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Original contribution

# T2 mapping with 3.0 T MRI of the temporomandibular joint disc of patients with disc dislocation

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ABSTRACT

*Introduction:* T2 mapping, as a quantitative biochemical MRI-technique that provides information on water and collagen fiber content and composition, was shown to be clinically feasible for the evaluation of healthy temporomandibular joints.
*Objectives:* The aim of our study was to compare the T2 values of whole discs in patients with and without disc dislocation, to evaluate the possible influence of morphological findings on T2 values and to assess the interrater agreement.
*Methods:* Sixty-six patients were included in the study. Three experienced examiners assessed the perceptibility of the morphological parameters and the position of the articular disc on the morphological MR images. On the T2 maps, the T2 values of the region-of-interest (ROI) were assessed.
*Results:* The ICC (Intraclass Correlation Coefficient) for the reproducibility of the T2 values was 0.717. The assessment of the morphologic parameters was excellent or good in most of the discs. There was no significant difference in the T2 values based on disc position or signal intensity. But, a statistically significant moderation effect ($p = .014$) could be identified, indicating that the effect of disc position differs for different signal intensities. Condyle position, effusion, and degenerative changes showed pronounced moderation effects on the T2 values.
*Conclusion:* Due to the high sensitivity to effusion, T2 mapping currently seems to be unsuitable as a diagnostic tool for routine use in the temporomandibular joint. The moderation effect clearly shows the influence of factors such as signal intensity, effusion, arthrosis, and condyle position. Perhaps a solution for these problems could be the development of dedicated TMJ coils for higher field strengths at 7.0 T.

## 1. Introduction

Disc dislocation of the temporomandibular joint (TMJ) is very common and involves symptoms such as clicking noises, restricted mouth opening, and pain. Displacement of the disc can occur on the anterior, medial, or lateral side. The reposition of the disc during the opening movement can be experienced as clicking. In severe cases, when the reposition of the disc is not possible, a restricted opening movement may be the consequence and these problems can lead to an overall reduction in the oral, health-related quality of life [1].

Magnetic resonance imaging (MRI) is a non-invasive diagnostic technique that provides excellent soft-tissue contrast with delineation of disc morphology and position. In addition, the bony articular structures of the TMJ, as well as joint effusion, can be evaluated [2]. High-field-strength MR systems operating at 3.0 T have been available for several years and have been increasingly used to evaluate the TMJ [2]. In a study of healthy TMJs, Stehling et al. were able to demonstrate that the use of 3.0 T scanners allowed for an improved analysis of the small

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joint structures [3]. Precise visibility and clear evaluability of joint structures are of major importance for the diagnostic assessment of abnormalities and are also important tools for optimum therapy planning and for the control of splint therapy [4,5]. As clinical diagnosis does not always provide a complete evaluation of joint structures [6–10], accurate diagnostic assessment with MRI is indispensable. A statistically significant correlation between an increased signal on T2-weighted images in the posterior disc attachment and the presence of pain has been demonstrated [11]. Schmid-Schwap et al. showed that 3.0 T MRI at the same resolution as 1.5 T yielded better results for perceptibility of joint structures without increasing the examination time [12]. In morphological MRI, the diagnosis of the TMJ disc is limited to changes in the signal intensity within the articular disc, changes in shape, and the evaluation of the position of the TMJ disc relative to the surrounding structures. Structural changes of the disc so far can only be estimated by signal alterations and inhomogeneities in morphological MRI. Biochemical imaging techniques offer the chance of detection of these changes in earlier stages and hence foster therapy to avoid severe structural damage of the joint. The compositional (biochemical) T2 mapping, as a quantitative MRI technique, was shown to be feasible for the evaluation of healthy temporomandibular joints [13]. Using optimized protocols at a field strength of 3.0 T and a dedicated TMJ coil, the collagen fiber content and water content can be quantified [14].

The aim of our study was to compare the T2 mapping data for the entire TMJ with dislocated discs (subluxation, partial anterior disc dislocation [ADD]) with T2 values of TMJs with discs in a normal position, to evaluate the possible influence of morphological findings and to assess the interrater agreement.

## 2. Materials and methods

### 2.1. Patients

Approval from the local ethics committee was obtained before the examinations of the patients. Patients participating in the study signed written, informed consent.

Between 2013 and 2015, 95 patients were recruited. Included were patients who had pain in one or both TMJ and who showed a displaced disc with or without reposition (ADD) in one or both joints on routine clinical MRI of the TMJ. Exclusion criteria were as follows: age under 18 years; fixed orthodontic appliances; foreign metallic bodies in the head and neck area; cardio-stimulators; claustrophobia; tremor or movement disorders; gravidity; and severe osteoarthritis in the TMJ. Twenty-one patients refused to participate, eight failed to appear for the MRI examination.

Sixty-six patients (48 [72.7%] female and 18 [27.3%] male) were included in this study.

### 2.2. Magnetic resonance imaging

All MR examinations were performed on a 3.0 T MR scanner (Magnetom TIM Trio, Siemens Healthcare, Erlangen, Germany) using a dedicated eight-channel, flexible, multi-element coil (Noras, Würzburg, Germany). Parasagittal- and paracoronal-oriented MR images in the supine position with the mouth closed and the mouth opened were acquired using standardized wedge blocks (25 mm; depending on mouth-opening restrictions). A multi-echo multi-slice Carr-Purcell-Meiboom-Gill (CPMG) sequence was used in the sagittal plane with the mouth in the closed position [15]. The echo train of 10 echoes was used for data acquisition. Echoes were as follows: 11.2, 22.4, 33.6, 44.8, 56.0, 67.2, 78.4, 89.6, 100.8, 112.0 ms. All together 12 slices were acquired, 6 slices covered left TMJ disc and 6 slices covered right TMJ disc. Slices were 2 mm thick with 10% inter-slice gap. Field-of-view was setup to 155 mm × 155 mm, while matrix was 384 × 384. It resulted in the nominal in-plain resolution of 0.4 mm × 0.4 mm. The examination time for one series of T2 maps was approximately 15 min. The T2 maps were calculated immediately after the examination on the Siemens console, using build in T2 mapping software Mapit (Siemens, Erlangen, Germany). Resulting images were anonymized and exported from the

**Table 1**
List of the most important MRI parameters used for the examination.

| | CPMG | CPMG | PD |
|---|---|---|---|
| | Sagittal (closed position) | Sagittal (open position) | Parasagittal (closed position) |
| FOV (mm × mm) | 155 × 155 | 155 × 155 | 90 × 90 |
| Number of slices (left + right) | 6 + 6 | 6 + 6 | 11 + 11 |
| Slice thickness (mm) | 2 | 2 | 2 |
| Slice separation (mm) | 2.2 | 2.2 | 2.2 |
| Number of averages | 1 | 1 | 1 |
| TR (ms) | 1440 | 1440 | 1810 |
| TE (ms) | 11.2–112.0 | 11.2–112.0 | 30 |
| Echo train | 10 | 10 | 1 |
| Total acquisition time (min:*sec*) | 14:47 | 14:47 | 4:56 |
| Acquisition matrix (pix) | 384 × 384 | 384 × 384 | 384 × 384 |
| Percent phase field of view (%) | 100 | 100 | 100 |
| Percent sampling (%) | 100 | 100 | 100 |
| Pixel bandwidth (Hz/pix) | 200 | 200 | 161 |
| MR acquisition type | 2D | 2D | 2D |
| Reconstructed matrix (pix) | 384 × 384 | 384 × 384 | 768 × 768 |
| Pixel spacing (mm) | 0.40 × 0.40 | 0.40 × 0.40 | 0.12 × 0.12 |

**Fig. 1.** Figure shows contours of TMJ disc drawn in first echo of multi-echo multi-slice T2 mapping sequence.

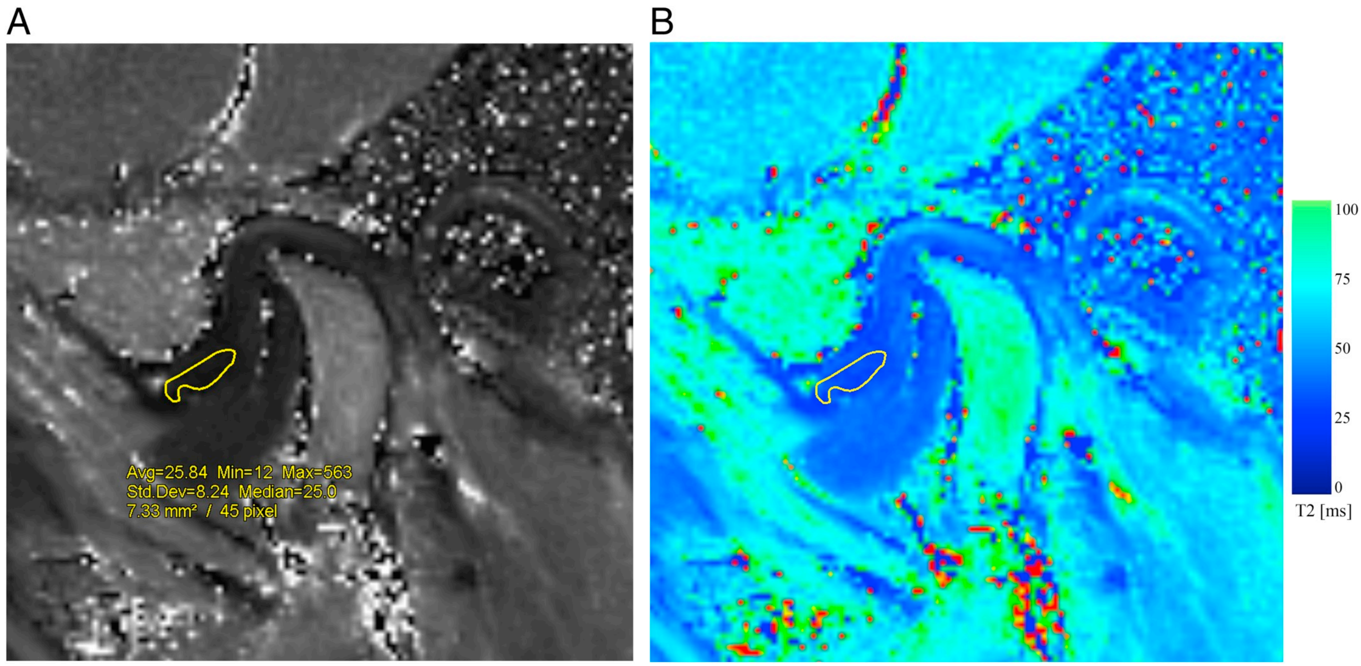


**Fig. 2.** A: T2 map of the TMJ with disc dislocation and contour of the disc in grayscale. The values of the ROI area, mean T2 value within the ROI, and its standard deviation are displayed.
B: Color interpretation of the same TMJ disc with color-bar indicating range of T2 values.

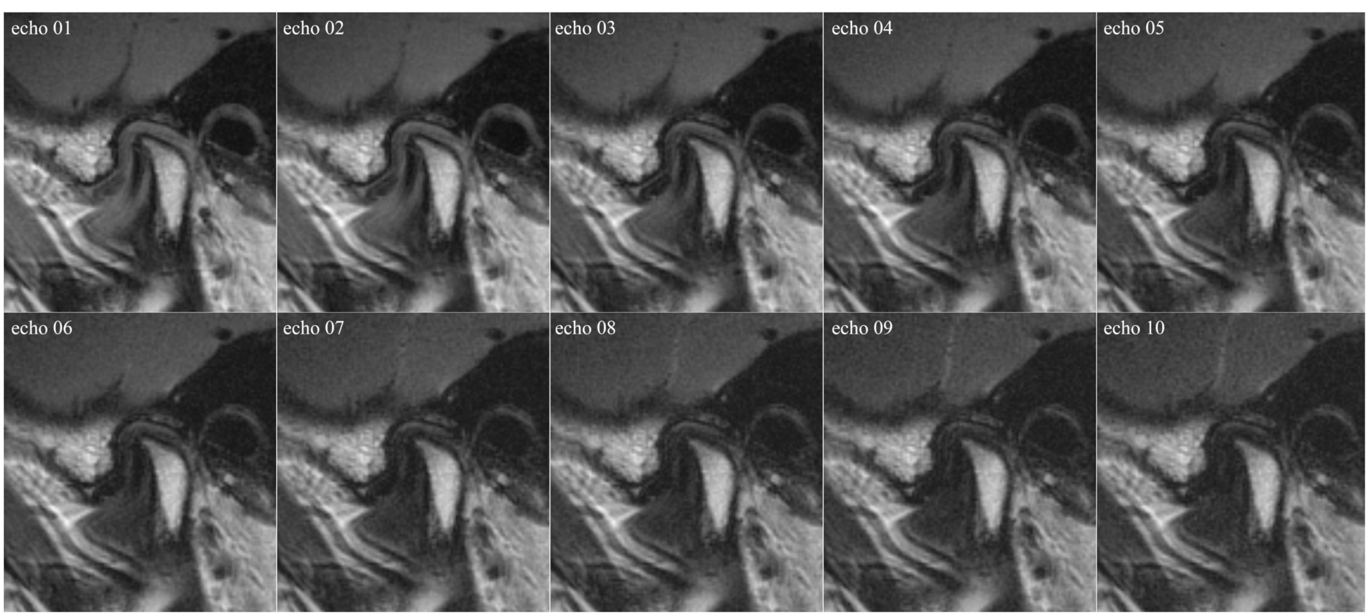


**Fig. 3.** Series of single-echo images showing signal intensity decay along echo time-evolution. Figure "echo 01" represents image acquired with echo time of 11.2 ms. Figure "echo 10" represents longest echo-time images of 112 ms.

**Table 2**
The mean T2 relaxation times values of right vs. left joint is shown.

| | Side | N | Mean | Std. deviation | p-Value |
|---|---|---|---|---|---|
| T2 [ms] | Right | 61 | 25.8 | 3.8 | 0.903 |
| | Left | 61 | 25.7 | 3.6 | |
| | Total | 122 | 25.8 | 3.7 | |

Siemens console into the DICOM format. Such data were processed offline. The most important MR imaging parameters are summarized in Table 1.

### 2.3. Image analysis

Ten joints were excluded from T2 analysis due to extreme artifacts and degeneration (disc remnants). Therefore, a total 122 discs were included in the evaluation. Three experienced examiners (dentists who

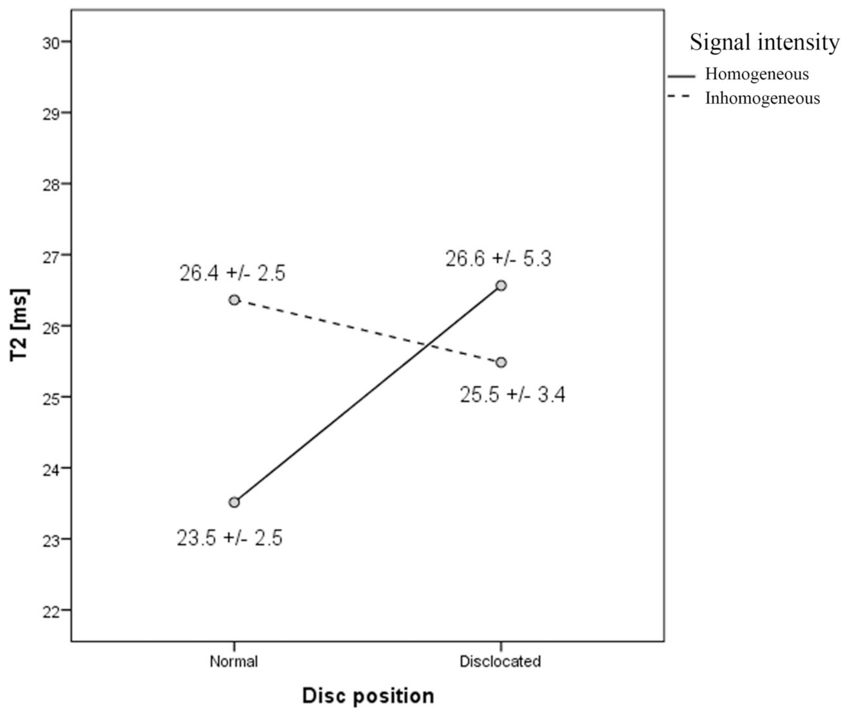


**Fig. 4.** Moderation Effect of disc position vs. signal intensity.

**Table 3**
Moderation effect of disc position and signal intensity vs. T2 values.

| Disc position | Signal intensity | Mean | Std. deviation | N |
|---|---|---|---|---|
| Normal | Homogeneous | *23,5* | *2,5* | *10* |
| | Inhomogeneous | *26,4* | *2,5* | *31* |
| | Total | *25,7* | *2,8* | *41* |
| Disclocated | Homogeneous | *26,6* | *5,3* | *25* |
| | Inhomogeneous | *25,5* | *3,4* | *56* |
| | Total | *25,8* | *4,1* | *81* |
| Total | Homogeneous | *25,7* | *4,8* | *35* |
| | Inhomogeneous | *25,8* | *3,1* | *87* |
| | Total | *25,8* | *3,7* | *122* |

| Source | p-Value |
|---|---|
| Disc position | *0.171* |
| Signal intensity | *0.264* |
| Disc position ∗ Signal intensity | *0.014* |

specialized in TMJ dysfunction syndrome for 12–20 years) assessed the morphological parameters and the perceptibility of position/delineation in relation to the surrounding tissue and morphology of the disc on morphological MR images, using a five-point scale (1 = excellent, 5 = very poor/insufficient). The main parameters that were evaluated included: disc shape; signal intensity; condyle position; effusion; and osteoarthritis in the TMJ.

The OsiriX® software (Pixmeo SARL, Geneva area, Switzerland) was used for offline quantitative evaluation of MR images.

The assessment of the morphology of the disc in "homogenous signal intensity" or "signal inhomogeneities" classification was performed on PD FSE according to Katzberg 2005 [2].

The T2-weighted image with the best contrast between the TMJ disc and the surrounding structures was selected from 12 slices total (one image from six slices on the left side and one image from six slices on the right side). In these images, the contours of the whole TMJ discs (ROI) were drawn following the protocol of the pilot study (Fig. 1) [13]. These contours were transferred via the Copy & Paste function onto the T2 maps. This procedure was performed by the three examiners separately to assess the interrater agreement. The software provides the values of the ROI area, mean T2 value within the ROI, and its standard deviation (Fig. 2A).

### 2.4. Statistical analysis

All statistical evaluations were performed using IBM SPSS Statistics for Windows version 24.0. Metric data, such as T2 values, are presented using mean ± SD. Different joint (dis)locations were compared using a two-way mixed-model ANOVA (fixed effect: disc location, random factor: patient) in order to take into account multiple joints per patient. A three-way mixed-model ANOVA (fixed effects: disc position and signal intensity; random effect: patient) was used to test the effect of disc position and signal intensity on T2 values. In order to take additional effects, such as effusion, osteoarthritis, and condyle position, into account, three separate four-way mixed-model ANOVAs were used.

To assess the reproducibility of T2 evaluation, inter-observer variability was calculated, using an Intraclass Correlation Coefficient (ICC), from three different evaluations, in each disc, by three experienced independent raters. *p*-Values equal to or below 0.05 ($p \leq .05$) were considered statistically significant results.

## 3. Results

The mean age of the patients was 36.12 years (range, 20–69). Example T2 map in grayscale (Fig. 2A) and in color representation (Fig. 2B) show contrast between cartilage and surrounding tissue. Fig. 3 shows series of echo-time weighted images from the same slice, as

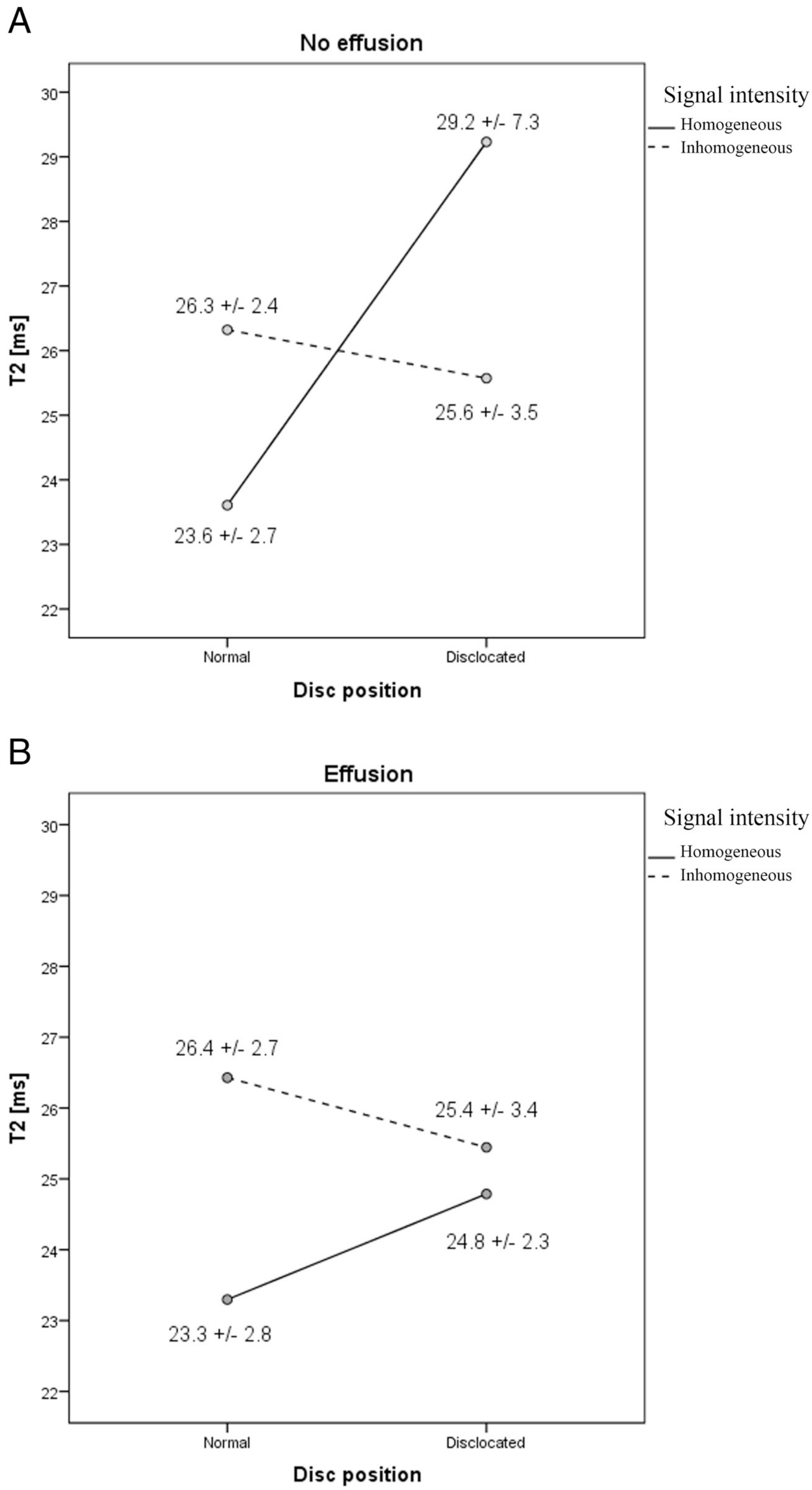


**Fig. 5.** A/B: Moderation Effect of disc position vs. signal intensity and effusion.

**Table 4**
Moderation effect of disc position and signal intensity effusion vs. T2 values.

| Disc position | Signal intensity | Effusion | Mean | Std. deviation | N |
|---|---|---|---|---|---|
| Normal | Homogeneous | No effusion | 23,6 | 2,7 | 7 |
| | | Effusion | 23,3 | 2,8 | 3 |
| | | Total | 23,5 | 2,5 | 10 |
| | Inhomogeneous | No effusion | 26,3 | 2,4 | 19 |
| | | Effusion | 26,4 | 2,7 | 12 |
| | | Total | 26,4 | 2,5 | 31 |
| | Total | No effusion | 25,6 | 2,7 | 26 |
| | | Effusion | 25,8 | 3,0 | 15 |
| | | Total | 25,7 | 2,8 | 41 |
| Disclocated | Homogeneous | No effusion | 29,2 | 7,3 | 10 |
| | | Effusion | 24,8 | 2,3 | 15 |
| | | Total | 26,6 | 5,3 | 25 |
| | Inhomogeneous | No effusion | 25,6 | 3,5 | 17 |
| | | Effusion | 25,4 | 3,4 | 39 |
| | | Total | 25,5 | 3,4 | 56 |
| | Total | No effusion | 26,9 | 5,4 | 27 |
| | | Effusion | 25,3 | 3,1 | 54 |
| | | Total | 25,8 | 4,1 | 81 |
| Total | Homogeneous | No effusion | 26,9 | 6,4 | 17 |
| | | Effusion | 24,5 | 2,4 | 18 |
| | | Total | 25,7 | 4,8 | 35 |
| | Inhomogeneous | No effusion | 26,0 | 2,9 | 36 |
| | | Effusion | 25,7 | 3,2 | 51 |
| | | Total | 25,8 | 3,1 | 87 |
| | Total | No effusion | 26,3 | 4,3 | 53 |
| | | Effusion | 25,4 | 3,1 | 69 |
| | | Total | 25,8 | 3,7 | 122 |

| Source | p-Value |
|---|---|
| Disc position | 0.104 |
| Signal intensity | 0.388 |
| Effusion | 0.149 |
| Disc position * Signal intensity | 0.008 |
| Disc position * Effusion | 0.186 |
| Signal intensity * Effusion | 0.152 |
| Disc position * Signal intensity * Effusion | 0.237 |

shown on Fig. 2A and B. Images differ in increasing echo time (echo 01 is shortest: 11.2 ms, echo 10 is longest: 112 ms). There is obvious change of contrast between individual tissue types, based on the echo time.

The ICC with regard to the reproducibility of the T2 values by the three raters was 0.717.

The assessment of the morphologic parameters was excellent or good in most of the discs. The disc morphology assessment was moderate in eight (rater 1 + 2) or 10 (rater 3) discs and poor in one disc (rater 3).

The resulting T2 values did not show statistically significant differences between different subgroups (subluxation, partial anterior disc dislocation [ADD], with and without repositioning). Therefore, for further statistical analyses dislocated discs were summarized in one group and compared to joints with normal discs position.

The mean values of biochemical analysis (T2 relaxation time mapping) are shown in Table 2.

The lowest T2 values were found in discs in a normal position with homogeneous signal intensity, and the highest T2 values appeared in dislocated discs with homogeneous signal intensity. In discs with inhomogeneous signal intensity the T2 values were the opposite. These discs showed high T2 values in a normal disc position and low T2 values in dislocated discs (Fig. 4, Table 3). This moderation effect showed a statistical tendency over all raters, but, when calculated for a single rater, this effect became statistically significant for rater 1 ($p = .014$).

The parameters effusion (Fig. 5A, B, Table 4), degenerative changes (Fig. 6A, B, Table 5), and condyle position (Fig. 7A,B, Table 6) showed an additional influence on the T2 values depending on the signal intensity of the disc in terms of a moderation effect.

## 4. Discussion

The results show, that there was no significant difference in the T2 values based on disc position or signal intensity. But, a statistically significant moderation effect ($p = .014$) could be identified, indicating that the effect of disc position differs for different signal intensities. Condyle position, effusion, and degenerative changes showed pronounced moderation effects on the T2 values.

The importance of MRI in the diagnosis of TMD has been confirmed in numerous studies [2,6]. Improvement in the quality of TMJ MRI could be achieved with the use of higher field strengths as a result of the higher signal-to-noise ratio obtained at higher field strengths [16]. T2 mapping is a method that allows quantification of the composition of structures of the joint cartilage. Biochemical T2 mapping has been used to evaluate the early stages of cartilage degeneration and to monitor the healing process of transplants in larger joints, such as the ankle [17], knee [18–22], and femoral condyle [23,24], as well as for the diagnostic and follow-up therapy monitoring of the intervertebral discs [25,26]. In a pilot study with 10 symptom-free volunteers, T2 mapping was shown to be feasible in the temporomandibular joint. These joints showed a normal disc position and no effusion or degenerative changes [13]. In the present study, patients with disc dislocation and pain were enrolled. Therefore, the included joints showed morphologic alterations, such as signal inhomogeneities, degenerative changes, and effusion.

One of the most important functional structures of the TMJ is the fibrocartilaginous disc, composed of collagen type I and II, a significant component of elastic fibers, glycosaminoglycans, and water [27]. Therefore, the detection of early changes in the composition, before morphological changes occur, would be desirable. Early therapy could prevent chronic symptoms. T2 mapping, which has been proven effective in detecting collagen and water content, is a powerful technique that can provide information on the status of cartilage collagen networks without the use of contrast agents [28–30].

In our study, T2 values surprisingly did not show statistically significant differences between discs in a normal position and different subgroups (subluxation, partial anterior disc dislocation [ADD], with and without repositioning). But, the results also show that T2 values are influenced by many factors. Taking other criteria into account, morphological parameters, such as condyle position, signal intensity of the disc, effusion, and degenerative changes, had an effect on the T2 values. When combining the influence of more than one factor, it became clear that the different effects partially canceled each other out; however, as a moderation effect (Figs. 4–7, Tables 4–6). There is a significant moderation effect of signal intensity on the effect of disc position on T2 values ($p = .014$).

Morphologic changes in the disc cartilage can be seen on morphologic MRI sequences as changes in the signal intensity. The strong impact of these changes on the T2 values, shown by the pronounced moderation effect, suggests the conclusion that this is attributable to changes in the collagen and water content of the articular disc.

Different factors, e.g., pressure, may influence the water content of

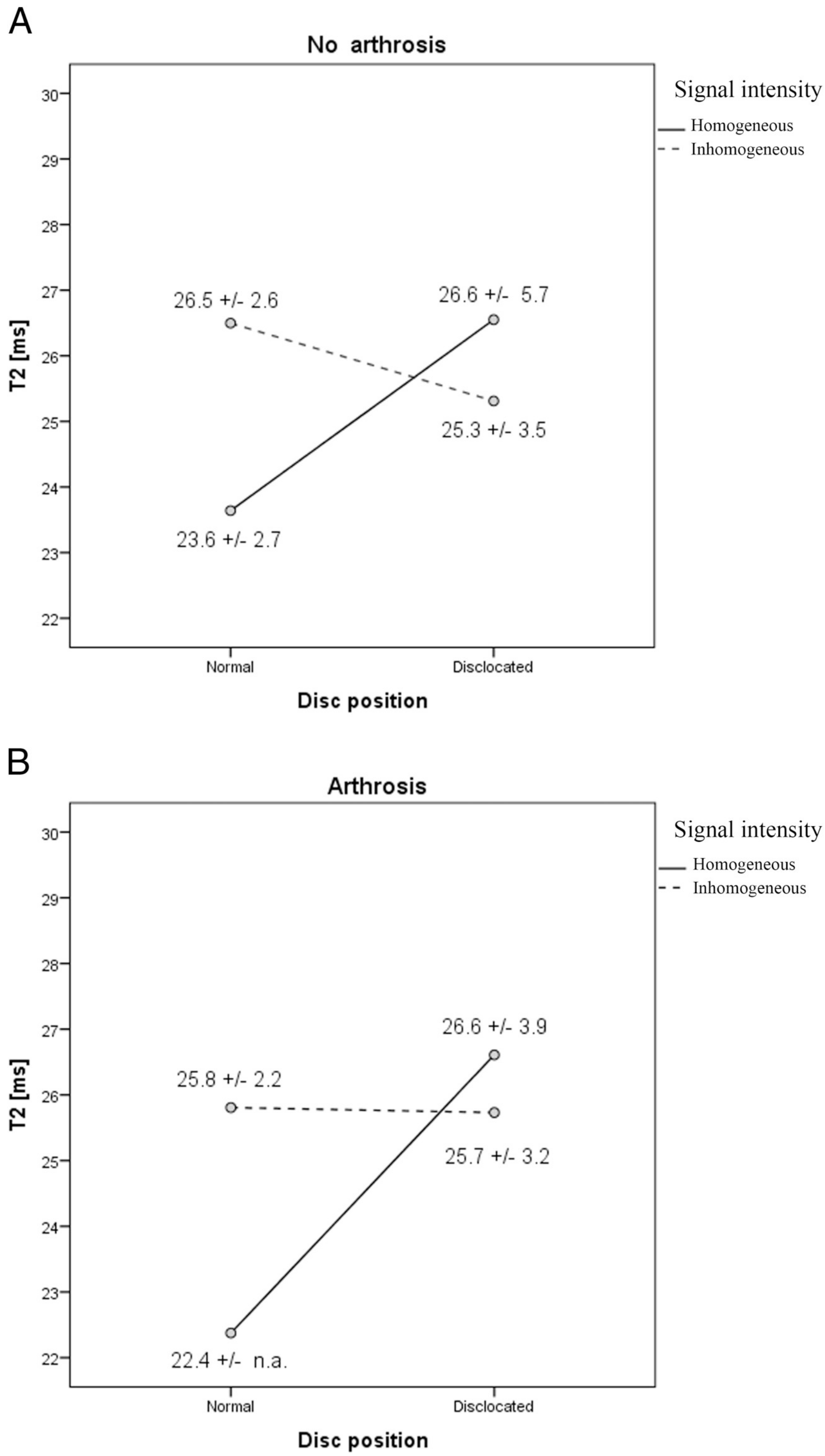


**Fig. 6.** A/B: Moderation Effect of disc position vs. signal intensity and degenerative changes.

**Table 5**
Moderation effect of disc position and signal intensity and degenerative changes vs. T2 values.

| Disc position | Signal Intensity | Arthrosis | Mean | Std. deviation | N |
|---|---|---|---|---|---|
| Normal | Homogeneous | No arthrosis | 23,6 | 2,7 | 9 |
| | | Arthrosis | 22,4 | . | 1 |
| | | Total | 23,5 | 2,5 | 10 |
| | Inhomogeneous | No arthrosis | 26,5 | 2,6 | 25 |
| | | Arthrosis | 25,8 | 2,2 | 6 |
| | | Total | 26,4 | 2,5 | 31 |
| | Total | No arthrosis | 25,7 | 2,9 | 34 |
| | | Arthrosis | 25,3 | 2,4 | 7 |
| | | Total | 25,7 | 2,8 | 41 |
| Disclocated | Homogeneous | No arthrosis | 26,6 | 5,7 | 19 |
| | | Arthrosis | 26,6 | 3,9 | 6 |
| | | Total | 26,6 | 5,3 | 25 |
| | Inhomogeneous | No arthrosis | 25,3 | 3,5 | 33 |
| | | Arthrosis | 25,7 | 3,2 | 23 |
| | | Total | 25,5 | 3,4 | 56 |
| | Total | No arthrosis | 25,8 | 4,5 | 52 |
| | | Arthrosis | 25,9 | 3,3 | 29 |
| | | Total | 25,8 | 4,1 | 81 |
| Total | Homogeneous | No arthrosis | 25,6 | 5,1 | 28 |
| | | Arthrosis | 26,0 | 3,9 | 7 |
| | | Total | 25,7 | 4,8 | 35 |
| | Inhomogeneous | No arthrosis | 25,8 | 3,2 | 58 |
| | | Arthrosis | 25,7 | 3,0 | 29 |
| | | Total | 25,8 | 3,1 | 87 |
| | Total | No arthrosis | 25,8 | 3,9 | 86 |
| | | Arthrosis | 25,8 | 3,1 | 36 |
| | | Total | 25,8 | 3,7 | 122 |

| Source | p-Value |
|---|---|
| Disc position | 0.209 |
| Signal intensity | 0.372 |
| Arthrosis | 0.751 |
| Disc position * Signal intensity | 0.074 |
| Disc position * Arthrosis | 0.602 |
| Signal intensity * Arthrosis | 0.841 |
| Disc position * Signal intensity * Arthrosis | 0.963 |

the joint. The disc's water content sinks as pressure from the osseous joint structures causes increased leakage. This might explain the moderation effect. In normal joints, the condyle is in a relaxed position. In symptomatic patients with clicking noises and pain, a disc dislocation, often in combination with a compression or retral position of the condyle—or sometimes a combination of both—can be observed. The changes in the pressure distribution on the cartilage and the soft tissues can have an impact on the water content, and therefore, on the T2 values. Joints with degenerative changes often show edema in the condyle, which also represents changes in the liquid content of the joint. Similar reactions to changes in T2 values by loading/unloading were demonstrated for the intervertebral discs of the spine [31]. This influence of environmental conditions, such as loading and degeneration on intervertebral discs, was confirmed in a review by Newell et al. [32].

Increased fluid accumulation/retention affects T2 values as well. In the present study, the difference in values of dislocated discs without signal inhomogeneities was amplified by increased fluid levels. In a small joint like the temporomandibular joint, the influence of surrounding parameters seems to be pronounced. But, a similar effect can be demonstrated in larger joints; Çağlar et al. found a statistically significant difference in T2 values between patients with and without an effusion in the knee joint [33].

The strengths of the presented study are the data analysis by three researchers, with a good interrater variability comparable to that of the feasibility study, the exact inclusion criteria, and the verified diagnosis through routine MRI and the high number of examined joints. Limitations should also be noted, such as the high degree of sensitivity of T2 values to artifacts [34] and the presence of fluid in the joint (effusion), and the small surface and volume of the examined articular disc compared to large joints, such as knee joints. Considering that the T2 values of the TMJ disc are relatively short (25 ms), an ultra-short-echo-time (UTE) T2* techniques would be more appropriate for images acquisition. Unfortunately, the UTE techniques are still clinically not available and therefore we utilized more standard CMPG multi-echo multi-slice T2 technique. There was no control group of healthy volunteers, only patients with a normal disc position on one side and with disc dislocation on the other side. The data of symptom free volunteers (mean 26.0 ± 5.0) were published in a feasibility study [13].

## 5. Conclusion

Due to the high sensitivity of T2 mapping and the small size of the TMJ, T2 mapping currently seems to be unsuitable as a diagnostic tool for routine use in the temporomandibular joint of patients with temporomandibular disorders. The moderation effect clearly shows the influence of factors such as signal intensity, effusion, arthrosis, and condyle position. Perhaps a solution for these problems could be the development of dedicated TMJ coils for higher field strengths of 7.0 T and also to utilize the UTE sequence, which would allow to acquire higher signal along the T2* decay, what could result in future in images having higher Signal-to-Noise ratio. Evaluation of such T2* maps could provide lower fluctuation of the T2* values.

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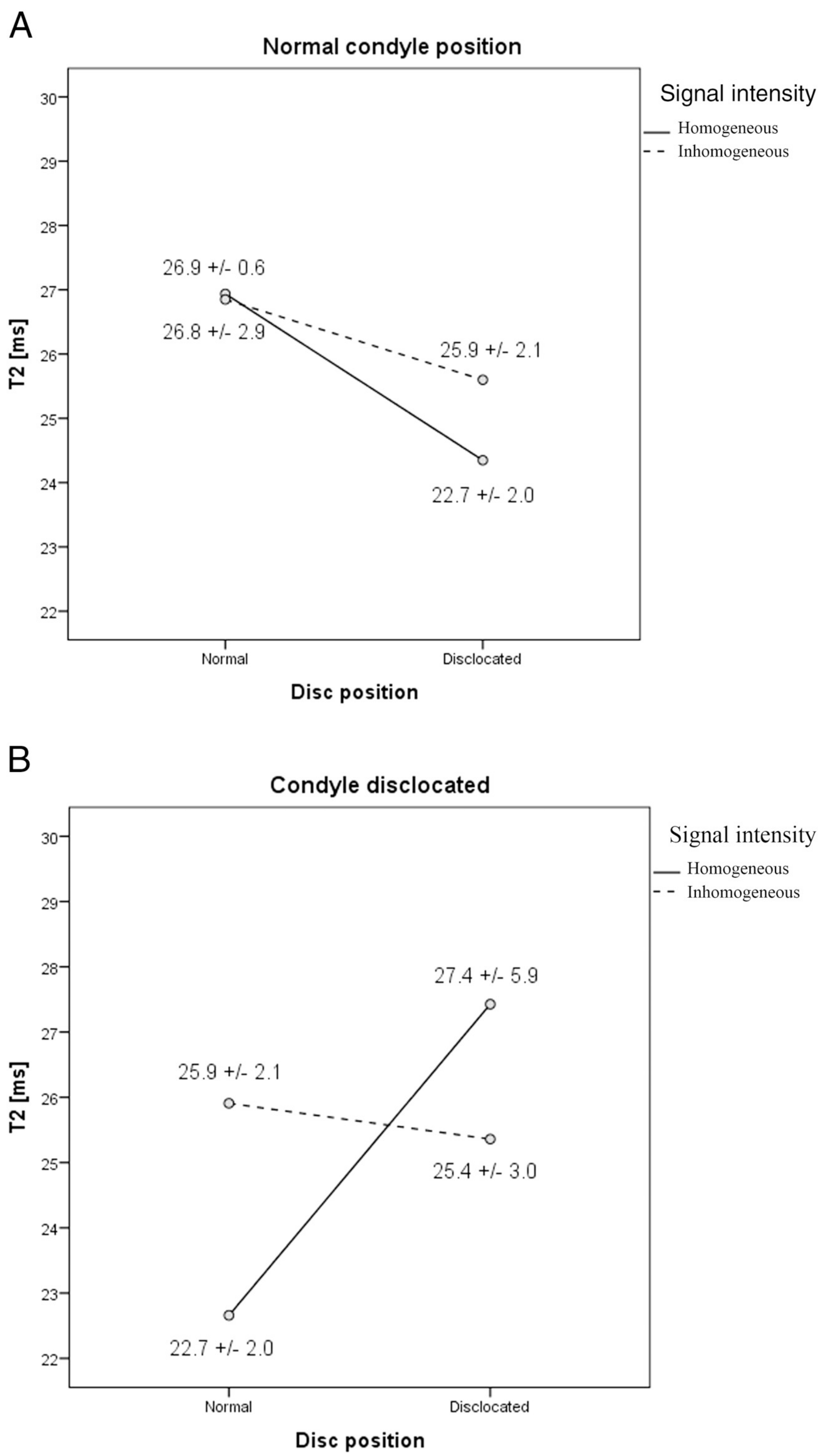


**Fig. 7.** A/B: Moderation Effect of disc position vs. signal intensity and condyle position.

**Table 6**
Moderation effect of disc position and signal intensity and condyle position vs. T2 values.

| Disc position | Signal intensity | Condyle position | Mean | Std. deviation | N |
|---|---|---|---|---|---|
| Normal | Homogeneous | Normal | 26,9 | ,6 | 2 |
| | | Disclocated | 22,7 | 2,0 | 8 |
| | | Total | 23,5 | 2,5 | 10 |
| | Inhomogeneous | Normal | 26,8 | 2,9 | 15 |
| | | Disclocated | 25,9 | 2,1 | 16 |
| | | Total | 26,4 | 2,5 | 31 |
| | Total | Normal | 26,9 | 2,7 | 17 |
| | | Disclocated | 24,8 | 2,5 | 24 |
| | | Total | 25,7 | 2,8 | 41 |
| Disclocated | Homogeneous | Normal | 24,3 | 2,1 | 7 |
| | | Disclocated | 27,4 | 5,9 | 18 |
| | | Total | 26,6 | 5,3 | 25 |
| | Inhomogeneous | Normal | 25,6 | 3,7 | 29 |
| | | Disclocated | 25,4 | 3,0 | 27 |
| | | Total | 25,5 | 3,4 | 56 |
| | Total | Normal | 25,4 | 3,5 | 36 |
| | | Disclocated | 26,2 | 4,5 | 45 |
| | | Total | 25,8 | 4,1 | 81 |
| Total | Homogeneous | Normal | 24,9 | 2,1 | 9 |
| | | Disclocated | 26,0 | 5,5 | 26 |
| | | Total | 25,7 | 4,8 | 35 |
| | Inhomogeneous | Normal | 26,0 | 3,5 | 44 |
| | | Disclocated | 25,6 | 2,7 | 43 |
| | | Total | 25,8 | 3,1 | 87 |
| | Total | Normal | 25,8 | 3,3 | 53 |
| | | Disclocated | 25,7 | 3,9 | 69 |
| | | Total | 25,8 | 3,7 | 122 |

| Source | p-Value |
|---|---|
| Disc position | 0.916 |
| Signal intensity | 0.518 |
| Condyle position | 0.512 |
| Disc position * Signal intensity | 0.274 |
| Disc position * Condyle position | 0.028 |
| Signal intensity * Condyle position | 0.996 |
| Disc position * Signal intensity * Condyle position | 0.068 |

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