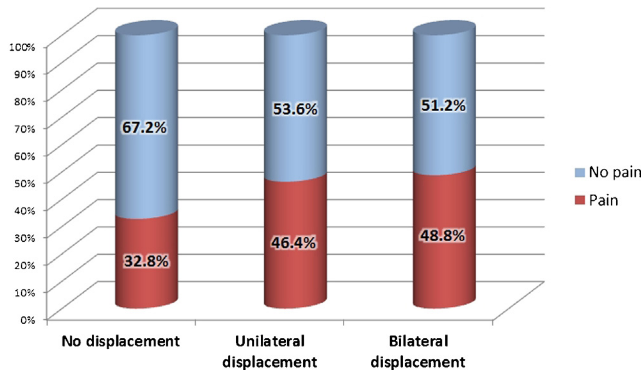


*Fig. 3.* Association between joint pain as reported by the patient and the presence of disc displacement. Differences were not statistically significant ($P = 0.065$).

TMJs with disc displacement ($P < 0.05$). Similarly, Table 3 presents mean condylar measurements of TMJs in the OMP, showing that discs in normal position had higher values for all linear measurements ($P < 0.05$) than discs in abnormal positions. These results demonstrate that patients with articular disc displacement tend to present narrower mandibular condyles, both antero-posteriorly and transversely.

Although patients reported pain more often in cases where unilateral or bilateral disc displacements were present when compared to those without disc displacement (Fig. 3), this difference was not statistically significant ($P > 0.05$). Similarly, pain was more frequent among patients who presented abnormal disc positions unilaterally or bilaterally in OMP (Fig. 4), however this difference was not statistically significant ($P > 0.05$).

## Discussion

Excellent soft tissue contrast and high resolution are regarded as the major advantages of MRI for analyzing soft tissue components of the TMJ, and MRI is considered the gold standard for the diagnostic evaluation of the location and anatomic characteristics of the articular disc.[5,10,11,14–16,23–26] This study also used MRI to perform measurements of bony structures of the TMJ. Although this imaging modality is not the first choice for the purpose of analyzing hard tissues, previous studies have shown that MRI may be considered as an adequate examination for the assessment of bone, such that further examinations (e.g. computed tomography) that may expose patients to ionizing radiation are not required.[18,20,27–30]

Disc displacement is an alteration that may compromise the proper function of the TMJ.[3] Diagnostic evaluation of disc position by MRI is performed mainly using sagittal acquisitions. However, combined use of sagittal and corrected coronal MR images increases the diagnostic accuracy of this method. Brooks and Westesson[31] observed that this association reduced the prevalence of false-positive and false-negative diagnoses when only sagittal sections were analyzed in 11% of cases. Tasaki and Westesson[32] obtained similar results, avoiding false-negatives in 13% of cases. Katzberg et al.[33] found an accuracy of 83% for coronal and sagittal MR images to identify the position of the disc, and suggested that coronal slices can better determine the actual position of the disc because these images can display lateral displacements without the presence of anterior displacement. Matsuda et al.[25] observed that the coronal and sagittal images are complementary. In the present study, the examinations were analyzed on axial, coronal, and cross-sectional images, corrected according to the horizontal angle of the condyle, and every slice from the medial pole to the lateral pole was viewed, in CMP and OMP, minimizing the possibility of false-positives or false-negatives.

Some studies have shown that bilateral disc displacements are three times more common than unilateral displacements, and disc displacements without reduction are the most common.[25] Mariz et al.[29] demonstrated bilateral disc displacement in 70% of patients. Milano et al.[23] found that 80% of patients were affected by bilateral dislocation. Our findings show bilateral disc displacements approximately two times more often (46%) than both groups with unilateral dislocation together (23%). These results reinforce the idea that contralateral TMJs tend to be equally affected by disc displacements because TMJs constitute one functional unit.[18]

A possible association between articular disc position in OMP and linear measurements was also examined. The results showed statistically significant differences in the transverse length of the condyle of TMJs with normal and abnormal disc positions, suggesting that the condyles that are narrower transversely are more likely to present disc displacement without reduction. Furthermore, TMJs with discs in normal positions in OMP had a tendency to present higher values for all linear measurements compared with those in abnormal positions (Figs. 3 and 4). We suggest that when significantly reduced dimensions of bony condylar morphology are observed in conventional radiographs, such as panoramic radiographs, MRI could be indicated, especially if this is associated with pain.

Pain is the most relevant event associated with TMJ disorders.[26,34] Many authors have emphasized the importance of the association of clinical information and imaging for the diagnosis of TMJ disorders,[10,11,23–26,29,34,35] as altered position of the disc may or may not be associated with clinical symptoms.[23,24,35] Emshoff et al.[34] studied the effect of TMJ pain on the prevalence of intra-articular disorders,

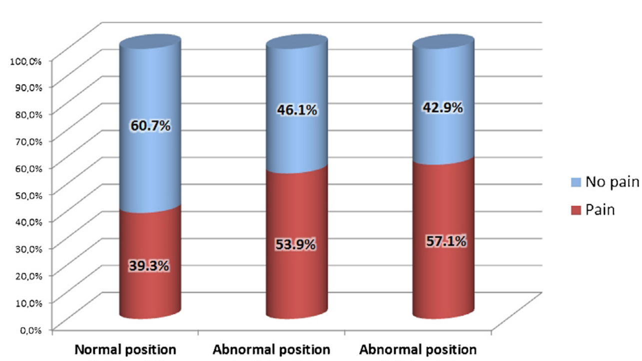


*Fig. 4.* Associations between joint pain as reported by the patient and the disc position in open mouth position. Differences were not statistically significant ($P = 0.076$).

assessed on MRI scans. Their results showed that TMJ pain was significantly associated with abnormal positions of the disc, and the pain was more frequent in patients with disc displacement without reduction. Campos et al.[36] also found that joint pain was significantly more frequent in cases of disc displacement without reduction. However, in the present study, the presence of pain could not be associated with imaging findings of disc displacement, showing that although most patients with altered disc positions reported pain (Figs. 3 and 4), a statistically significant difference when compared to those with normal disc positions could not be demonstrated.

Pain may also be associated with TMJ effusion, which may be better assessed with T2-weighted MRI sequences. T2-weighted protocols are thus indicated in cases of acute pain,[37] however these MRI sequences were not the object of our study. For analysis of disc position and measurement of distances, we analyzed only anatomical T1 sequences available from a databank, and the presence of pain was registered according to the patient records, i.e. based on their report of pain.

Pedullà et al.[30] evaluated linear measurements on MRI axial sections of 28 subjects without TMJ disorders. The mean transverse length of the condyle was 17.13 mm for female patients and 18.17 mm for male patients. The mean antero-posterior diameter was 6.86 mm for females and 7.2 mm for males. In the present study, we found slightly higher values. The median transverse length of the condyle (D2) of asymptomatic patients was 19.64 mm for females and 20.47 mm for males. In addition, it was observed that the median antero-posterior diameter was slightly greater in females (D1L 7.0 mm; D1M 6.7 mm) than in males (D1L 7.0 mm; D1M 6.2 mm).

Inter-rater agreement was relatively lower for D1L and higher for D2. A possible explanation is the fact that D1 distance measurements were in general much smaller than D2. Thus, small differences in measurements, which may be expected when dealing with millimetric distances, have a higher impact on the concordance correlation coefficient.

Girardot[38] assessed the difference in condylar position between hyperdivergent and hypodivergent facial types. The author found that the amount of condylar distraction was greater among subjects with hyperdivergent facial types, both in the horizontal and vertical planes. The forward displacement of condyles in the hyperdivergent group was over twice the forward displacement totalled for the hypodivergent group. This is particularly relevant considering that posterior displacement of the condyle away from the eminence may compromise joint stability and/or function. Thus, individuals with hyperdivergent facial types are more prone to TMJ internal derangements,[38] which may also be more common with those who present narrower mandibular condyles. Careful planning of orthodontic treatments for patients with narrower condyles and hyperdivergent facial types is advised, since changes in dentition affecting condylar position may further influence stability and/or articular function.

It is concluded that narrower mandibular condyles, in both the antero-posterior and transverse directions, are more associated with articular disc displacements, and such patients do not necessarily have a higher prevalence of pain than those without disc displacement.

## Funding

There was no funding agency for this paper.

## Competing interests

There are no conflicts of interest for this paper, either personal or commercial.

## Ethical approval

The study was approved by the Human Research Ethics Committee of the Federal University of Bahia, Brazil (reference No. 0022036800010).

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