

Diagnostic quality of dynamic high-resolution ultrasonography of the TMJ—a pilot study

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Abstract. The aim of this study was to compare sensitivity, specificity, accuracy and positive and negative predictive value for high-resolution ultrasonography (HR-US) in diagnosing degenerative changes, effusion and disk displacement using magnetic resonance imaging (MRI) as a reference. Over a period of 6 months, 100 patients with TMJ disorders (200 TMJs) were investigated by an experienced radiologist with HR-US and magnetic resonance imaging (MRI). The MRI investigation showed degenerative changes in 190 joints (95%), while an effusion was found in 59 (29.5%) joints. At closed-mouth position a disc dislocation was found in 138 joints (69%) and in maximum-mouth-opening position disc dislocation was diagnosed in 76 joints (38%). In the determination of degenerative changes HR-US showed a sensitivity of 94%, a specificity of 100% and an accuracy of 94%. In the detection of effusion HR-US yielded a sensitivity of 81%, a specificity of 100% and an accuracy of 95%. In the determination of disk displacement at closed-mouth position HR-US showed a sensitivity, specificity and an accuracy of 92% each. At maximum-mouth-opening position HR-US reached a sensitivity of 86%, a specificity of 91% and an accuracy of 90%. The results of the current study imply that HR-US is a valuable diagnostic imaging method of the TMJ which can be used as an alternative method to a MRI-investigation, but is yet not able to replace it. Further studies have to be done to reduce false-negative results.

Key words: TMJ; ultrasonography; MRI.

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Clinical investigation of the temporomandibular joint (TMJ) is, combined with imaging diagnosis, an important part in the diagnostic process of temporomandibular disorders (TMD)^{6,18,20}. The most used imaging methods of the temporomandibular joint (TMJ) are computed tomography¹¹ (CT), arthrography¹⁹ and magnetic resonance imaging (MRI)^{7,11,12,15,17,21,23} which is described as the gold-standard in the literature. Ultrasonography (US) was

described to be an alternative method in the imaging of the TMJ^{2,16,22}, especially since high-resolution ultrasonography (HR-US) was described to show satisfying results^{3–5,8–10} (Fig. 1). These results all refer to a static investigation of the TMJ, where the disc position is determined at closed-mouth position and maximum-mouth-opening position. A great advantage of HR-US is, that the investigation can be performed as well “real-time”, which means that the

articular disc could be viewed during the mouth opening movement. This view of the moving could help the investigator to detect its position more clearly than in a singular static investigation. The aim of this study was to compare sensitivity, specificity, accuracy and positive and negative predictive value for high-resolution ultrasonography (HR-US) in diagnosing degenerative changes, effusion and disk displacement using magnetic resonance

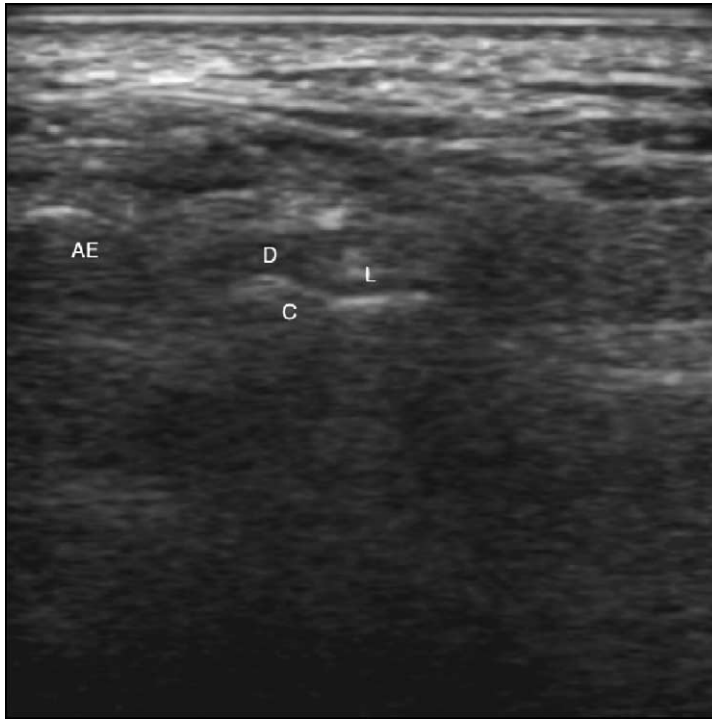


Fig. 1. Ultrasonographic image of a temporomandibular joint with a lateral luxated disk at closed-mouth position (AE, articular eminence; C, condyle; D, disk; L, capsule).

imaging (MRI) as a reference. The hypothesis of the study is that dynamic HR-US has a high diagnostic accuracy as regards the investigated parameters and may replace MRI for routine examinations of the TMJ (Figs 2–7).

Materials and methods

The study design was prospective. Over a period of 6 months 100 patients with

TMJ disorders (200 TMJs) were investigated by two experienced radiologists. TMJ disorders were classified by the CDC-TMD Classification by TRUELOVE et al.²⁵. The patients were selected consecutively. Inclusion criteria for the study were patients with TMJ disorders where an MRI was required (age: ≥ 16 years). The following criteria for an MRI were used: (1) inability to make a definitive diagnosis on history and clin-

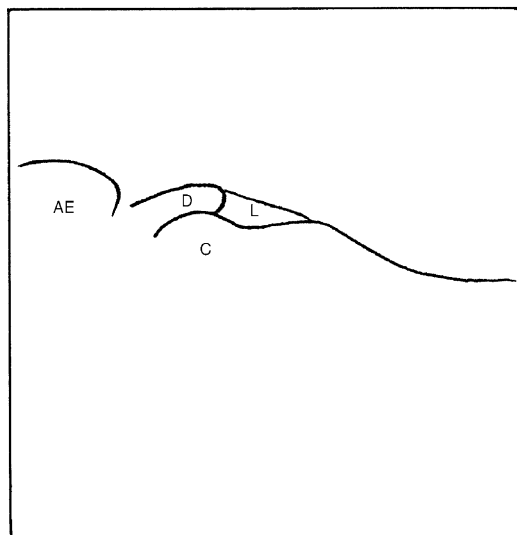


Fig. 2. Interpretation of the ultrasound image in Fig. 1 (AE, articular eminence; C, condyle; D, disk; L, capsule).

ical examination; (2) failure to respond to medical therapy; (3) pre-surgical imaging after a decision for surgery. The HR-US investigation was performed immediately afterwards the MRI investigation. The radiologist performing the HR-US investigation did not have any information about the result of the MRI investigation. HR-US was performed by an Advanced Technology Laboratories (ATL, Bothell, Washington) HDI 5000-machine using software applications such as sonographic computed tomography (sono-CT) and three-dimensional imaging. HR-US was performed at closed-mouth position and maximum-mouth-opening position and the movement of the disk was viewed during the mouth opening movement. In every patient an MRI investigation was performed as the reference method. MRI was also performed at the closed-mouth and maximum-mouth-opening position, as in HR-US. MRI was carried out with a 2.2 T MR-scanner (Vision, Siemens AG, Erlangen, Germany) and a dedicated circular-polarized transmit-and-receive TMJ coil. Data were collected on a 252×256 matrix with a field of view of 145 mm giving a pixel size of $0.60 \text{ mm} \times 0.57 \text{ mm}$. With the patient in a supine position 15 coronal slices and 8 para-sagittal slices were obtained of each TMJ using a TSE-PD sequence (TR 2800 ms, TE 15 ms) with 3 mm thin slices. The orientations of the MRI scans were corrected to become perpendicular to the long axis of the condyle. The MR images selected for the analysis of the disk-condyle relationship depicted the disk, condyle, articular eminence, and glenoid fossa. Normal disk position was defined by the location of the posterior band of the disk at the superior or 12 o'clock position relative to the condyle. Disk displacement was diagnosed in patients in whom the posterior band of the disk was in anterior, anteromedial, anterolateral, medial or lateral position relative to the superior part of the condyle^{5,24}. The following dichotome diagnostic criteria¹ were used: degenerative changes, disk displacement (closed-mouth and maximum-mouth-opening position) and effusion^{13,14,23,24}. Degenerative changes were defined as erosions on the surface of the condyle. Sensitivity (SE), specificity (SP), accuracy (AC), positive predictive value (PPV) and negative predictive value (NPV) were calculated. SPSS[®] Version 7.5 (SPSS Inc.) was used.

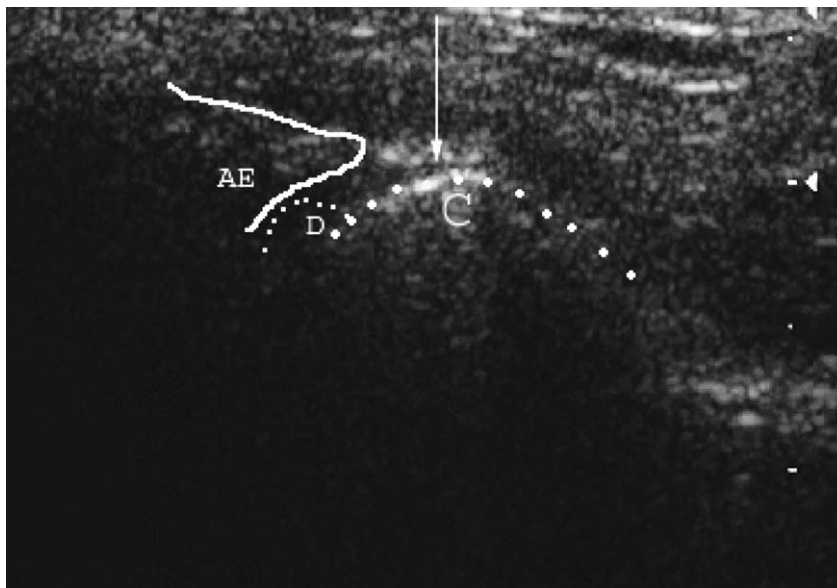


Fig. 3. Ultrasonic image of a temporomandibular joint with a regular disc. The arrow shows to the narrow joint space. The disc (D) is marked with small dots. The condyle (C) is marked with big dots. Articular eminence (AE).

Results

The MRI investigation showed degenerative changes in 190 joints (95%), while an effusion was found in 59 (29.5%) joints. At closed-mouth position

a disc displacement was found in 138 joints (69%) and in maximum-mouth-opening position disc displacement was diagnosed in 76 joints (38%). The HR-US investigation was true-positive in the diagnosis of degenerative changes in

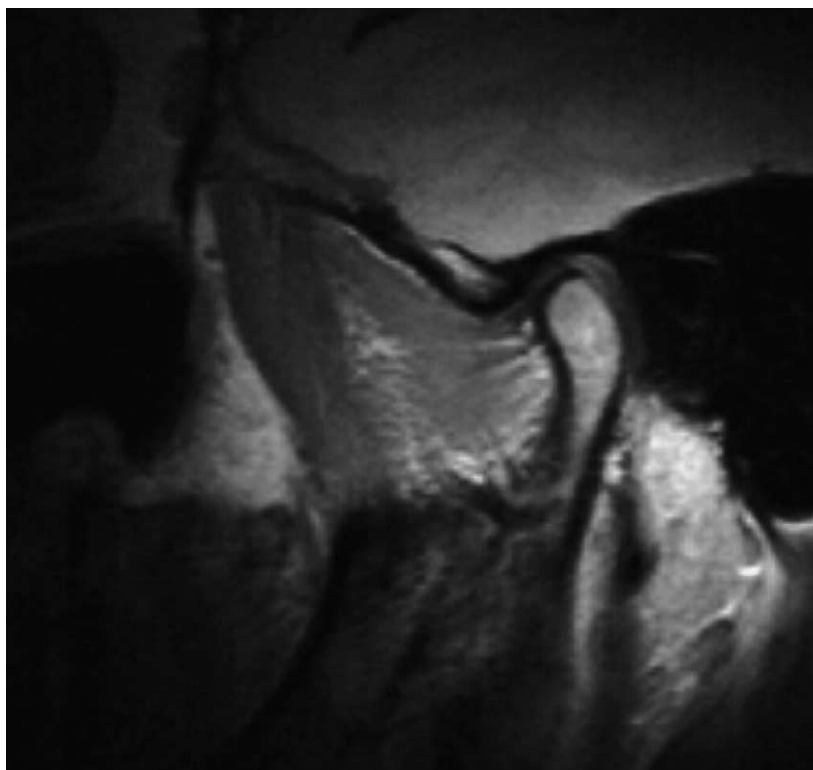


Fig. 4. MRI image (Pd) of the temporomandibular joint. The articular disc appears in its regular position.

178 joints and true-negative in 10 joints (Table 1). False negative results were found in 12 joints. In the detection of effusion HR-US showed 48 true-positive and 141 true-negative results. In 11 joints the HR-US investigation was false negative. In the determination of disc displacement at closed-mouth position the ultrasound investigation was true-positive in 127 joints and true-negative in 57 joints. False-positive results were found in 5 joints and in 11 joints the HR-US investigations were false-negative. The detection of disc displacement at maximum-mouth-opening position by HR-US was true-positive in 66 patients and true-negative in 113 patients. In 11 joints HR-US showed a false-positive result in the determination of disc displacement at maximum-mouth-opening position while in 10 joints a HR-US showed a false negative result (Table 1).

In the determination of degenerative changes HR-US showed a sensitivity of 94%, a specificity of 100% and an accuracy of 94%. PPV was calculated to be 100% and NPV reached 45% (Table 2). In the detection of effusion HR-US yielded a sensitivity of 81%, a specificity of 100% and an accuracy of 95%. PPV reached 100% and NPV was found to be 93%. In the determination of disk dislocation at closed-mouth position HR-US showed a sensitivity, specificity and an accuracy of 92% each. PPV yielded 96% while NPV reached 84%. At maximum-mouth-opening position HR-US reached a sensitivity of 86%, a specificity of 91% and an accuracy of 90%. PPV yielded 86% and NPV was found to be 92% (Table 2).

Discussion

A comparison with previously reported results in the literature is difficult, because all these studies used static HR-US, while in the current study the movement of the disk was viewed as well. The way how the disk is moving during the mouth opening movement can only be described qualitatively which makes a statistical evaluation difficult. However, the visualization of the disk-movement could help the investigator to determine its position at the beginning and the end of the mouth opening movement more clearly. A real-time dynamic investigation by MRI is not possible, but MRI is the gold-standard we have to use to compare our results. HR-US is a method where the disc movement could be visualized directly and if something is unclear the patient could be asked to move his

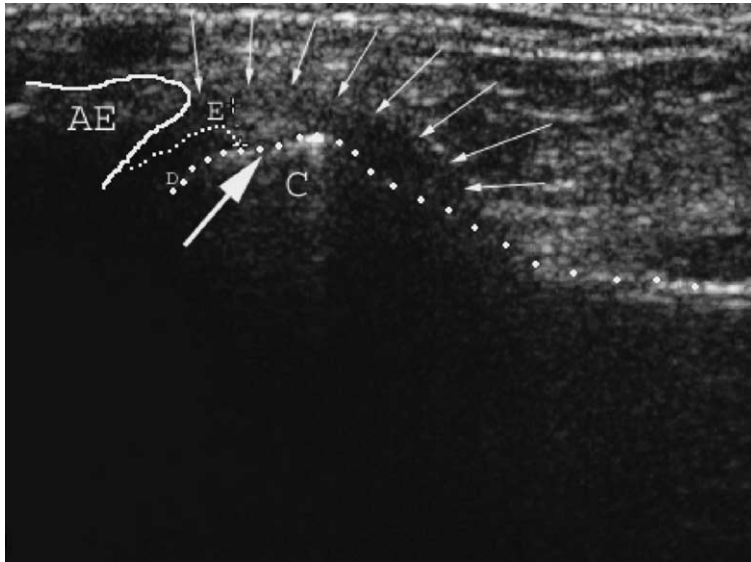


Fig. 5. Ultrasonic image of a temporomandibular joint with disc displacement, destructive changes and an effusion. The displaced disc (D) is marked with small dots. The condyle (C) is marked with big dots. The effusion (E) is marked with small arrows. The surface of the condyle is irregular, which indicates degenerative changes (big arrow). Articular eminence (AE).

jaw again. In the end the result can be reduced to the question if the disk is dislocated at closed-mouth position and maximum-mouth-opening position or not.

At the moment there exists no classification system for TMJ-sonography, which makes a comparison between MRI and HR-US difficult. Therefore, we



Fig. 6. MRI image (Pd) of the temporomandibular joint shown in Fig. 5. The articular disc appears laterally luxated.

suggest, that in the future a classification system for TMJ-sonography has to be established to make this method easier and more reproducible for the investigator.

In previous studies the detection of disk displacement at closed-mouth position showed a sensitivity between 89%^{2,8} and 90%^{9,10}, and a specificity between 84%^{2,8,10} and 87%⁹, while at maximum-mouth-opening position showed a sensitivity between 73%^{2,8,10} and 88%⁹, and a specificity between 88%⁹ and 95%^{2,8,10}, were reported. The accuracy is documented in the literature with values of 79%⁹, 86%¹⁰ and 88%^{2,8} at closed-mouth position, while at maximum-mouth-opening position accuracy was reported with values between 83%⁹ and 86%^{2,8,10}. Compared to the interpretations in the current study, dynamic HR-US achieved the same or even better statistical values than those reported in the literature^{2,8-10}. The HR-US interpretations of the TMJ showed acceptable results, because SE, SP, PPV and NPV reached in nearly all of the investigated parameters values over 85%. According to degenerative changes and effusion a comparison with previous studies is impossible because these parameters have not been reported yet. With the exception of the NPV the interpretations reached statistical values over 85%. This seems to be a sign that these parameters could be investigated with a high reliability by HR-US.

MRI is still the gold-standard in the literature^{7,11,12,15,17,21,23} and the results in the current study show, that dynamic HR-US could not reach the diagnostic quality of the MRI-investigation. However, in some cases a MRI-investigation is impossible like in patients with claustrophobia and intracerebral vessel-clips. Further, a MRI-investigation takes about 20 min time, which makes such an investigation especially in smaller children impossible or requires a sedation or general anesthesia. In the two cases mentioned above an ultrasound investigation of the TMJ could be a helpful diagnostic method. MRI is not available in every clinic and the patients often have to wait for a long time to get an appointment for a MRI-investigation, while ultrasound is a widely available. Of course, TMJ-sonography requires excellent US equipment which is normally not available in private practices. However, in an Oral and Maxillofacial Department there should be the possibility for ultrasound investigation, which leads to the possibility that clinical and

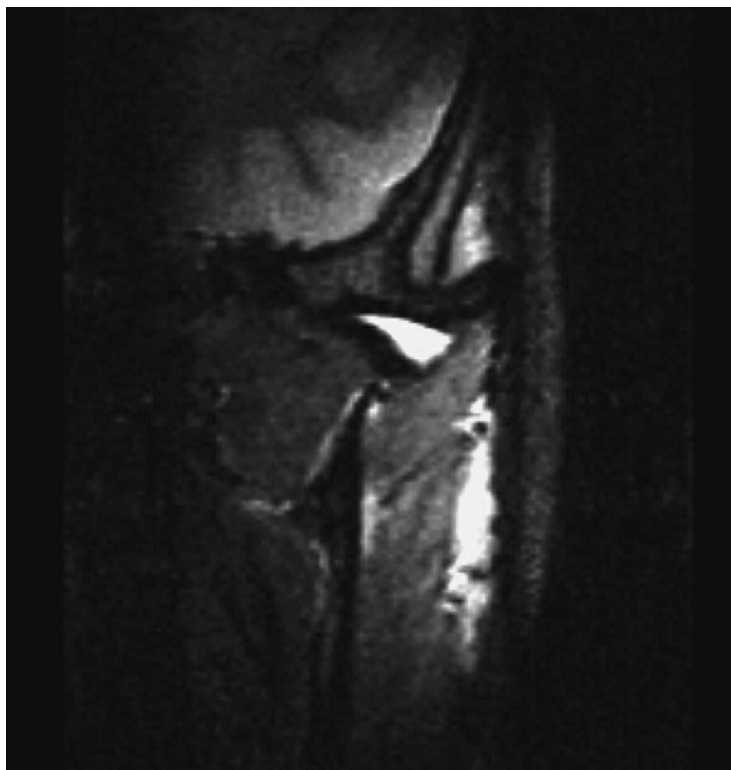


Fig. 7. MRI image (Ti) of the temporomandibular joint shown in Fig. 5. The effusion appears as a white triangle.

imaging investigation could be performed by one person. A great advantage of ultrasonography is, that the dentist or maxillofacial surgeon himself can perform this investigation. Referring to this fact the clinical and radiological diagnosis is in the same hand, which could lead to a diagnostic progress. A further disadvantage is the high cost of

an MRI investigation of the TMJ. The cost in Austria of such an investigation is approximately 450 Euro, while an ultrasound investigation costs about 40 Euro in Austria. The question is, if HR-US is able to be an alternative method to a MRI investigation and if the results of the current study imply a revision of the criteria for a MRI investigation. In

Table 1. Interpretations of ultrasonography in the investigation of the TMJ

	Deg.	Eff.	Disl. CM	Disl. MOP
True-positive	178	48	127	66
True-negative	10	141	57	113
False-positive	0	0	5	11
False-negative	12	11	11	10

Deg., degenerative changes; Eff., effusion; Disl. CM, disc dislocation at closed-mouth position; Disl. MOP: disc dislocation at maximum-mouth-opening position.

Table 2. Statistical results of ultrasonography in the evaluation of the TMJ

	Deg.	Eff.	Disl. CM	Disl. MOP
Sensitivity	0.94	0.81	0.92	0.86
Specificity	1.0	1.0	0.92	0.91
PPV	1.0	1.0	0.96	0.86
NPV	0.45	0.93	0.84	0.92
Accuracy	0.94	0.95	0.92	0.90

Deg., degenerative changes; Eff.: effusion; Disl. CM: disc dislocation at closed-mouth position; Disl. MOP: disc dislocation at maximum-mouth-opening position; PPV: positive predictive value; NPV: negative predictive value.

the authors opinion further studies have to be done, before MRI could be replaced by HR-US completely. At the moment the authors would not feel comfortable going on surgery on the basis of HR-US criteria alone.

The problem of US is, that the investigator is moving the transducer while he is looking on the screen. A print of the US image does not contain all the information which the investigator can see on the screen during the real-time investigation; therefore a video could be helpful. Further, if one would go to surgery on the basis of HR-US, the surgeon proceeding with the surgical intervention should do the US investigation as well. US is a diagnostic method which requires a lot of experience and the documentation is difficult, so the responsibility for an open surgery should lie completely with the surgeons.

One possibility would be to perform an ultrasound investigation first, and if there are some unclear symptoms or signs remaining then perform an MRI-investigation with a special focus on these items. The results of the current study imply that HR-US is a valuable diagnostic imaging method of the TMJ which can be used as an alternative method to a MRI-investigation, but is yet not able to replace it. Further studies have to be done to reduce false-negative results.

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