RESEARCH

Diagnostic concordance between MRI and electrovibratography of the temporomandibular joint of subjects with disc displacement disorders

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Objectives: The aim of this study is to evaluate the diagnostic concordance of MRI and electrovibratography (EVG) of the temporomandibular joint (TMJ) in the diagnosis of articular disc displacement with reduction (ADDwR) and articular disc displacement without reduction (ADDw/oR).

Methods: 50 patients (12 males, 38 females; mean age 37.46 ± 15.64 years) with a hypothesis of disc displacement were selected. For each patient an MRI of the TMJ was performed. MRIs were evaluated sorting the 100 TMJs by kind of pathology (no pathology, ADDwR, ADDw/oR, and joint hypermobility). Afterwards, the patients had an EVG exam. The EVG exams were performed with vibration transducers over each TMJ, enabling simultaneous, bilateral recording of vibrations emanating from joint sounds during the opening and closing movements. The presence of a sound peak was compared with the MRI diagnosis of ADDwR, while a multipeak aspect was compared with ADDw/oR diagnosis using Cohen's kappa test.

Results: The presence of a peak-shaped track has high specificity for ADDwR (90.27%). The Cohen's kappa calculated for the ADDwR was 0.5615 (good–moderate). The presence of a multipeak-shaped track has low specificity (65.22%) and sensitivity (70.42%). The Cohen's kappa calculated for the ADDw/oR was 0.2992 (poor).

Conclusions: The present study recommends the use of EVG to support the clinical diagnosis of a disc displacement with reduction when MRI is not available or when subjects cannot be investigated by MRI.

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Introduction

According to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD),[1] temporomandibular disorders (TMD) can be classified in three subgroups: muscle disorders (Group I); disc displacements (Group II); and arthralgia, arthritis and arthrosis (Group III). Population-based evaluation of the prevalence of TMD among community cases show that Groups II and III TMD alone are relatively uncommon (about 11.4% and 2.6% of all cases of TMD, respectively).[2] However, these conditions are commonly diagnosed in association with other subgroups in community cases.[3]

Evaluation of joint sounds is considered a key diagnostic criterion in determination of TMD. Clicking and crepitation should be considered signs of morphological alterations, being indicative of articular disc displacement with reduction (ADDwR)[3] and arthrosis, respectively. Unfortunately, the clinical detection of joint

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sounds is not so easy. In a previous study trained and untrained observers evaluated the presence of joint sounds, on jaw opening, by digital palpation and by listening aided by stethoscope. The conclusion was that detecting and classifying joint sounds associated with jaw opening by these means yielded by far the lowest reliabilities of any clinical sign or symptom assessed in the entire study.[3] In a more recent study Naeije et al[4] confirmed the fact that clinically, even under the guide of the RDC/TMD, it is a challenge to discriminate between the two most prevalent internal derangements: ADDwR and symptomatic hypermobility.

The electrovibratography (EVG) analysis of the temporomandibular joint (TMJ) could assist clinicians in their diagnosis of TMJ sounds. Ishigaki et al reported that EVG produced sensitivities and specificities of 0.75–0.95 in distinguishing between normal subjects and those with internal derangement and in distinguishing among various categories of internal derangement.[5] In a different report Ishigaki et al reported that a disc displacement with reduction generates a "click" in the lower frequencies (under 300 Hz) and that a degenerative condition generates "crepitus" in the higher frequencies (over 300 Hz).[6]

Christensen showed also that, in comparison with clinically normal TMJs, the vibrations of clinically abnormal temporomandibular joints had higher median (+79%) and peak (+137%) frequencies, higher peak amplitudes (+740%), and higher intensities as expressed through the estimated total energy contents (+1843%) and the integrals (+1215%) of power spectrum density functions.[7]

MRI is the gold standard for imaging techniques used to visualize the TMJ, allowing the depiction of inflammatory changes within the joint space,[8,9] cartilage abnormalities, bone remodelling and positional alterations of the joint disc.[10–13] Tasaki et al reported a 95% accuracy in the assessment of disc position and configuration, and 93% accuracy in the assessment of osseous changes of the TMJ.[14] MRI cannot be carried out in some patients (those with pacemakers, claustrophobics), and its use is limited by its cost and the time it takes.[9] The need has grown for alternative techniques that have good diagnostic accuracy and reliability.

The aim of this study is to compare the diagnostic adequacy of EVG and MRI in a sample of patients with articular disc displacement with and without reduction in order to verify the hypothesis of reducing the number of requested MRI, thus reducing the social costs of diagnosing a TMJ internal derangement.

Materials and methods

Subjects

50 patients (12 males and 38 females; age range 17–70 years; mean age 37.46 ± 15.64 years) with ADDwR or articular disc displacement without reduction (ADDw/oR) were selected by means of clinical examinations according to the RDC/TMD;[1] only subjects with a diagnosis of Groups IIa and IIc were selected. These patients were selected among all the orofacial pain patients visited at the gnathology unit of the dental school of the University of Torino, in the period March–December 2011. As inclusion criteria, all patients should have clicking in one or both TMJs upon mouth opening and/or closing, in order to facilitate the EVG detection. Patients with a history of facial trauma, TMJ surgery, systemic inflammatory arthritis, mandibular growth disturbance or TMJ tumour were excluded. The selected subjects gave written informed consent for the study, which was approved by the human investigation committee at our institutions.

MRI

For all these selected patients an MRI study of both TMJs was requested. The study was conducted in intercuspal position and at the maximum opening, in order to investigate the disc position and the eventual reduction during mouth opening. Thus a total of 100 TMJs were investigated.

MRI was carried out with a 1.5 T Gyroscan scanner (Philips Healthcare, Best, Netherlands) with a bilateral dedicated circular (8 cm diameter) surface coil for concomitant right and left TMJ study.

MRI of each subject was completed and interpreted by radiologists, who were blinded to the clinical examination findings and to the research. The investigation protocol provided a first axial scan "scout", from which were established seven sagittal oblique slices in a lateral–medial direction and coronal sections deviated obliquely in a posteroanterior direction. Gradient echo sequences were performed: two-dimensional T_1 weighted in sagittal oblique sections at closed and open mouth, and coronal sections at closed mouth [time of repitition (TR) = 340 ms, time of echo (TE) = 16 ms, field of view = 15 cm, slice thickness = 3 mm, matrix 256 × 192] with an interslice gap of 0.5 mm. Sequential bilateral images in both closed-mouth and maximum open-mouth positions were made. The articular disc was directly identified, in sagittal oblique images, as an area of hypointensity with a biconcave shape above the condylar structure, and its position was categorized according to literature data.[15] Bone contours, cartilage integrity, bone marrow abnormalities, disc shape and structure, and joint effusion were evaluated (see Figures 1 and 2 for examples of ADDwR and ADDw/oR). The diagnostic accuracy of MRI on fresh autopsy material using oblique sagittal and oblique coronal sections has been found to be 95% and 93% in determining the disc position and the bone status, respectively.[12–14]

Electrovibratogaphy

Patients had TMJ vibrations evaluated by EVG using the ESG-2 device (Myotronics Inc., Kent, WA) connected to a K-7 system (Myotronics Inc.). The ESG-2 is a lightweight headset that holds highly sensitive
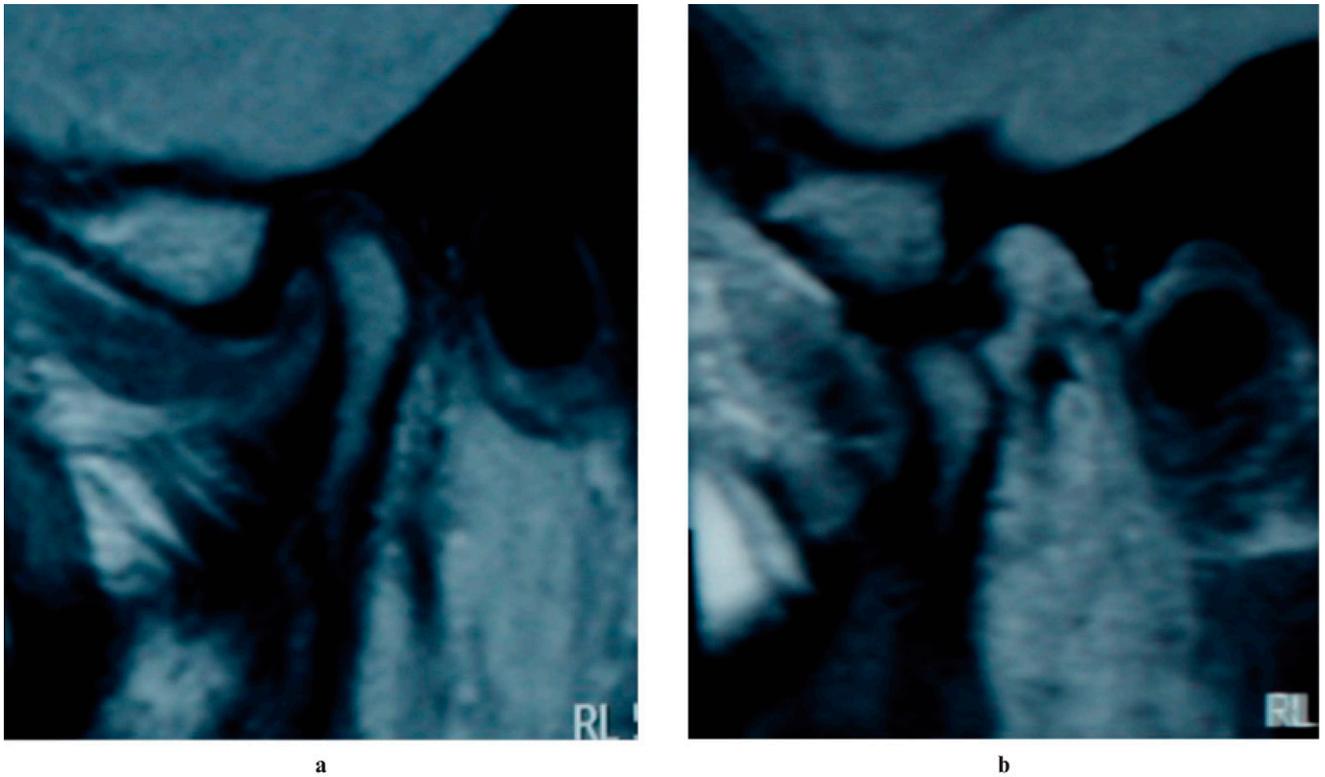
Figure 1 (a) Sagittal slices of a temporomandibular joint with articular disc displacement with reduction using MRI. Mouth closed. (b) Sagittal slices of a temporomandibular joint with articular disc displacement with reduction using MRI. Mouth opened. It is possible to observe the recapture of the disk
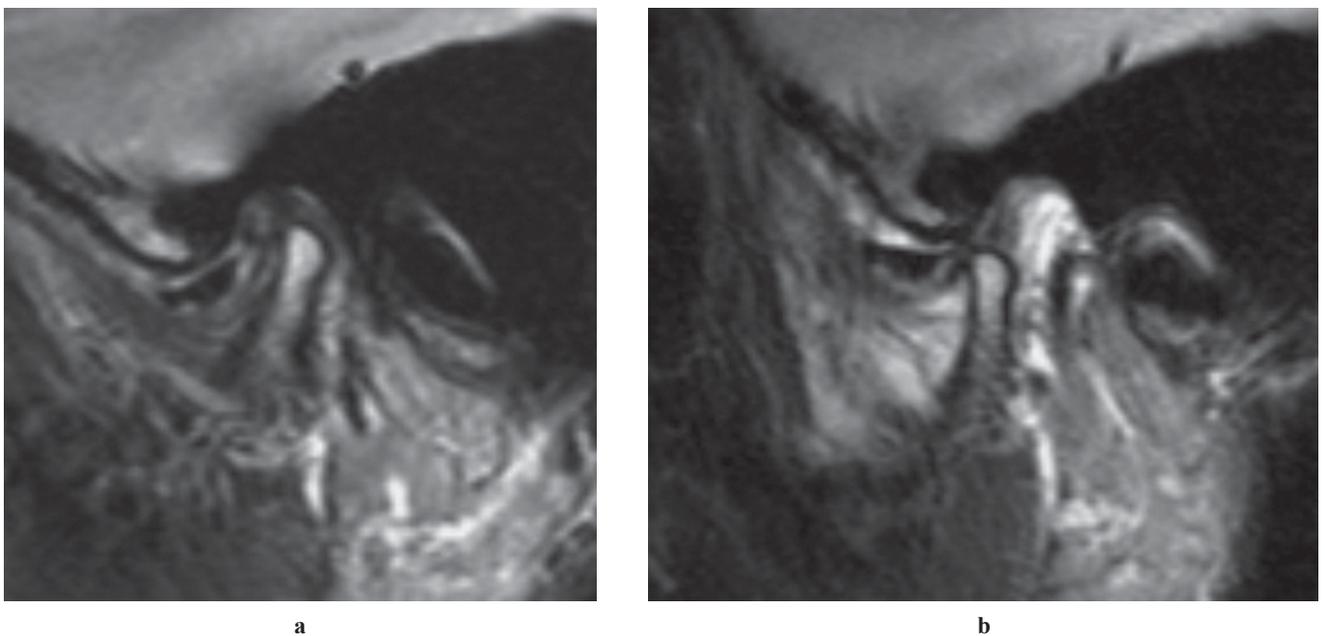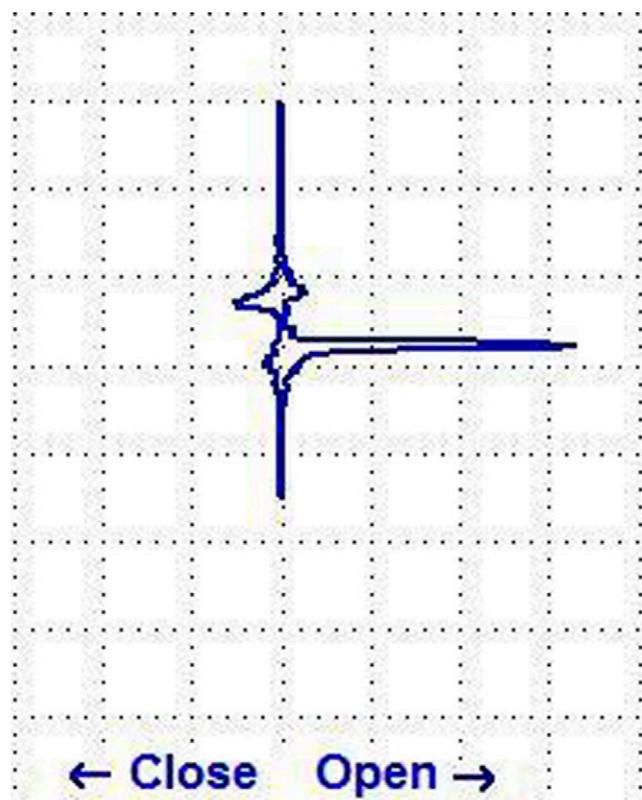

Figure 2 (a) Sagittal slices of a temporomandibular joint with articular disc displacement without reduction using MRI. Mouth closed. (b) Sagittal slices of a temporomandibular joint with articular disc displacement without reduction using MRI. Mouth opened. It is possible to observe the absence of recapture of the disk

vibration transducers over each TMJ, enabling simultaneous bilateral capture of tissue vibrations emanating from joint sounds. It includes an amplifier to transfer and record the collected data. Vibration (sound) data is correlated to vertical dimension of opening and closing provided by the K-7 jaw-tracking device, used simultaneously to the ESG-2. The frequency response of the EVG device is between 15 Hz and 720 Hz, with a special filter that rejects 50 Hz frequency.

The skin over the lateral TMJ pole was slightly degreased (Every Paste; Meditec, Parma, Italy) before the beginning of the analysis. After positioning the sensors, the patients were asked to open and close the mouth accompanying an arrow motion on the monitor screen. All patients were allowed 1 min of training to synchronize the movement with arrow motion. After confirming synchronism, the records were accepted and saved on a hard disk for further analysis. The analysis was performed by an operator blinded to the clinical and MRI diagnosis.

Each record consisted of four movements of opening and closing the mouth, and it was repeated 3 times with the same technique for a total of 12 movements. The recorded vibrations were displayed as tracking on a monitor (Figure 3). From an EVG point of view, TMJ clicking is characterized by a typical "peak" morphology; if the reduction is present, the protrusion shift of the mandible and the execution of opening and closing movement in this condition

should eliminate the clicking and thus the "peak morphology" vibration.

The twelve opening/closing movements were examined searching for a sound peak (Figure 3). If the peak was present in at least 7 out of 12 moves, the patient was considered positive for the presence of peak.

For patients in whom the peak was not present in any of the 12 movements, the moves were examined to assess the presence of multiple peaks of low intensity (Figure 4). These aspects are a widespread sign of noise throughout all the movements. If this multiple peaks aspect was present in at least 7 out of 12 moves, the patient was considered positive for the presence of multiple peaks.

Statistical analysis

The Cohen's kappa coefficient (κ) is a statistical measure of interrater agreement or interannotator agreement for qualitative items. For this reason it was used in this study to measure the agreement between the MRI and the EVG diagnosis. It is generally thought to be a more robust measure than simple percentage agreement since kappa takes into account the agreement occurring by chance.[16]

Considering the MRI as the gold standard for the diagnosis of ADDwR and ADDw/oR, the sensitivity, specificity, positive predictive value (PPV) and the negative predictive value (NPV) of the EVG were evaluated.

Figure 3 Example of peak morphology in electrovibratography
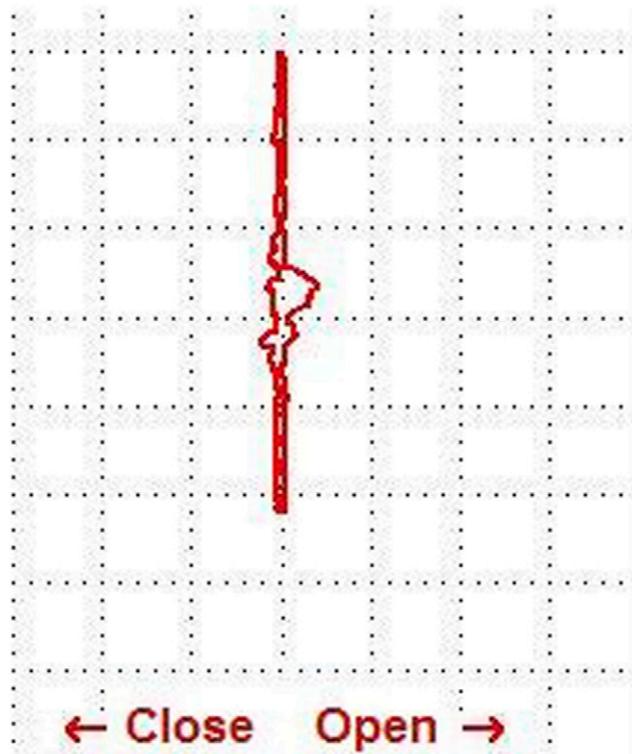
Figure 4 Example of multipeak morphology in electrovibratography

Table 1 Distribution of the different pathologies within the sample

Pathology	TMJ
ADDwR	53
ADDw/oR	23
Subluxation	6
Healthy joint	18

ADDwR, articular disc displacement with reduction; ADDw/oR, articular disc displacement without reduction; TMJ, temporomandibular joint.

In medical diagnostics, test sensitivity is the ability of a test to correctly identify those with the disease, whereas test specificity is the ability of the test to correctly identify those without the disease.[17] Sensitivity and specificity were calculated as follows:

$$sensitivity: \text{ number of true}-positives/\text{number of} \\ true-positives+\text{number of false}-negatives$$

$$specificity: \text{ number of true}-negatives/\text{number of} \\ true-negatives+\text{number of false}-positives$$

The predictive values of the diagnostic test were calculated with a Bayesian analysis as follows:

$$positive \text{ predictive value} = Se \times P/Se \times P+ \\ (1-Sp) \times (1-P)$$

$$negative \text{ predictive value} = Sp \times 1-P/Sp \times 1-P+ \\ (1-Se) \times P$$

where Se is sensitivity, P is prevalence and Sp is specificity.

Results

The diagnostic results from the MRI analysis are reported in Table 1. Out of the 100 joints, 53 were diagnosed as ADDwR, 23 as ADDw/oR, 6 with joint hypermobility and 18 healthy. The six joint hypermobility cases were not used in the subsequent part of the study.

Table 2 Accordance between the peak morphology and the articular disc displacement with reduction (ADDwR)

Peak	ADDwR		
	Yes	No	Total
Yes	36	4	40
No	17	37	54
Total	53	41	94

Table 3 Accordance between the multipeak morphology and the articular disc displacement without reduction (ADDw/oR)

Multipeak	ADDw/oR		
	Yes	No	Total
Yes	15	21	36
No	8	50	58
Total	23	71	94

The presence of ADDwR and the peak aspect in the EVG are reported in Table 2. Out of the 53 TMJs with MRI diagnosis of ADDwR, 36 also had a peak aspect in EVG. Out of the 41 TMJs without an MRI diagnosis of ADDwR, 4 had a peak aspect in EVG.

The presence of ADDw/oR and the multipeak aspect in the EVG are reported in Table 3. Out of the 23 TMJs with MRI diagnosis of ADDw/oR, 15 also had a multipeak aspect in EVG. Out of the 71 TMJs without an MRI diagnosis of ADDw/oR, 21 had a multipeak aspect in EVG.

Comparing the MRI diagnosis of ADDwR with the EVG sound aspect of a peak morphology, the Cohen's kappa coefficient was 0.56. This value can be considered as good according to the Fleiss scale, where a value of >0.75 is considered "excellent", a value between 0.40 and 0.75 is considered "good", and a value below 0.40 is considered "poor".[18] The resulting sensitivity was 67.92% and the specificity was 90.24%, with a PPV of 90% and an NPV of 68.52%.

Comparing the MRI diagnosis of ADDw/oR with the EVG sound aspect of a low multipeak frequency and low frequency and amplitude during the entire sound, the Cohen's kappa coefficient was 0.29, and thus "poor" according to the Fleiss scale.[18] The resulting sensitivity was 65.22% and the specificity was 70.42%, with a PPV of 41.67% and an NPV of 86.21%.

Discussion

The importance of MRI in the diagnosis of TMDs has been confirmed in numerous studies.[15,19,20] The articular disc displacement is one of the most common expressions of TMD.[17,21,22]

MR has excellent reliability for assessing disc position.[23] This characteristic was confirmed by studies in which a comparison between MRI and autopsy specimens revealed an accuracy of about 90–95% for detecting disc position abnormalities when both coronal and sagittal images are evaluated.[24,25] The most salient sign of a disc derangement with reduction is a repeatable, audible click. On occasion the click is not audible but may be heard by auscultation. In addition, the shift in disc position may be felt by palpation. The EVG analysis of the TMJ could assist clinicians in their diagnosis of TMJ sounds with sensitivities and specificities of 0.75–0.95[5] in distinguishing between normal subjects and those with

disc displacement. The present study showed a good agreement between the MRI diagnosis of disc displacement with reduction and the EVG peak morphology, with a Cohen's kappa coefficient of 0.56. A specificity of 90.24% and a PPV of 90% of the EVG peak morphology with respect to the MRI diagnosis of disc displacement with reduction indicate rare false-positive cases and that the presence of this morphology is related to a diagnosis of ADDwR in 90% of the observed cases. These results reflect those obtained by Huang et al, demonstrating a specificity of 84.6% and a sensitivity of 85.7% for the EVG diagnosis of ADDwR,[26] considering the MR as the gold standard, when the total integral of the joint sounds was considered. Mazzetto et al showed that a complete analysis of the joint sounds by EVG (amplitude and frequency domains) should provide complete information for a diagnostic classification of the observed TMJs.[27]

Abrão et al described an excellent statistical agreement in the comparison between the clinical diagnosis of disc disorders and EVG findings.[28] However, they did not perform an MRI investigation of the analysed joints; therefore, their conclusions should be interpreted with caution. Naeije et al confirmed the fact that clinically, even under the guide of the RDC/TMD, it is a challenge to discriminate between the two most prevalent internal derangements: ADDwR and symptomatic hypermobility.[4]

Considering the fact that MRI cannot be performed in all cases, and its use is limited by its cost and the time it takes,[9] there is a need for alternative techniques that have good diagnostic accuracy and reliability. In this sense the execution of an EVG evaluation can support the clinical diagnosis of ADDwR. This study confirmed the results reported by Gay et al in describing a brief peak

appearing during the opening and/or closing phase that can be associated with the click sound of a displaced disc.[29]

The same consideration cannot be performed in the evaluation of the ADDw/oR, considering the level of agreement between the MRI and the EVG: a poor agreement was observed between the MRI diagnosis of ADDw/oR and the EVG multipeak morphology, with a specificity of 70.42% and a sensitivity of 65.22%. This is in contrast to the results reported by Tallents et al, who did not perform any MRI to confirm his EVG diagnosis.[30] Furthermore, several MRI studies of adults have demonstrated disc displacement in about one-third of volunteers with no symptoms.[31–34] On the basis of the results of our study, the role of EVG in supporting the clinical diagnosis of ADDw/oR is of limited value. However, we have to consider the fact that patients selected for this study were Group IIa and IIc subjects according to the RDC/TMD. This implies that the cases selected were more likely to be ADDwR or symptomatic hypermobility joints. The number of false-positives in diagnosis of ADDw/oR by EVG may therefore be a result of this selection of patients.

The main limitation of the present study is represented by the comparison between a morphological (MRI) technique and a functional (EVG) technique. All functional assessments are exposed to more variables, and therefore subject to multiple interpretations.

In conclusion, the clinical diagnosis of ADDw/oR cannot be supported by EVG, when only the wave morphology and the relative amplitude are considered. The present study recommends the use of EVG in supporting the clinical diagnosis of a disc displacement with reduction when MRI is not available or when the subject cannot be investigated by MRI.

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