Clin Oral Invest
DOI 10.1007/s00784-013-0984-5

ORIGINAL ARTICLE

Comparison of magnetic resonance imaging findings in temporomandibular joints of the two sides

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Received: 5 August 2012 / Accepted: 8 April 2013

Abstract
Objectives The aim of this investigation was to assess the association of magnetic resonance imaging (MRI)-diagnosed temporomandibular joint (TMJ) disorders [i.e., disc displacement with reduction, disc displacement without reduction (DDNR), osseous changes (OC), joint effusion] on the same side as well as in the joints of the two sides of the same individual.
Materials and methods A total of 199 patients undergoing bilateral MRI of the TMJs were included in the study. A single variable correlation matrix was created to assess the within- and between-side correlation of single diagnoses. Then, based on 12 possible combinations of diagnoses per each side, a contingency table was created to assess the chi-square values of the differences between the observed and expected frequencies of the different cross-combinations. Multiple variable permutation test was performed to assess the null hypothesis that the diagnoses in the right and left joints are not related.
Results Within the signs of the same side, DDNR was positively correlated with OC. As for combination of diagnoses, the presence of a specific combination of signs on one side implied the same combination of signs on the other side. The global multivariate permutation test with Tippett combination was significant at $p<0.001$, showing that the null hypothesis of independence between diagnoses of the two sides was rejected.
Conclusions It can be suggested that disc displacement without reduction is associated with osseous changes of the same joint and that joints of the two sides are likely to be affected by the same combinations of MRI signs.
Clinical relevance This investigation supports the concept that the two temporomandibular joints work as a unit.

Keywords Temporomandibular joint · Magnetic resonance · Disc displacement · TMJ effusion · Osseous changes

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Introduction

Among the instrumental devices that have been proposed over the years to integrate the clinical assessment of temporomandibular joint (TMJ) disorders, imaging techniques are the most investigated [1]. Several investigations showed that magnetic resonance imaging (MRI) is the most accurate technique to depict the anatomy of TMJ structures [2, 3] and to assess the agreement of imaging signs with clinical diagnoses [4–8].

Despite the amount of literature on the use of magnetic resonance imaging for TMJ disorders, there is a paucity of works on the relationship of different pathological signs. From the available literature, it emerged that advanced stages of disc displacement are associated with bone degenerative changes within the TMJ [9] as well as with intra-articular effusion [10–12], but no data are available on the MRI findings in contralateral joints. Knowing the imaging signs that are associated with certain findings in the joints of the opposite sides may be important in terms of both pathophysiological and clinical viewpoints. Indeed, while much debate has been made over the years on the peculiar nature

Published online: 03 May 2013

of the temporomandibular joints of the two sides (i.e., they are unique in the body, since they cannot work independently from each other) [13], the frequency and pathophysiology of disorders affecting the two joints at an individual level are not known, and the clinical implications of diagnosing and treating a TMJ disorder may be worthy to be explored also on the basis of the expected presence of pathologies in the contralateral joint.

Based on these premises, the present investigation aimed to answer the clinical research question: in an individual with TMJ disorders, are MRI findings of the joints of the two sides (right vs. left) related? The specific aim was to assess the association of three TMJ disorders (i.e., disc displacement, intra-articular effusion, and osseous changes), as diagnosed with magnetic resonance imaging, in joints of the two sides. The null hypothesis was that the findings in the right and left joints were not related. As an additional aim, the correlation of the three disorders within the same joint was also assessed.

Materials and methods

Study sample and design

Participants were recruited from patients attending the TMD Clinic, Department of Maxillofacial Surgery, University of Padova, Italy, and seeking treatment for temporomandibular disorders. All subjects who underwent a bilateral magnetic resonance imaging of the temporomandibular joints during the diagnostic process in the period from January 2009 to December 2011 (N=276) were asked to give their consent to use their MRI findings from scientific purposes, and all of them accepted. MRI from 77 patients was excluded from statistical analysis due to the presence of systemic diseases affecting joint and/or masticatory muscles, such as fibromyalgia or other rheumatic diseases diagnosed according to the American College of Rheumatology criteria [14].

Therefore, a total of 199 patients (78 % females; mean age 53.7; range 18–75) were included in the statistical analysis for an evaluation of the association between MRI signs of disc displacement, osseous changes, and joint effusion. Ethical approval for using the patients' MRIs for research purposes was achieved by the local Institutional Review Board.

Magnetic resonance

MRI was carried out with a 1.5 Tesla (GE Signa Contour; GE Medical Systems, Buc, France) with a bilateral dedicated circular (8 cm diameter) surface coil for the study of the right and left TMJs. Sequential Gradient Echo T1-weighted and Fast Stir T2-weighted bilateral images with the subjects at both closed mouth with teeth in the maximum intercuspal and maximum opening mouth positions were made. The latter position was obtained by means of a wooden intermaxillary device at the same opening as measured clinically.

The articular disc was identified, in sagittal T1-weighted images, as an area of hypointensity with a biconcave shape above the condylar structure, and its position has been categorized according to the literature [15, 16] as follows:

Superior (normal) disc position (N) Posterior band of articular disc was located above the apex of the condylar head ("between the 11:30 and 12:30 o'clock positions") in the intercuspal position and thin intermediate zone between the condyle and the eminence in the maximum opening mouth position.

Disc displacement with reduction Posterior band of the disc was located anteriorly to the condylar head at the closed

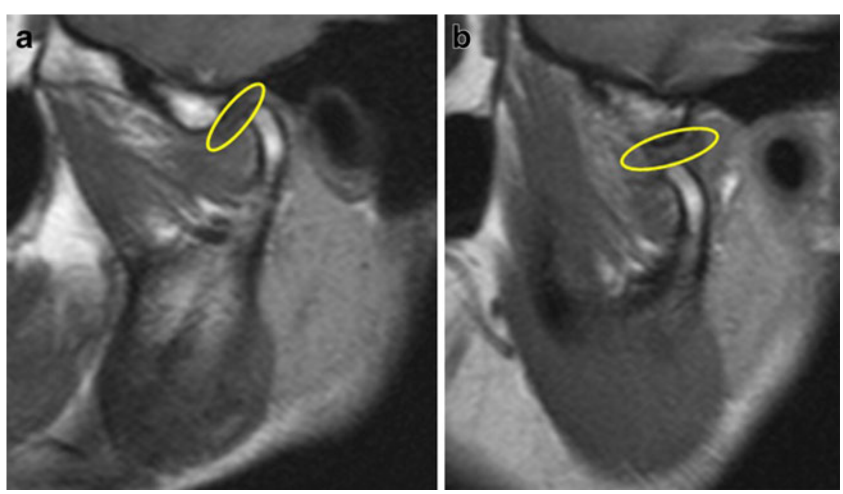

Fig. 1 Disc displacement with reduction in closed (**a**) and open mouth (**b**) positions

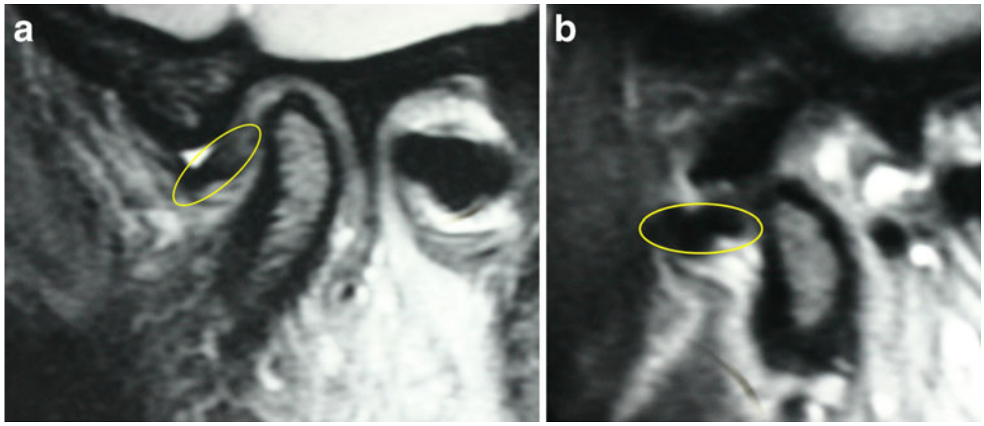

Fig. 2 Disc displacement without reduction in closed (**a**) and open mouth (**b**) positions

mouth position, but normal disc condyle relationship was established in the maximal opening position.

Disc displacement without reduction Posterior band was positioned anteriorly to the condyle either at closed or maximal opening mouth position.

Osseous changes (OC) of the TMJ tissues were also assessed in the T1-weighted images and were diagnosed as follows [16]:

No osteoarthritis There were normal relative size of condylar head and no subcortical sclerosis or articular surface flattening and no deformation due to due to subcortical cyst, surface erosion, osteophytes, or generalized sclerosis.

Osteoarthritis There was a deformation due to subchondral cyst, surface erosion, osteophyte, or generalized sclerosis.

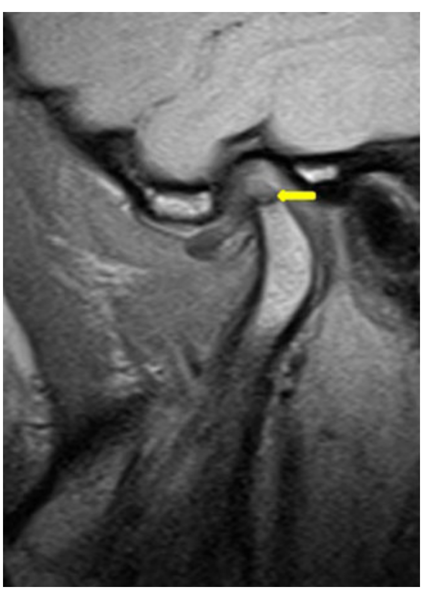

Fig. 3 Osseous changes with an erosion of the condylar cortical bone in a joint with an anteriorly displaced disc

Joint effusion (JE) has been identified as a large area of high signal intensity inside the joint space, so that the presence/absence of effusion was defined as follows, in accordance with the hypothesis that mild to moderate amount of fluid can be detected in normal joints, as well [16, 17]:

No effusion There was no area or thin lines of hyperintensity.

Effusion There was presence of areas of high signal intensity (bright signal) greater than 2 mm of superior–inferior height or anterior–posterior length inside either articular compartment.

To avoid interpretation bias related with the different radiologists assessing the images, magnetic resonance images were interpreted by the expert clinicians of this investigation (D.M.; L.G.N.), who recorded together the presence/absence of the different images signs and took each decision by consensus. In those cases where consensus was not reached, the certification provided by the radiologist who performed the examination was taken as the final decision (Figs. 1, 2, 3, and 4).

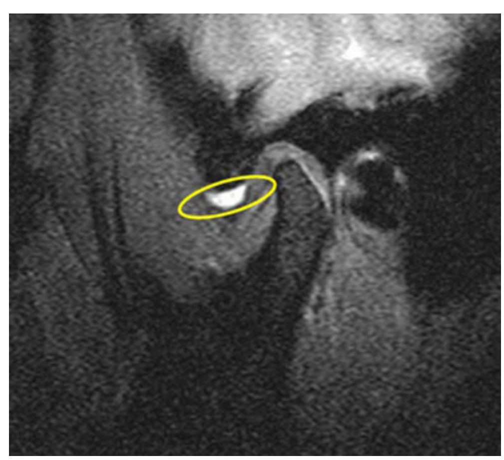

Fig. 4 Intra-articular effusion

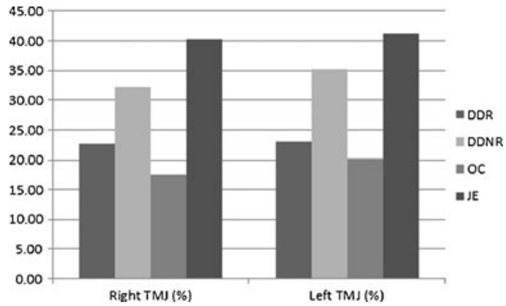

Fig. 5 Frequency of the different diagnoses in the right and left joints

Statistical analysis

The observed frequency of the MRI-detected disorders under investigation [disc displacement with reduction (DDR), disc displacement without reduction (DDNR), OC, and JE] was assessed for each joint, irrespective of the clinical diagnoses. A single-variable correlation matrix was created to assess the correlation between the MRI diagnoses of the same side and, for each diagnosis, with diagnoses of the contralateral joint. Then, 12 possible combinations of diagnoses per each side were identified based on the presence/absence of osseous changes, joint effusion, and either disc displacement with or without reduction, and a contingency table was created to assess the chi-square values based on the distance between the observed and expected frequencies of the different cross-combinations. Then, for testing the existence of correspondences between the diagnoses in the right and left joints, a multivariate permutation test with Tippett combination was performed to assess the significance of the global test. In case of significance of the global test, the partial p values can be adjusted with a closed testing procedure (for controlling the multiplicity) and compared with the significance α level to determine the partial test to which the global significance can be mostly attributed. The proposed procedure does not need any assumptions about the distribution of the test statistics (e.g., chi-square or others) and takes implicitly into account the dependence among them, even if the multivariate distribution is not known.

The null hypothesis underlying the statistical procedures was that the different combinations of diagnoses between the two sides were not related. The significance level for rejecting the null hypothesis was set at alpha equal to 0.05. All statistical procedures were performed with the software SAS 9.0.

Results

The frequency of each MRI diagnosis was similar between the right and left joints. In both joints, the most frequent sign was represented by osseous changes in TMJ tissues (more than 40 % of patients), followed by disc displacement without reduction (32–35 %), disc displacement with reduction (around 23 %), and effusion (17–20 %) (Fig. 5).

The pair-wise correlation matrix showed that within the signs of the same side, DDNR was positively correlated with OC. No correlations were found for JE or for DDR with other signs on the same joint, with the only exception of a positive correlation between JE and DDNR in the left joints. Comparing the right and left MRI signs, the main finding was that the presence of a specific diagnosis on the right side is correlated with the presence of the same symptom on the left side and vice versa; viz., the same MRI sign was detected in both joints. The correlation was stronger for

Table 1 Pairwise correlations matrix

	Right joint				Left joint			
	DDRr	DDNRr	JEr	OCr	DDRl	DDNRl	JEl	OCl
Right joint								
DDRr	1.00	–	0.00 (0.999)	0.07 (0.385)	0.47 (0.001)[a]	−0.12 (0.082)	−0.09 (0.304)	0.16 (0.030)[a]
DDNRr	–	1.00	0.08 (0.319)	0.23 (0.002)[a]	−0.17 (0.012)[b]	0.28 (0.000)[a]	−0.02 (0.758)	−0.07 (0.312)
JEr	0.00 (0.999)	0.08 (0.319)	1.00	−0.06 (0.443)	0.00 (0.984)	−0.06 (0.380)	0.26 (0.000)	−0.17 (0.014)
OCr	0.07 (0.385)	0.23 (0.002)[a]	−0.06 (0.443)	1.00	0.01 (0.858)	0.02 (0.788)	−0.16 (0.028)[b]	0.50 (0.000)[a]
Left joint								
DDRl	0.47 (0.001)[a]	−0.17 (0.012)[b]	0.00 (0.984)	0.01 (0.858)	1.00	–	0.05 (0.537)	0.03 (0.720)
DDNRl	−0.12 (0.082)	0.28 (0.000)[a]	−0.06 (0.380)	0.02 (0.788)	–	1.00	0.18 (0.018)[a]	0.26 (0.001)[a]
JEl	−0.09 (0.304)	−0.02 (0.758)	0.26 (0.000)	−0.16 (0.028)[b]	0.05 (0.537)	0.18 (0.018)[a]	1.00	−0.09 (0.282)
OCl	0.16 (0.030)[a]	−0.07 (0.312)	−0.17 (0.014)	0.50 (0.000)[a]	0.03 (0.720)	0.26 (0.001)[b]	−0.09 (0.282)	1.00

Raw correlation values are presented, with their respective p values in parentheses

[a] A positive significant correlation

[b] A negative significant correlation

Table 2 Contingency table to compare the frequency (no. of joints) distribution of the different combinations of the right and left MR signs

	Left joint											
	No[a]	DDR	DDNR	JE	OC	DDR/JE	DDR/OC	DDNR/JE	DDNR/OC	JE/OC	DDR/JE/OC	DDNR/JE/OC
Right joint												
No[a]	26 (5.73)	2 (1.28)	5 (0.05)	1 (0.32)	3 (1.16)	5 (1.0)	1 (4.0)	4 (0.40)	8 (0.06)	1 (0.29)	0	2 (0.45)
DDR	1 (2.9)	7 (25.5)	3 (1.16)	0 (0.51)	1 (0.23)	1 (0.00)	1 (0.29)	0 (0.85)	1 (0.95)	0 (0.17)	0	2 (1.19)
DDNR	8 (0.73)	2 (0.11)	7 (12.4)	0 (0.63)	0 (2.0)	0 (1.16)	0 (2.11)	2 (0.84)	2 (0.42)	0 (0.21)	0	0 (1.16)
JE	3 (0.08)	0 (0.67)	0 (0.85)	3 (27.4)	0 (0.85)	2 (4.53)	1 (0.01)	0 (0.45)	0 (1.35)	0 (0.09)	0	0 (0.49)
OC	3 (1.03)	0 (1.43)	0 (1.81)	0 (0.57)	12 (57.1)	0 (1.05)	0 (1.91)	0 (0.95)	1 (1.21)	0 (0.19)	0	3 (3.62)
DDR/JE	1 (0.47)	1 (0.42)	1 (0.16)	1 (2.94)	0 (0.66)	1 (0.97)	0 (0.70)	0 (0.35)	1 (0.0)	0 (0.07)	0	1 (0.97)
DDR/OC	1 (3.80)	1 (0.17)	0 (1.91)	0 (0.60)	1 (0.43)	0 (1.10)	15 (83.9)	0 (1.0)	2 (0.34)	0 (0.20)	0	0 (1.10)
DDNR/JE	2 (0.0)	1 (0.42)	0 (0.66)	0 (0.21)	0 (0.66)	2 (6.72)	0 (0.7)	2 (7.72)	0 (1.05)	0 (0.07)	0	0 (0.38)
DDNR/OC	6 (0.57)	1 0.64)	2 (0.21)	1 (0.01)	1 (1.13)	0 (1.60)	2 (0.28)	1 (0.14)	13 (17.0)	0 (0.29)	0	2 (0.09)
JE/OC	1 (0.01)	0 (0.30	1 (1.0)	0 (0.12)	1 (1.0)	0 (0.22)	0 (0.40)	0 (0.20)	0 (0.60)	1 (22.9)	0	0 (0.22)
DDR/JE/OC	1 (1.83)	0 (0.07)	0 (0.09)	0 (0.03)	0 (0.09)	0 (0.05)	0 (0.10)	0 (0.05)	0 (0.15)	0 (0.01)	0	0 (0.05)
DDNR/JE/OC	3 (0.53)	0 (0.52)	0 (0.66)	0 (0.21)	0 (0.66)	0 (0.38)	0 (0.70)	1 (1.19)	2 (0.84)	0 (0.07)	0	1 (0.97)

The respective chi-square values are shown in parentheses; diagnoses for the right joints, rows; and diagnoses for the left joints, columns. For the column DDR/JE/OC, the chi-square values were not shown because no diagnoses were made

[a] Absence of any diagnoses

DDR (R=0.47) and OC (R=0.50). Also, negative correlations were found between OC and JE and between DDR and DDNR on the opposite sides (Table 1).

Correspondence analysis between the different combinations of diagnoses for the left and right joints showed that the frequencies are primarily concentrated in the main diagonal; thus, the presence of a specific combination of signs on one side implies the same combination of signs on the other side. As pointed out by the frequencies in the first column (left joint) and in the first row (right joint), bilateral absence of signs was described in 26/199 (13.0 %) of patients, while unilateral signs, viz., presence of signs on one side but absence of MRI signs on the other one, were described in 30/199 (15.1 %) of the left joints and 32/199 (16.0 %) of the right joints. The combination DDR/JE/OC was not observed on the left side. The observed frequencies of the cells corresponding to equal combination of symptoms in the right and left joints were much greater than the expected frequencies in the hypothesis of independence between the two sides. The highest chi-square values, indicating association of MRI signs combinations between the two sides, were related with the bilateral presence of DDR and OC (X^2=83.9), OC alone (X^2=57.1), JE alone (X^2=27.4), DDR alone (X^2=25.5), JE and OC (X^2=22.9), and DDNR and OC (X^2=17.0). Other less evident positive associations were between JE on the right and DDR/JE on the left (X^2=4.5), DDNR/JE on the right and DDR/JE on the left (X^2=6.7), and OC on the right and DDNR/JE/OC on the left (X^2=3.6). Also, some negative correspondences of pathologies could be observed, for which the observed frequency was much lower than the expected frequency in the case of no association. Relevant negative associations were between the absence of pathology in one joint and the presence of DDR and OC in the other joint (X^2=4.0 for the right vs. left joints and 3.8 for the left vs. right joints) (i.e., in the presence of DDR/OC on the left side, it is probable to observe some disease on the other side). Similar negative associations were pointed out between DDNR and OC on one side and the absence of pathology on the other side (Table 2).

The global multivariate permutation test with Tippett combination was significant at p<0.001, showing that the null hypothesis of independence between the diagnoses of the two sides was rejected in favor of the hypothesis of positive global association at the significance level α=0.001. The adjusted p values exceeded the significance level, except for the tests where a specific symptom on one side was compared with the same symptom on the other side (Table 3). Hence, the presence of a specific MRI sign on the right joint implies the presence of the same MRI sign on the other side and vice versa.

Table 3 Partial adjusted p values of the subtests of the permutation analysis based on the pairwise comparisons between MR signs of the right (r) and left (l) joints (Bonferroni–Holm MinP method)

	Left joint			
	DDRl	DDNRl	JEl	OCl
Right joint				
DDRr	0.001*	1	1	0.149
DDNRr	1	0.003*	0.999	1
JEr	0.999	1	0.006*	1
OCr	0.997	0.997	1	0.001*

*p<0.01, significant

Discussion

The temporomandibular joint has always been considered an atypical joint, because the joints of the two sides (i.e., right and left) act synergically to allow a characteristic anterior displacement. The fact that the two joints are not independent from each other has been a matter of debate concerning if and how the presence of pathologies in one joint may affect the joint of the opposite side. Most of the literature described the prevalence of TMJ disorders at the individual level, and only few studies focused on the prevalence of such disorders at the joint level [18]. Also, the available literature is based on clinical assessments, and there are very few reports on the prevalence of the different combinations of disorders affecting only one or both joints [19]. Based on these premises, the present investigation was performed to depict the status of both temporomandibular joints in a selected population of patients, with the aim to assess the correlation between the different MRI findings in the same joint and in joints of the two sides.

In the present investigation, MRI was used because it is the reference technique for depicting the TMJ disc position and detecting the presence of effusion, and it also allows visualizing the anatomy of TMJ bone structures with an acceptable accuracy [20]. The risk for bias in the interpretation of the images due to the involvement of different radiologists was minimized by the two clinicians performing the study, who examined all images together and took each decision by consensus. The MRI findings assessed in this investigation were disc displacement, osseous changes, and TMJ effusion, as suggested by the recent revised diagnostic algorithms for temporomandibular disorders [16, 21, 22]. Within the limitations due to the selected patient population, this study allowed to draw interesting suggestions as for the association of findings within the same joint and between joints of the opposite sides.

First, it was described an association between disc displacement without reduction and degenerative disease within the same joint(s). This finding provided support to the amount of literature on the protective role of the temporomandibular joint disc to prevent remodeling/damage of the articular bone structures [23] and is in-line with previous findings of an association between long-lasting disc displacement and degenerative changes of the osseous structures [24, 25]. Despite the current study design which does not support cause and effect interpretations, from a clinical viewpoint, it is more likely that disc displacement without reduction affects the onset of articular remodeling than vice versa and that the presence of DDNR may be considered a risk factor for osteoarthrosis of the TMJ [26].

Second, the main finding of the cross-tabulation of contralateral MRI signs is that diagnoses on one side are mainly associated with the same diagnoses on the other side. This observation suggests the existence of a mutual interaction between joints of the two opposite sides and is in-line with the hypothesis that an unbalance between the loads exerted on the joint (i.e., prolonged jaw clenching) and the joint's resistance (i.e., structural anatomy) is likely to affect the TMJs bilaterally [27]. Such finding was never described in the TMJ imaging literature so far and adds to the amount of literature on the need to report findings of the bilateral joints' clinical assessment [18, 19].

Third, it must be pointed out that the findings from this study, viz., the observation that MRI findings are similar between the two TMJ sides, need to be discussed on the basis of the presence of clinical symptoms on one or both sides. The prevalence of unilateral vs. bilateral TMD clinical symptoms at the general population level and their relative frequency in patient populations has still to be determined [19]. In any case, from a clinical viewpoint, it seems plausible to suggest that some patients may have the same MRI findings on the two sides, while complaining of unilateral clinical symptoms or vice versa. Such an hypothesis is in-line with the suggestions that the agreement between clinical and imaging diagnoses is not perfect [7, 8] and can be viewed as a further recommendation for future researches assessing the significance of imaging signs in the absence of clinical symptoms.

Data gathered with this study design should need to be cross-tabulated with clinical findings to increase the external validity of this report [28]. Notwithstanding that, in the light of the controversy surrounding the decision on which assessment (viz., clinical vs. imaging) should be considered the diagnostic standard [29], it is not likely that the inclusion of a clinical evaluation in such an investigation may influence the present study's findings of a mutual interaction between the TMJs of the two sides.

Conclusions

The present study on bilateral magnetic resonance assessment of the temporomandibular joints in 199 patients investigated the association between disc displacement, osseous changes, and joint effusion within the same joint and between joints of the contralateral sides. Based on the correlation analyses, it can be suggested that (1) disc displacement without reduction is associated with osseous changes of the same joint, and (2) joints of the two opposite sides are likely to be affected by the same combinations of MRI signs.

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

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