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Static and dynamic MR imaging in the evaluation of temporomandibular disorders

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Abstract. – OBJECTIVE: The aim of this study is to prove if dynamic HASTE (half-Fourier acquisition single-shot turbo spin-echo) sequences can be used in the diagnosis of internal derangement disorders of temporomandibular joint (TMJ) as an alternative to static proton density (PD) weighted/turbo spin echo (TSE) T2-weighted sequences which are considered up to now as the gold standard in the evaluation of TMJ disorders (TMDs).

PATIENTS AND METHODS: 194 patients for a total of 388 TMJs were examined with a 1.5 Tesla field strength superconducting magnet. Sagittal static PD-weighted/TSE T2-weighted and dynamic HASTE sequences have been used. Three experts in the field of oral radiology (specialist A, B and C) independently and blinded to clinical symptoms and any treatment, assessed the articular disc position in each TMJ (rated as normal or disc displacement with reduction or disc displacement without reduction). The agreement between static and dynamic images and between the three different specialists in the assessment of the articular disc position was evaluated using kappa statistic.

RESULTS: The agreement between static and dynamic images is: for specialist A, K = 0.862; for specialist B, K = 0.870 and for specialist C, K = 0.862.

CONCLUSIONS: Since there is no complete agreement between these two MR techniques, dynamic sequences can not be used as a reliable alternative to static sequences in the evaluation of internal derangement disorders of TMJ.

Key Words:
Temporomandibular joint disorders, Temporomandibular joint, Temporomandibular joint disc, MRI.

Introduction

The study of TMJ (Temporomandibular Joint) through different imaging technologies represents a fundamental step in defining the morphology of anatomical structures and detecting several organic pathologies and dysfunctional phenomena.

MRI (Magnetic Resonance Imaging) allows the acquisition of images in condition of complete occlusion, partial occlusion and opening of the mouth. In order to reproduce the joint movement, several authors have performed MRI exams with static examinations of the joint in different positions during the various phases of the movement, rebuilding then the movement of opening and closing of the mouth through dedicated cinematographic softwares[1-7].

Only recently, we see the emergence of studies that employ optimized sequences for the acquisition of dynamic images, which capture the patient while he opens and closes his mouth. In order to obtain these results, true-FISP (True-fast imaging with steady state precession)[8] and HASTE (half-Fourier acquisition single-shot turbo spin-echo) sequences[9] have been utilized. These sequences assess almost in real time, the TMJ movement, creating a more reliable picture than the pseudo-dynamic sequences.

The purpose of this study is to prove if dynamic HASTE (half-Fourier acquisition single-shot turbo spin-echo) sequences can be used in the diagnosis of internal derangement disorders of temporomandibular joint (TMJ) as an alternative to static proton density (PD) weighted/turbo spin echo (TSE) T2-weighted sequences which are considered up to now as the gold standard in the evaluation of TMJ disorders (TMDs).

Patients and Methods

This study was approved by the Ethics Review Board of our institution.

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From January 2008 to December 2011, in the Radiology Department of the Sapienza University of Rome, 274 patients have been studied for suspected TMD. All patients signed an informed consent form before the MRI examination. Patients with a history of trauma**,** or malignancies of the head and neck, or specific arthritis were not included in our study. Therefore, thirty-tree patients were rejected.

Of 208 patients screened, 14 patients were rejected for the poor quality of the images. Therefore, the sample is composed of 194 patients of Caucasian race, 46 males and 148 females with an average age of 33 years old, for a total of 388 TMJs. A superconducting magnet of 1.5 Tesla field strenght (Siemens, Erlangen, Germany) with double loop array coil was used for the experiment.

After performing an axial scout (thickness 5 mm, distant factor 20%, matrix 256 × 256, TR (repetition time) 105 ms, TE (echo time) 13 ms, Fov (field of view) 300 × 300, we acquired static images in closed mouth position and maximal mouth opening position employing double echo PD weighted/TSE T2-weighted sequences (TR 3500 ms, TE 15/102 ms, Fov 140, 2 mm thickness, flip angle 150, matrix 256 × 256, 2 acquisitions) following a parasagittal plane, perpendicular to the long axis of the condylar head, in order to assess the position of the disc in both joints.

Afterwards, HASTE sequences (TR 1100, Fov 256 × 154, 6 mm thickness, 1 acquisition, flip angle 150, Fov read 250, Fov phase 75, acquisition time of 1sca/sec) have been performed with 80 seriated acquisitions in a single sagittal plane in the middle of the condylar head, while patients slowly and repeatedly opened and closed their mouths (about 10 seconds from closed mouth position to maximal mouth opened position), so that dynamic images, almost in real time, were obtained.

Three experts in the field of oral radiology (M.M. professor of radiology with 35 years experience; D.M. doctor in dental surgery with 15 years experience; L.L. radiologist with 30 years experience), blinded to clinical symptoms and any treatment, independently evaluated static sequences and dynamic sequences by means of a dedicated cine software (Infinit pacs version 3.0.8.1. BN16, Infinit Co., Ltd. Seoul, Korea). In order to assess the reliability of the dynamic sequences, these have been compared to standard static sequences which are considered up to now as the gold standard in the evaluation of TMDs.

The evaluated criteria were:

1. The quality of the dynamic and static sequences according to a qualitative scale (excellent, good, satisfactory, fair, poor)
2. The diagnostic reliability of the dynamic sequences in the assessment of the articular disc position through a comparison with static sequences. The disc position was considered as normal (posterior band of the disc being located at the superior or 12 o'clock position relative to the condyle), anterior disc displacement with reduction (DdwR) (Figures 1 and 2) or anterior disc displacement without reduction (DDw/oR).

Statistical Analysis

Through the Fleiss kappa index (with values included between -1 and +1), we carried out a statistic research to evaluate the agreement of the results both between the different sequences utilized and the different specialists; the error probability considered was of first kind (alfa) equal to 0.05. We did not perform a previous calibration test of the examiners.

Results

The results of the qualitative assessment of the dynamic images, carried out by the three specialists (A, B, C), have been summarized in Table I.

The statistic analysis provided the following results: A-B agreement 90.2% with K 0.843 and $p = 0.0001$; A-C agreement 88.2% with K = 0.724 and $p = 0.0001$; B-C agreement 96.9% with K = 0.864 and $p = 0.0001$.

The results of the qualitative assessment of the static images, carried out by the three specialists (A, B, C), have been summarized in Table II.

The statistic assessment provided the following results: A-B 97.9% agreement with K = 0.872 and $p = 0.0001$; A-C 97.4% agreement with K= 0.868 and $p = 0.0001$; B-C 95.0% agreement with K = 0.850 and $p = 0.0001$.

The results for TMD visualization in static images have been summarized in Table III, while the results for TMD visualization in dynamic images have been summarized in Table IV.

The statistic analysis of the data revealed the following results: the agreement between the methods of analysis is:

- According to the specialist A K = 0.862 $p = 0.0001$ (-0.068 < CI 95% < 0.068)
- According to the specialist B K = 0.870 $p = 0.0001$ (-0.066 < CI 95% < 0.066)

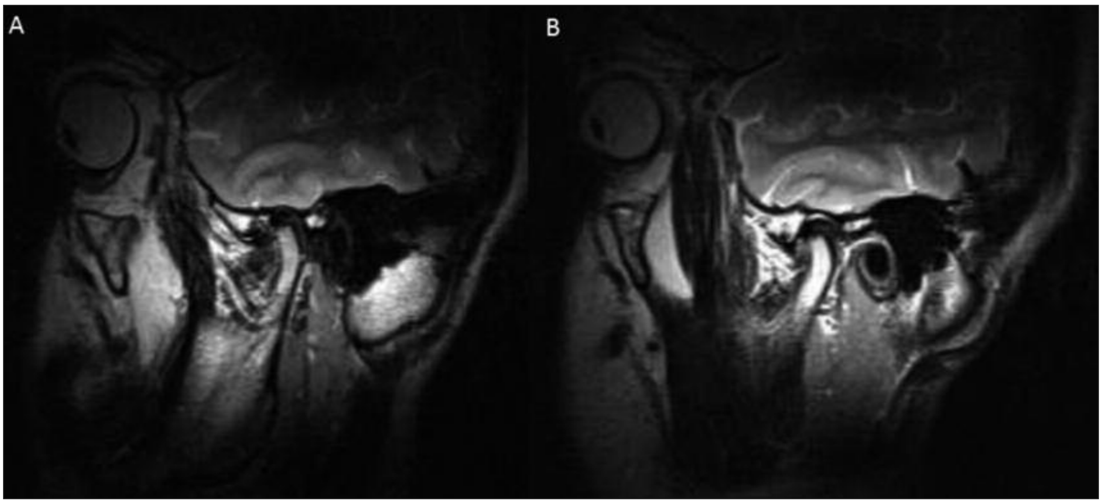

Figure 1. Parasagittal MR images of static TSE T2-weighted sequences at closed *(A)* and opened *(B)* mouth position: on the left side the disc is displaced in front of the condyle, while on the right side there is a correct relationship between the condyle and the disc.

- According to the specialist C K = 0.862 p = 0.0001 (-0.068 < CI 95% < 0.068)

The agreement between the static images recorded by the individual specialists is:

- A-B K = 0.963 p = 0.0001 (-0.035 < CI 95% < 0.035)
- A-C K = 0.981 p = 0.0001 (-0.025 < CI 95% < 0.025)
- B-C K = 0.963 p = 0.0001 (-0.035 < CI 95% < 0.035)

while for dynamic images is:

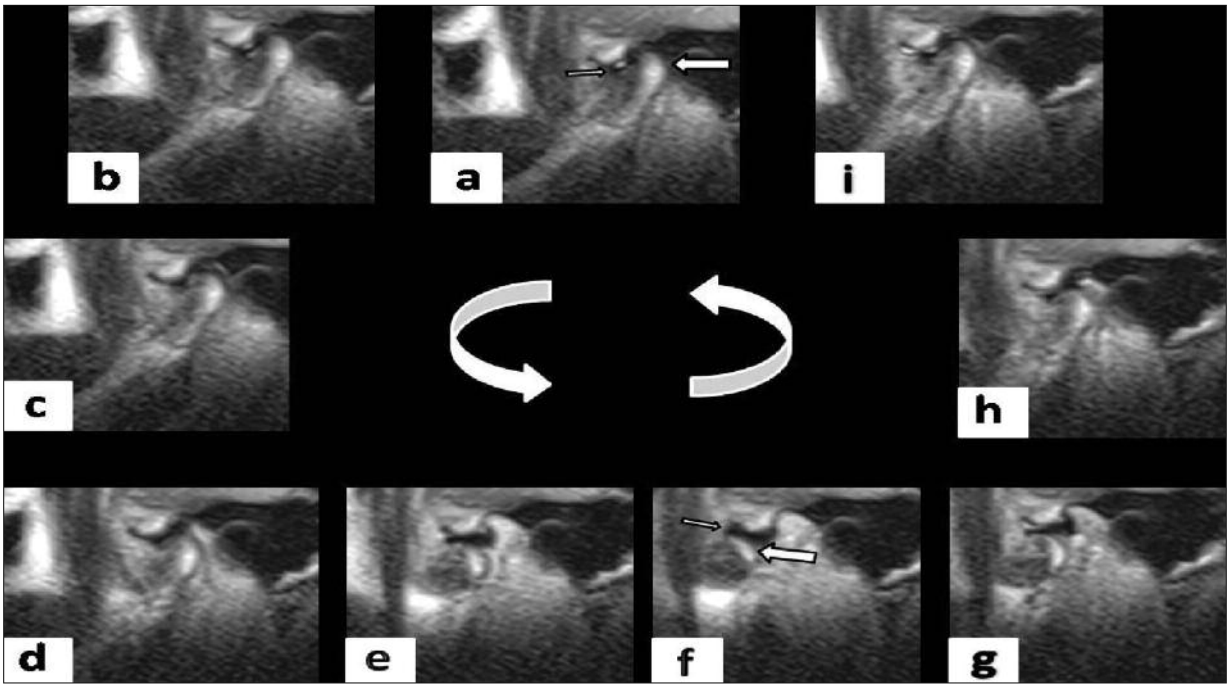

Figure 2. Series of sagittal MR images HASTE T2 weighted sequences, almost in real time, demonstrating reducing disc displacement. The images show the temporomandibular joint during various stages of opening *(a-f)* and closing *(f-i)* movement. a) closed mouth position: the hypointense disc is clearly demarcated from the eminence by the high signal intensity of synovial fluid in the upper anterior recess (thin arrow) and it is located in front of the condyle (*large arrow*). f) opened mouth position: the condyle (*large arrow*) is below the eminence and the disc (*thin arrow*) is in its physiological position.

Table I. Qualitative assessment of the dynamic images of the disc position.

Specialist A	Specialist B	Specialist C
Excellent 90 = 23.2% Good 98 = 25.3% Satisfactory 106 = 27.4% Fair 24 = 6.1%	Excellent 78 = 20% Good 96 = 24.7% Satisfactory 108 = 27.8% Fair 36 = 9.2%	Excellent 72 = 18.7% Good 104 = 26.8% Satisfactory 102 = 26.2% Fair 40 = 10.3%

Table II. Qualitative assessment of the static images of the disc position.

Specialist A	Specialist B	Specialist C
Excellent 280 = 71% Good 88 = 22% Satisfactory 20 = 6%	Excellent 288 = 74% Good 76 = 20% Satisfactory 24 = 6%	Excellent 284 = 73% Good 78 = 20% Satisfactory 26 = 7%

Table III. TMD visualization in static images.

Disc position	Specialist A	Specialist B	Specialist C
Normal	48	50	48
DDwR	208	210	212
DDw/oR	122	118	118

Table IV. TMD visualization in dynamic images.

Disc position	Specialist A	Specialist B	Specialist C
Normal	48	48	48
DDwR	214	216	210
DDw/oR	116	114	120

- A-B K = 0.972 $p = 0.0001$ (-0.031 < CI 95% < 0.031)
- A-C K = 0.981 $p = 0.0001$ (-0.254 < CI 95% < 0.254)
- B-C K = 0.954 $p = 0.0001$ (-0.041 < CI 95% < 0.041).

Discussion

Recent studies compared the 1,5 Tesla MRI with the more recent 3 Tesla MRI[11], and, although both MRIs are equally valid for this study, they demonstrated a major accuracy of 3 Tesla MRI in improving the quality of the images and the diagnostic performance in affections of tendons and cartilage[12].

The dynamic evaluation of TMJ has been the object of several studies of MRI: the first movement simulations have been performed in 1987 by Burnett et al[1], and then by Conway et al[2], who, in 1988, published a paper on the TMJ movement evaluation through MRI.

Eberhard et al[3], Yoshida et al[4], Behr et al[5], Maniere-Ezvan et al[6], utilized sequences with seriated acquisitions of static images of TMJ during the different stages of mouth opening, through the use of dedicated mechanic tools and then merging the single snapshots on a magnetic tape in order to project them (cine-loop). Sequences such as Gradient Echo[3,6], Gradient Recalled Acquisition in Steady State[4], Fast Low Angle SHot Magnetic Resonance Imaging 20°[5] have been utilized. These sequences did not provide the best TMJ images, because of their low spatial resolution and the low signal/noise ratio[7]. The authors of the latest publications on pseudo-dynamic MRI utilized ultra fast turbo spin echo sequences with images that permit a good visualization of disc position in both healthy volunteers and patients.

Recent studies[8,9] obtained optimized sequences to acquire dynamic images, by asking the patients, at the desired time, to open and close their mouths.

These sequences allow the evaluation of the TMJ movement almost in real time, showing it in a better way than the pseudo-dynamic sequences do.

By improving the temporal resolution, dynamic imaging could potentially depict diseases seen only during the course of the opening movement, that might otherwise be missed by static imaging.

In our study we compared static PD weighted/TSE T2 weighted sequences and dynamic HASTE sequences, which we used in a previous study for TMD diagnosis, but in static modality[12].

Although patient cooperation and some patient preparation are important factors for good results, we found that all patients were able to comply with the given instructions. Additionally, given the short sequence-time of the dynamic sequence, multiple acquisitions are easily obtained.

Likely the static and dynamic sequences are not concordant in the evaluation of disc position because static sequences at open mouth position showed a different disc position from dynamic sequences, and not because of the quality or the interpretation of images from all the specialists.

Therefore, we assume that the difference of interpretation between static and dynamic sequences resulted from a real different disc position in two different moments.

Because of the lower quality of the images, we cannot use only dynamic sequences to evaluate TMD. Nevertheless, these are a useful tool to integrate the information provided by the standard PD or TSE T2 weighted sequences.

In order to obtain good TMJ dynamic sequences, it is necessary to acquire them before static sequences at opened mouth position to visualize the condyle head on axial plane and to place correctly the scanning plane.

Conclusions

The dynamic sequences are very useful to assess the dislocation of the articular disc because they allow us to see more times the movement of opening and closing of the mouth and show the real joint movement. However, as there is no complete agreement between static and dynamic sequences, dynamic sequences cannot be used as a reliable alternative to static sequences in the evaluation of internal derangement disorders of TMJ.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

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