Application value of Magnetic Resonance T2 Mapping Imaging in anterior Disc displacement of Temporomandibular Joint

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Abstract:

Objective: To evaluate the changes of T2 value of articular disc in patients with temporomandibular joint disc displacement by magnetic resonance T2 Mapping imaging, and to explore its application value in anterior disc displacement of the temporomandibular joint(TMJ).

Methods: A total of 28 patients with temporomandibular disorder (TMD) were selected from June 2020 to January 2021. 47 cases of diseased joints were diagnosed by diagnostic Criteria for the most common temporomandibular disorder (DC/TMD). Through MRI examination, 9 cases of diseased joints were not displaced, and the other 38 cases of diseased joints were divided into two groups: ADDwoR group (n = 20) and ADDwR group (n = 18). 10 volunteers with normal temporomandibular joints were selected as the control group. Both groups were diagnosed by MR T2-mapping imaging, and the results of the two groups were compared.

Results: there was a significant difference in the total T2 value of the articular disc among the three groups. The T2 value of the articular disc in 20 patients in the ADDwoR group was higher than that in the ADDwR group and normal group. There was no significant difference in T2 value between the ADDwR group and the normal group. There was a significant difference in the anterior zone and posterior zone among the three groups ($P < 0.05$), but there was no significant difference among the three groups. In the anterior zone and posterior zone, the value of T2 in the ADDwoR group was significantly higher than that in the ADDwR group and normal group.

Conclusions: T2 Mapping imaging can be used to evaluate the changes of T2 components of the temporomandibular joint disc, and it is feasible to measure the T2 relaxation time of the temporomandibular joint disc. T2-mapping imaging can accurately detect the T2 value of temporomandibular joint disc in patients with anterior disc displacement of the temporomandibular joint. Among them, the anterior and posterior bands of the articular disc in patients with ADDwoR have more serious pathological changes than those in patients with ADDwR and volunteers, and timely treatment is needed to prevent further progression of the disease.

Keywords: T2 Mapping; temporomandibular joint; joint disc; temporomandibular disorder

Introduction

Temporomandibular disorder (TMD) is one of the common diseases of oral and maxillofacial region. Many temporomandibular joint disorders are related to disc dysfunction, among which anterior disc displacement is a common clinical phenomenon. It includes anterior disc displacement (ADDwR) and anterior disc displacement without the reduction (ADDwoR)(Lai, Huang, Zhou, Xia, & Xiong, 2020).Studies have shown that DC/TMD have excellent reliability in the diagnosis of joint pain(Asendorf et al., 2021). While testing for common intra-articular diseases lacks sufficient validity, it can be used for screening purposes (Schiffman et al., 2014).MRI has the advantages of high resolution and non-invasiveness in surrounding soft tissues, and can distinguish not only the bone cortex and bone marrow, but also the articular disc and cartilage (Ferreira, Grossmann, Januzzi, de Paula, & Carvalho, 2016), and has gradually become the preferred examination method for TMD. Today, the accepted consensus is that MRI is the gold standard for describing the position and shape of the articular disc (Serindere & Aktuna Belgin, 2021).

Although morphological imaging can indeed monitor macro changes more accurately, it cannot provide information about the ultrastructural composition of cartilage (Schreiner et al., 2017). Among them, functional MRI -- T2 Mapping technology is a popular imaging technology in recent years, which has been increasingly applied to large joints, such as knee joints (Yoon et al., 2016). It can measure the T2 value of cartilage to quantitatively analyze the changes in tissue composition of articular cartilage and evaluate the early lesions of articular cartilage (Lindner et al., 2020). The articular disc is similar to the meniscus of the knee in the composition of collagen I and II, glycosaminoglycan, and water (Detamore et al., 2005). The abundant collagen in articular cartilage is arranged in a cross-network, in which the proteoglycan and water are embedded, and the water is fixed in the cartilage by the collagen polysaccharide matrix, in the state of binding water. Therefore, the signal intensity of normal articular cartilage on T2-weighted images is low. If pathological changes occur in cartilage, the loss of collagen and proteoglycan will increase the fluidity of water, leading to an increase in T2 value (Blumenkrantz & Majumdar, 2007; Gold, Chen, Koo, Hargreaves, & Bangerter, 2009; Subburaj et al., 2012; Xia, 2000). For patients with disc displacement, in addition to pain, pop, and other symptoms, changes in the pressure distribution of the displaced disc will affect water content and T2 value. Therefore, patients with anterior disc displacement of the Temporomandibular joint are at increased risk of degenerative changes and joint effusion (Roh, Kim, Kim, & Lee, 2012). The purpose of this study was to explore the application value of T2 Mapping imaging in anterior disc displacement of the temporomandibular joint.

1 Material and Methods

1.1 Population

A total of 28 patients admitted to the Department of Oral and Maxillofacial Surgery of the First Affiliated Hospital of Jinan University from June 2020 to June 2021 were selected. Consent was obtained from all patients and informed consent was signed. DC/TMD was used for preliminary diagnosis, and an MRI imaging examination was performed to obtain the location of the articular disc. Finally, 47 cases of affected joints were obtained, among which the articular disc was not displaced in 9 cases. The other 38 patients were divided into two groups: 20 patients in the ADDwoR group and 18 patients in the ADDwR group. In addition, we recruited 11 normal volunteers as controls, and one of them showed abnormal findings on MRI images, such as disc displacement, so 10 were finally included in the study. Inclusion criteria: meet DC/TMD; the patient did not receive orthodontic, occlusal reconstruction, or TMJ-related treatment; Informed non-consent and non-compliance. Exclusion criteria: Patients with systemic, metabolic, neurological, psychiatric, or immune diseases; MRI contraindications; the patient had a history of oral and maxillofacial trauma. In this study, there were 3 males and 17 females in the normal group, aged 20-52(28.70±8.01) years. In the ADDwR group, there were 4 males and 14 females, aged 18-56(29.22±11.81) years. In the ADDwoR group, there were 1 male and 19 female patient's aged 18-55(27.85±10.43) years. There was no significant difference in the general data of patients in the three groups (P>0.05), as shown in Table 1.

Table 1: Comparison of general data between the two groups [N (%), (x ± s)]

Group	n	Left and right side		Gender		Age
		Left side	Right side	Man	Female	
Normal	20	10(50.0)	10(50.0)	3(15.0)	17(85.0)	28.70±8.01
ADDwR	18	8(44.4)	10(55.6)	4(22.2)	14(77.8)	29.22±11.81
ADDwoR	20	11(55.0)	9(45.0)	1(5.0)	19(95.0)	27.85±10.43
X^2/F	—	0.422		2.401		0.072
P	—	0.810		0.301		0.930

1.2 MRI

The superconducting MRI scanner Signal GEHDxt1.5T was used with a DUAL Temporomandibular joint coil. The closed position scan is carried out first, and then the open position scan is carried out. The shape and position of the articular disc were evaluated mainly based on oblique sagittal adipose inhibition proton density-weighted imaging, and joint effusion was evaluated mainly based on oblique sagittal adipose inhibition T2-weighted imaging. All patients were scanned by the same radiologist, and the scanning sequence and parameters were shown in Table 2.

Table 2: Sequence parameters of 1.5T MRI and T2 Mapping

Sequence(axial plane)	Field of vision (mm)	thick (mm)	Layer spacing(mm)	Repeat the time(ms)	The echo time(ms)	Incentive frequency	Gathering matrix(mm)
T1WI(Sagittal plane)	120x120	2	0.2	400	12	4	256x224
T2WIfs(Sagittal plane)	120x120	2	0.2	3000	85	4	256x224
T2WI PDWI(Coronal axis plane)	120x120	2	0.2	3000	40	4	256x224
T1WI(Coronal axis plane)	120x120	2	0.2	400	12	4	256x224
T2 Mapping(Sagittal plane)	120x120	2	0.2	1200	10	1	256x192

1.3 MR image evaluation

All MR images were independently evaluated by 2 radiologists with more than 8 years of experience. In cases of disagreement, the final diagnosis is made by consensus. The position of the articular disc refers to the classification criteria proposed by DRACE J E.(Drace & Enzmann, 1990): (1) the position of the normal articular disc. In the closed position, the posterior band of the articular disc was located at 12 points relative to the condyle apex, and the joint of the posterior band and the double plate area was located within 10° of 12 points. In the open position, the posterior band was located at the dorsal position of 12 points, which was a normal disk-process relationship. (2) Reversible disc displacement. In the closed position, the posterior band of the articular disc moved forward beyond the normal range, and the opening position returned to the normal disc-protrusion position. (3) Irreversible disc displacement. In the closed position, the posterior band of the articular disc forward exceeded the normal range, and the opening position could not return to the normal disc-protrusion position. The configuration of the articular disc was classified by MURAKAMI S.(Murakami, Takahashi, Nishiyama, Fujishita, & Fuchihata, 1993): (1) double concave; (2) biplane; (3) double convex; (4) semi-convex, (5) folded.

1.4 Measurement of T2 relaxation time

According to the histological study of the articular disc by ALOMAR X et al.(Alomar et al., 2007), the anterior and posterior bands are mainly transverse fibers with inner and outer diameters, while there are anteriorly oriented fibers in the middle. The anterior, middle, posterior, and global T2 values were measured according to the histological structure of the articular disc. Transfer image data to independent workstations (Advantage Workstation, version 4.5; Funtool4.5.5). The Region of interest (ROI) for measuring T2 relaxation time was manually placed over the entire disc, anterior disc, disc, and posterior disc by two independent observers. The T2 relaxation time of the articular disc was calculated using a software program (Functool4.5.5).

To reduce the error of manual measurement, two doctors used the software of the same computer to measure the data of each group 3 times respectively, and then calculated the average value. To measure intra-observer reproducibility, ROI was placed on the entire articular disc of 10 healthy volunteers 10 times on different dates by 2 observers.

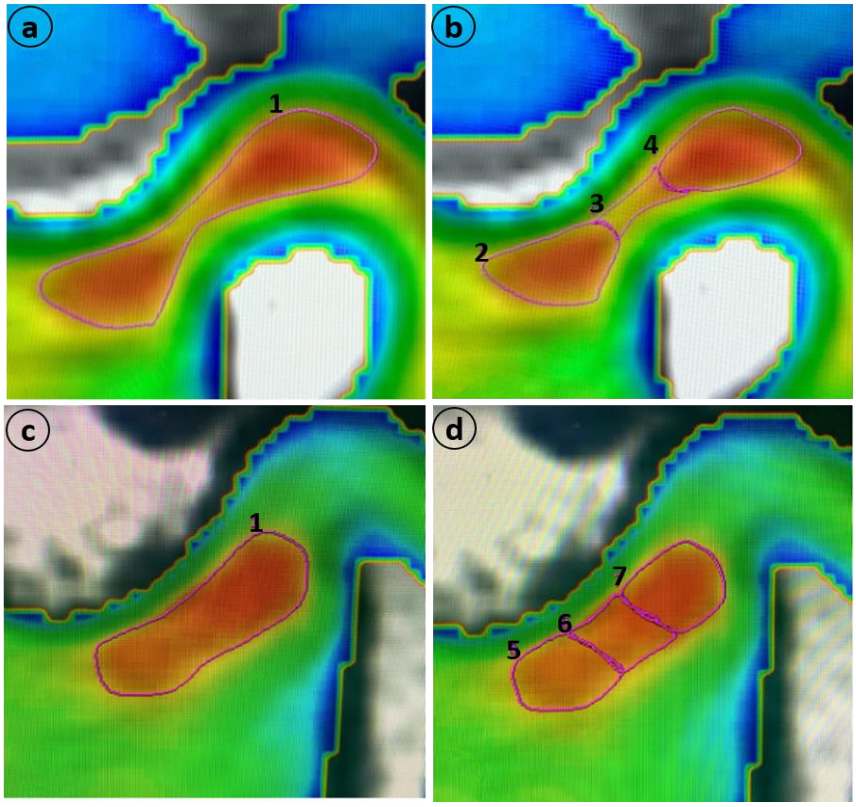

Fig1a and Fig1c: outline of the articular disc in healthy volunteers and the profile of a patient with anterior disc displacement (biplanar); Fig1b: The articular disc of healthy volunteers is divided into anterior (2), middle (3), and posterior bands (4); Fig1d: Anterior disc displacement in a patient the disc is divided into the anterior (5), middle (6), and posterior bands (7)

1.4 The data analysis

SPSS27.0 statistical software was used to analyze the data. The measurement data were presented using standard deviation and one-way analysis of variance. Multiple pairwise tests were performed using LSD analysis. The adoption rate of counting data (%) was indicated by the X2 test and $P<0.05$ was considered as a statistically significant difference.

2 Results

2.1 The total T2 values of the articular disc in each group were compared

The overall T2 values of the articular disc in the ADDwoR group, THE ADDwR group and the normal group were significantly different ($P<0.05$).See table 1.The results of FIG. 2 showed that multiple comparison by LSD test showed that the overall T2 value of the ADDwoR group was higher than that of the ADDwR group and the normal group, and the difference was statistically significant ($P<0.05$), while the overall T2 value of the ADDwR group was higher than that of the normal group, and the difference was not statistically significant ($P<0.05$).

Table3: Comparison of T2 values between the two groups (ms)

Group	n	Whole disc
Normal	20	25.19±1.15
ADDwR	18	25.82±0.69
ADDwoR	20	27.80±2.08
F	—	4.910
P	—	<0.001

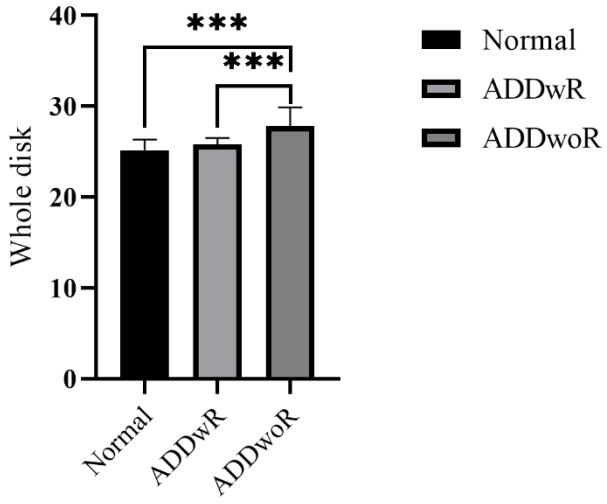

Fig2. Pairwise post-lSD comparison of overall T2 values of the three groups of articular discs

2.2 Comparison of T2 values in each area of the articular disc between the two groups

There were statistically significant differences between the anterior and posterior bands of the ADDwoR group, THE ADDwR group and the normal group (P<0.05), but there was no statistically significant difference between the three groups in the middle band (P>0.05).Are shown in table 2.As shown in Figure 3, multiple comparison by LSD test showed that THE T2 value of the ADDwoR group was higher than that of the ADDwR group and the normal group in both anterior and posterior bands, with statistical difference (P<0.005), indicating that the injury degree of the ADDwoR anterior and posterior bands was the most serious.

Table 4: Comparison of T2 values in each area of the articular disc of patients in the three groups (X ± S, MS)

Group	n	Anterior band	Middle band	Posterior band
Normal	20	25.66±1.43	26.15±2.41	24.08±1.42
ADDwR	18	25.29±1.62	26.09±3.24	24.89±1.10
ADDwoR	20	28.39±3.50	27.99±3.48	26.57±2.79
F	—	3.323	1.947	3.558
P	—	0.001	0.120	0.002

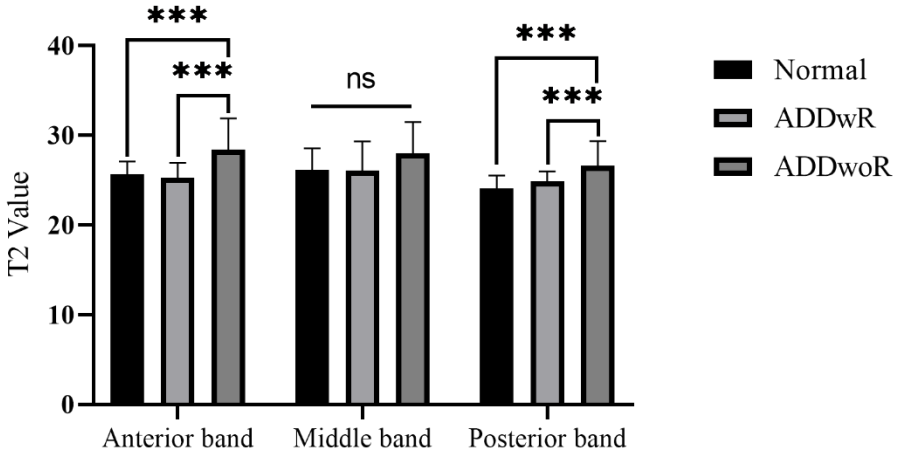

Fig3. Pairwise comparison of LSD of anterior、 middle and posterior bands of articular disc in three groups

3 Discussion

MR T2 mapping can provide information about the state of the cartilage collagen network without the help of contrast agents, objectively reflect the microscopic structural changes of TMD, and identify the early changes of this disorder (Matzat, van Tiel, Gold, & Oei, 2013).

This study showed that the T2 value of the TMJ disc had anteriorly and anteriorly spatial changes, which was consistent with the study of Cao Y et al.(Cao et al., 2012). They believed that it might be related to the different orientations of collagen fibers in different tissue layers of the disc or the magic angle effect. Our study showed that the T2 value of the anterior band was the highest in the diseased group and the normal group, followed by the anterior band and the posterior band. The T2 values of the anterior and middle bands were different from the 3T MRI study of Schmid-Schwapm M et al.(Schmid-Schwap et al., 2014). They concluded that the T2 relaxation time of the anterior band was the highest and that of the middle band was lower. Furthermore, they did a histological study of the articular disc and did not observe a magic angle effect, a local increase in T2 relaxation time. Previous studies have reported that collagen fibers are most abundant in the double plate region, with more anterior bands than posterior bands and the least middle bands (Clément et al., 2006; Gross, Bumann, & Hoffmeister, 1999). Histologically, although the middle zona is relatively thin, there is a dense arrangement of collagen fibers in the front, back, and inside of the middle zona, forming a tubular structure. At the same time, there are many vertical fibers, greatly enhancing the structural density of the middle zona, which may be the reason why the T2 value of the middle zona is higher than that of the other zona. Although the collagen fiber bundle of the posterior band is thicker than that of the anterior band, the collagen fibers of the anterior band move forward and backward, and on this basis interweave with the tendon fibers of the upper outer wing muscle, resulting in a lower T2 value than that of the anterior band.

Bristol M et al.(Bristela et al., 2019)found that there was no significant statistical difference in disc location and T2 value. Because we used 3T MRI, compared with 1.5tMRI, higher field intensity can obtain higher SNR, which can exchange for higher spatial resolution (Schreiner et al., 2017). But a statistically significant moderating effect could be identified (P =0.014).In this study, there were statistically significant differences in the overall T2 values of the articular disc between normal volunteers, ADDwoR patients, and ADDwR patients (P<0.001). The mean value of global T2 in the ADDwoR group was higher than that in the ADDwR group and the normal group (P =0.003/P=0.003), and the mean value of global T2 in the ADDwR group was higher than that in the normal group (P>0.05). This indicated that the microstructural changes of the articular disc in both ADDwoR patients and ADDwR patients were most obvious in the ADDwoR group. Therefore, we further studied the articular disc by stratifying it according to the fiber arrangement of the articular disc. The results of PeREZDELPALOMARA A et al.(Pérez del Palomar & Doblaré, 2007)Three-Dimensional finite element model of TMJ showed that the maximum compressive stress of normal joint disc was located in the middle band, while the maximum compressive stress was located in the posterior band in ADDWOR and ADDWR patients before reduction.TANAKA E et al.(Tanaka et al., 2000)found that compressive stress occurred in the anterior, middle, and lateral regions of the condyle and articular fossa in the standard model, while tensile stress was observed in the latter and medial regions. In the model of anterior disc displacement, compressive stress was identified in all regions of the TMJ except the double plate region. Therefore, in this study, T2 values in the middle band of volunteers were higher than those in the anterior and middle bands. However, in the ADDwoR group and THE ADDwR group, the T2 value of the posterior band was not higher than that of the anterior band and the middle band, but lower than both, which may be related to the increase of T2 value caused by joint effusion and the dense arrangement of collagen fibers in the middle band. In addition, previous studies have shown that the T2 value is susceptible to the influence of surrounding parameters (Cağlar, Şahin, Oğur, & Aktaş, 2014), and the increase of joint effusion will cause the increase of the T2 value (Xiong et al., 2020). Therefore, the T2 value of the posterior band is lower than that of the anterior and middle bands due to various factors.

In this study, the T2 values of the ADDwoR group were significantly higher than those of the normal group (P<0.05), while there was no statistical difference in the comparison between the middle and middle bands. The T2 values of the ADDwoR group were higher than those of the ADDwR group and the normal group in the front and back bands, and the differences were statistically significant (P< 0.005). This indicates that the injury degree of anterior and posterior bands of the articular disc of ADDwoR is most serious. According to the pathogenesis of ADDwoR, it is because the articular dislocations are located in front of the condyle head, and the condyle of the mandible cannot be reset by itself during the movement of the mandibular condyle with opening and closing, which

hinders the sliding of the condyle. LIU Z et al.(Liu, Qian, Zhang, & Fan, 2016)performed a three-dimensional finite element model of the TMJ and found that the maximum stress of the anteriorly displaced disc was 12.09 times that of the same disc, higher than the stress in other directions of the displaced disc and that the anteriorly displaced disc was followed by an increase in the oblique plane stress. As for the ADDwR group and normal group in the joint plate of layering and completely, were not statistically significant, on the one hand, from the cause analysis, ADDwR patients due to the joint plate in silence when is in the forward position, and to restore the normal when opening a relationship of the condylar plate, on the other hand, there are literature research report ADDwR ultimate stress distribution are similar to those of healthy people(Pérez del Palomar & Doblaré, 2007).In conclusion, the posterior disc band and posterior disc tissue structure are not suitable to withstand large stress, and excessive strain energy is stored in the tissue, which may lead to tissue rupture(Hirose et al., 2006). So for articular disc displacement, especially not renaturation dish before a shift, previous studies have shown that transverse area of the joint plate and the lateral area under high stress(Barrientos et al., 2020), unilateral articular disc displacement may affect unaffected (contralateral) joint stress(Hattori-Hara et al., 2014), if not treated, its geometry may change, seriously affecting the perforated plate area.

As we know, a low Signal-to-noise ratio(SNR) will affect the accurate measurement of the T2 value. In recent years, studies on TMJ T2 Mapping mostly use 3TMRI. Compared with 1.5T MRI, higher field intensity can obtain a higher SNR, and a higher signal-to-noise ratio can obtain higher spatial resolution(Schreiner et al., 2017).In addition, literature(Matzat et al., 2013; Wang & Regatte, 2015)reported that the interaction between free water and collagen fiber also caused the complexity of the T2Mapping method, namely the magic Angle effect. When the collagen fibers in cartilage were at an angle of about 55° with the direction of the B0 magnetic field, T2 relaxation time increased. Schmid-Schwalm M et al.(Schmid-Schwap et al., 2014)proved by the histological observation that the orientation of collagen fiber was not magic horn, and no magic horn effect was observed in the disc of the TMJ. BRISTELA M(Bristela et al., 2019)believed that due to the high sensitivity of T2 Mapping technology and the small surface area and volume of TMJ disc, the influence of surrounding parameters seems to be obvious, so it is not suitable for routine diagnosis of PATIENTS with TMJ disorders at present. However, measures such as 7.0T field intensity and UTE sequence are not feasible for clinical application at present. Therefore, the application of T2Mapping in TMJ needs further study. However, in the current clinical context, TMJ T2Mapping with 3TMRI may be the main choice (Eder et al., 2018). However, 1.5TMRI was used in this study, which has certain limitations. Therefore, a comparative analysis of T2 values under the two field intensities is required in subsequent studies.

Finally, there are some limitations to this study. First of all, current researchers generally divide the articular disc into different regions for study, but there is no specific standard for division (Cao et al., 2012; Kakimoto et al., 2014).In this study, the collagen arrangement of each band of the articular disc was studied, because the author believed that according to the principle of T2 Mapping, the closer the articular disc layering is to the histological layering, the better. However, since the ROI was manually selected by the surveyors, the measurement error was also increased. Secondly, the sample size of this study is small. Further studies are needed on the application of T2mapping in patients with TMJ disorders. Finally, potential case changes of the disc were not histopathologically confirmed.

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