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Original Article

Orthodontic treatment improves magnetic resonance imaging features and quality of life in adult patients with temporomandibular disorders

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Abstract: Objective: This research intends to clarify the magnetic resonance imaging (MRI) features as well as changes in symptoms and quality of life (QoL) in adult patients with temporomandibular disorders (TMDs) before and after orthodontic treatment. Methods: Clinical data of 57 TMD patients before and after orthodontic treatment were collected and analyzed retrospectively. The anterior and posterior regions of the temporomandibular joint (TMJ)'s articular disc were checked before, during and after the treatment by MRI, and the anterior and posterior spaces of TMJ were measured with an electronic measuring ruler. Pre- and post-treatment alterations in the Visual Analogue Scale (VAS) score, TMJ clicking, maximum mouth opening (MMO), and Fricton's indexes (TMJ dysfunction index, DI; palpation index, PI; craniomandibular index, CMI) of the patients were comparatively analyzed. The Oral Health Impact Profile questionnaire was employed for QoL assessment before and after treatment. Results: On MRI, patients with TMDs presented clear changes in TMJ disc position, morphology, thickness and joint effusion, while those with pain symptoms also had condylar degeneration. In addition to a reduced VAS score, the line distance of the TMJ anterior space increased significantly, while the posterior space line distance decreased significantly after treatment, as compared with the baseline (before treatment). Before orthodontic treatment, a total of 46 TMD patients were accompanied by associated TMJ clicking, including 8 severe cases and 38 mild cases. The clicking disappeared in 39 cases after treatment, but mild unilateral clicking, mild bilateral clicking, and severe clicking were still observed in 5, 1, and 1 case(s), respectively. The patients exhibited an increase in MMO and a decrease in Fricton's indexes with significantly enhanced QoL after the orthodontic treatment. Conclusions: Patients with TMDs exhibit diverse clinical features, and MRI can accurately reflect changes in the position, morphology and thickness of the articular disc as the disease progresses, which can improve the accuracy of clinical diagnosis. In addition, orthodontic treatment for TMD patients can effectively alleviate adverse clinical symptoms and improve their QoL.

Keywords: Temporomandibular disorders, orthodontics, magnetic resonance imaging, clinical symptoms

Introduction

Temporomandibular joint (TMJ) is a ginglymoarthrodial joint consisting of the mandible, articular disc, joint protrusion and glenoid fossa that provides a middle pivot point for mandibular movement when chewing and speaking [1]. From an anatomical point of view, TMJ is complex in structure, and intervertebral disc (IVD) displacement or structural damage can lead to joint disorders, known as the symptoms of temporomandibular disorders (TMDs) [2]. According to statistics, the prevalence of TMDs in adults and children is 31.1% and 11.3%, respectively [3]. TMDs can cause IVD deformation, which in turn triggers pain at the TMJ, resulting in TMJ clicking and stiffness [4, 5]. Pathologically, TMDs may be closely related to gender, oral parafunctional habits, stress, and negative emotions [6], which not only cause symptoms such as headaches, arthritis, and synovitis [7, 8], but may also lead to depression [9, 10], seriously reducing the quality of life (QoL) of patients [11].

At present, the main purpose of treatment for TMDs is to reduce pain, relieve symptoms and improve TMJ function, with treatment options such as drug therapy, physical therapy, orthodontic therapy, as well as arthrocentesis and

other surgical treatments [12]. In general, reversible treatments such as drug therapy and physical therapy are the first choice for TMD patients, followed by irreversible treatments such as orthodontic treatment, arthrocentesis and surgery [13]. However, if a patient develops TMDs during orthodontic treatment, imaging tools are needed to diagnose the characteristics of TMJ lesions and guide the corresponding treatment [14]. Imaging examination is crucial to the treatment of TMDs. The TMJ is one of the most complicated joints in the human body, and imaging information can help doctors to evaluate diseased joints. However, it is limited by the aforementioned complex structure of TMJ, and traditional X-ray imaging is unable to accurately obtain the information of bone morphology and joint space, reducing the effectiveness in evaluating the dynamic function of the joint [15]. Magnetic resonance imaging (MRI), with the advantages of being non-invasiveness and having high visualization, can overcome these shortcomings in the diagnosis of TMDs. The latest MRI technology can also obtain dynamic changes in TMJ pathological and biochemical properties [16]. Moreover, MRI can accurately capture the brain changes of TMD patients complicated with chronic pain, facilitating TMD-related pain intervention and treatment [17]. Therefore, it is evident that MRI offers dependable and precise imaging data for diagnosing TMDs and improving comprehension of the clinical response to TMDs.

To explore the guiding value of MRI in the treatment of TMDs, the clinical data of 57 patients with TMDs before and after orthodontic treatment were retrospectively analyzed. The anterior and posterior margins of the articular disc were identified using MRI, and the anterior and posterior spaces of the TMJ were measured with an electronic measuring ruler before and 1 and 3 months after treatment, to identify alterations in TMJ. In addition, the Visual Analogue Scale (VAS) score, TMJ clicking, maximum mouth opening (MMO), Fricton's index and QoL score of the TMD patients were comparatively analyzed before and after treatment.

Methods

General information

A retrospective analysis of 57 adult patients with TMDs was performed. Inclusion criteria: age ≥18 years old; diagnosis of TMDs by imaging examination [18]; presence of clinical symptoms such as headache or joint pain; no history of TMD treatment. Exclusion criteria: allergies to the equipment or drugs used in the orthodontic treatment; use of hormones, non-steroidal anti-inflammatory drugs, glucosamine sulfate, opioid analgesics, antidepressants, or other drugs that may affect the immune system within the 6 previous months before treatment; mental or cognitive disorders; malignant tumors; serious diseases of heart, lung, liver or kidney. The study population was comprised of 26 males and 31 females averagely aged 29.54±5.85 years, with an average body mass index (BMI) of 20.56±0.95 kg/m^2. This research was approved by the Ethics Committee of Zhejiang Putuo Hospital.

MRI

Bilateral TMJ coils and spin-echo sequences were used to perform oblique sagittal and oblique coronal T1/T2-weighted MRI, respectively, with a TR/TE of 450/15 ms, a field of view of 150 mm × 150 mm, a matrix of 256 × 256, a layer thickness of 3 mm, and an interval of 0.1 mm. For closed-mouth positioning, the oblique sagittal scanning track was set to be perpendicular to the long axis of the medial-lateral diameter of the condyle. During open-mouth positioning, a plastic mouth opener was placed between the patient's upper and lower anterior teeth to enable the patient to achieve their maximum comfortable mouth opening position. The scanning method was the same as the closed-mouth positioning. Regarding quality control, all images were independently assessed by two imaging diagnosticians. In cases where differences of opinion arose, they reached an agreement through consultation to ensure accurate diagnosis and evaluation.

Orthodontic treatment

A straight wire appliance was used for orthodontic treatment of the patients. The maxillary appliance was bonded first, and the upper incisors were expanded lip-sided. Subsequently, the maxillary flat bite plate was applied to bond the mandibular orthodontic appliance, so as to complete the correction of the upper and lower dentition. Intermaxillary traction was avoided during treatment. The criteria for assessing the therapeutic effect were as follows: normal labial inclination of the upper anterior teeth, proper

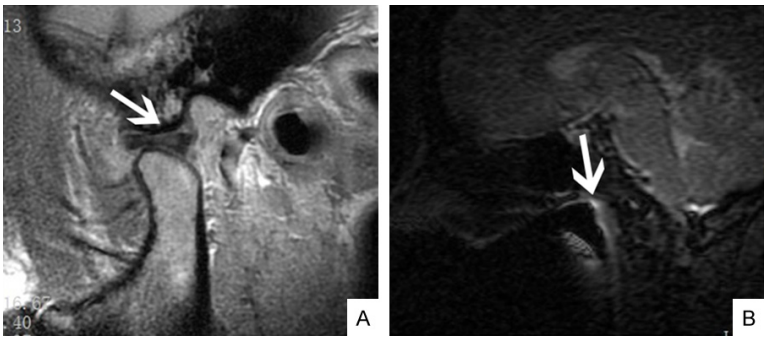

Figure 1. MRI features of temporomandibular disorders. A: Articular disc displacement; B: Joint effusion. MRI, magnetic resonance imaging.

overlap & overbite relation of the anterior teeth, neat alignment of upper and lower teeth, and a neutral relation between the canines and molars.

Outcome measures

(1) MRI was used to check the anterior and posterior borders of the articular disc before and after treatment. In addition, the anterior and posterior spaces of the TMJ were measured before and one and three months after treatment using an electronic measuring ruler to observe TMJ alterations.

(2) The VAS score [19] was used for assessing pain severity. Patients were asked to rate the severity of their pain on a scale of 0 to 10 based on their self-perception. Higher scores are associated more severe pain.

(3) Changes in pre- and post-treatment TMJ clicking and MMO [20] were recorded. MMO refers to the vertical distance between the upper and lower middle incisors measured by the patient's active mouth opening action to the maximum extent possible.

(4) Fricton's TMJ dysfunction index (DI) [21]: TMJ DI, palpation index (PI) and craniomandibular index (CMI) were recorded before and after treatment. Of them, CMI is the sum of DI and PI divided by 2. The score range of all three is 0-1 point, which is proportional to dysfunction.

(5) QoL [22]: The Oral Health Impact Profile (OHIP) questionnaire was adopted for assessing QoL in patients from seven aspects, with a total of 14 items from domains of functional limitation, physical pain, psychological discomfort, handicapped, as well as psychological, physical, and social disabilities. Evaluation: 0, never/not know; 1 point, almost never; 2 points, occasionally; 3 points, frequently; 4 points, all the time. The total QoL score, which ranged from 0 to 56 and indicated an inverse association with patients' QoL, was recorded both before and after treatment.

All the above indicators were primary outcome measures.

Statistics and analysis

Categorical variables and quantitative data were denoted by the number of cases (percentage) and the mean ± standard deviation, respectively. Paired sample t-tests were utilized to compare differences in TMJ anterior-posterior space, joint clicking degree, MMO, and Fricton's indexes before and after treatment, and a repeated variance analysis was applied to compare changes in pre- and post-treatment VAS scores. There was a significant difference between groups when $P<0.05$ was defined. A 95% confidence interval was used in this study.

Results

General data and typical cases

The study population was comprised of 26 males and 31 females with mean age and BMI of 29.54±5.85 years and 20.56±0.95 kg/m^2, respectively. On MRI (**Figure 1**), the patients exhibited clear changes in the position, morphology and thickness of the articular disc as well as joint effusion, while condylar degeneration was also present in cases with pain symptoms. Most patients presented with joint pain, TMJ clicking, restriction of mouth opening and mandibular asymmetry.

MRI examination of TMJ anterior and posterior spaces before and after treatment

Before and after treatment, the anterior and posterior margins of the articular disc were identified by MRI, and the TMJ anterior and posterior spaces were measured by an electronic measuring ruler. As shown in **Figure 2**, the anterior space in TMJ increased obviously compared with the baseline (before treatment),

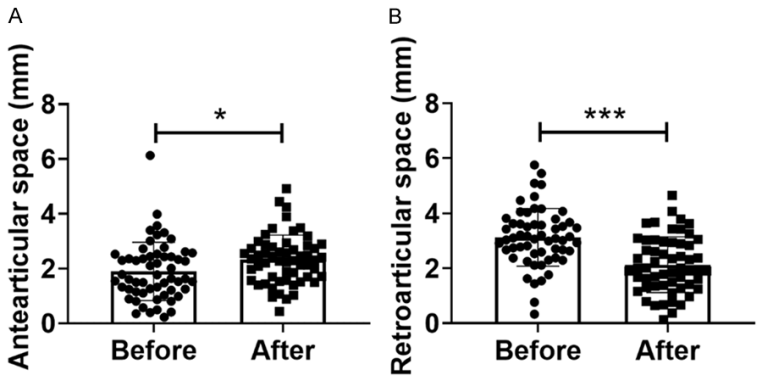

Figure 2. Changes of anterior and posterior spaces of the temporomandibular joint before and after treatment, n=57. A: Anterior space; B: Posterior space. *P<0.05; ***P<0.001. Paired sample t-test was used.

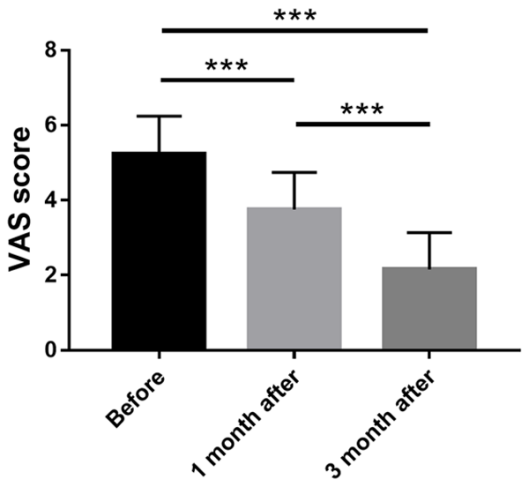

Figure 3. Comparison of VAS scores before and after treatment. ***P<0.001. Paired sample t-test was used. VAS, Visual Analogue Scale.

while the posterior space decreased significantly.

Evaluation of VAS scores before and after orthodontic treatment

In this study, all the TMD patients received orthodontic treatment, and their VAS scores before and 1 month and 3 months after treatment were analyzed. Compared with the baseline, the VAS scores decreased at 1 and 3 months after treatment, and the VAS score at three months after treatment was even lower than that at one month after treatment. The above results suggest that orthodontic treatment contributes to a significant relief in TMD-induced pain (**Figure 3**).

Changes in TMJ clicking and MMO before and after orthodontic treatment

Forty-six TMD patients exhibited TMJ clicking before orthodontic treatment, including 8 severe cases and 38 mild cases. After treatment, TMJ clicking was resolved in 39 cases, while 5 cases showed mild unilateral clicking, 1 case developed mild bilateral clicking and 1 case had severe clicking (**Table 1**). Overall, the TMJ clicking was obviously improved after orthodontic treatment. This study also recorded the MMO and Fricton's indexes of patients before and after orthodontic treatment (**Table 2**), and the results showed significantly increased MMO and decreased Fricton's indexes after orthodontic treatment.

Comparison of patients' QoL before and after orthodontic treatment

In this study, the OHIP questionnaire was used to assess QoL from seven aspects, namely, functional limitation, physical pain, psychological discomfort, handicapped, as well as psychological, physical, and social disabilities. As shown in **Table 3**, the post-treatment scores of the above seven aspects decreased statistically compared with the baseline, with the overall QoL score decreased from (16.60±1.16) points to (8.23±1.14) points, showing statistical significance (P<0.05).

Discussion

TMD, a disease involving oral and facial areas, mainly presents with TMJ pain, restriction of mandibular movement, and joint clicking [23]. TMD can occur not only in children and adolescents, but also in adults and the elderly, with about 60-70% of people showing associated signs and 5-12% diagnosed with TMDs [24]. TMD is a disease closely related to many conditions, such as depression [25], headache [26], and osteoarthritis [27]. A timely diagnosis of TMD will contribute to relief of pain, IVD diseases, arthritis and other clinical symptoms. This study, conducted based on MRI to comprehen-

Table 1. Degree of temporomandibular joint clicking

	Before treatment	After treatment	X^2	P
			43.72	<0.0001
No joint clicking	11	39		
Mild joint clicking	38	6		
Severe joint clicking	8	1		

Table 2. Comparison of MMO and Fricton's indexes before and after treatment

	Before treatment	After treatment	t	P
MMO (mm)	27.82±4.89	40.79±5.66	15.85	<0.0001
DI	0.63±0.13	0.22±0.12	11.86	<0.0001
PI	0.41±0.15	0.18±0.08	10.73	<0.0001
CMI	0.52±0.10	0.21±0.07	22.04	<0.0001

Note: MMO, maximum mouth opening; DI, dysfunction index; PI, palpation index; CMI, craniomandibular index.

Table 3. Comparison of patients' quality of life before and after orthodontic treatment

	Before treatment	After treatment	t	P
Functional limitation	2.74±0.89	1.04±0.57	10.00	<0.0001
Physical pain	2.84±0.84	0.98±0.29	14.26	<0.0001
Psychological discomfort	2.36±0.63	1.24±0.36	9.55	<0.0001
Psychological disabilities	1.55±0.47	1.01±0.29	7.21	<0.0001
Physical disabilities	2.44±0.29	1.18±0.44	11.64	<0.0001
Social disabilities	2.66±0.57	1.24±0.49	12.34	<0.0001
Handicapped	2.01±0.63	1.45±0.50	5.54	<0.0001
Total	16.60±1.61	8.23±1.14	33.20	<0.0001

sively observe the TMJ structure, indicates that MRI images can accurately describe the changes of the position, morphology, and thickness of the joint disc during TMD progression. After MRI diagnosis, we performed orthodontic treatment on patients and confirmed the treatment efficacy in relieving TMD symptoms and enhancing QoL.

The current imaging modalities include traditional X-ray imaging, computed tomography (CT), MRI, and ultrasound. Of them, X-ray imaging is limited by the complex joint structure of TMJ and the inability to overcome structural overlap. Ultrasound, though non-invasive and inexpensive, can't examine deeper bone structures and bone abnormalities. CT is most useful in assessing traumatic TMDs. In contrast, MRI is the first choice for evaluating intra-joint processes with high resolution and is the gold standard for judging IVD diseases [28]. Therefore, MRI has great potential in TMD imaging examinations. Increasing studies have been focusing on MRI features of TMDs. Jerele et al. [29] confirmed that unilateral TMD was associated with contralateral asymptomatic imaging abnormalities through MRI examination, suggesting that unilateral TMD progression did not exist independently. Piper MRI can also be applied to the examination of TMDs. A study [30] identified progressive degeneration of TMJ based on Piper MRI of articular pathology in TMD patients. Another piece of evidence obtained from MRI is that the thickness of the anterior disc band and the medial size of the condyle head are related to sex [31]. Similarly, we observed clearly visible changes in disc position, morphology, thickness changes, and joint effusion in TMD patients based on MRI, as well as condylar degeneration in those with pain symptoms. It is evident that MRI plays a critical role in the diagnosis of TMDs. This may be related to the bilateral TMJ coil used in MRI diagnosis, which can increase the signal-to-noise ratio to clearly visualize the pathological morphology of the disc and joint effusion in the image [32]. Previous studies have shown that disc displacement is a predisposing factor for joint effusion, and that joint effusion production can precipitate joint pain [33]. Similar to our findings, MRI has also been shown to have high diagnostic value in patients with degenerative temporomandibular arthropathy and can detect condylar abnormalities, but it cannot effectively identify the severity of condylar abnormalities [34]. Moreover, Vogl et al. [35] proposed that dynamic MRI could provide more information about TMJ morphology and function than static MRI in the diagnosis of TMDs, but it put forward higher requirements for patients' compliance and exhibited disad-

vantages such as interference of motion artifacts.

Selecting appropriate treatment after diagnosis is also an important step to improve TMDs. The relationship between orthodontic treatment and TMDs is currently controversial [36]. It has been suggested that stabilizing the occlusal device is helpful to reduce TMD pain and IVD displacement [37]. Orthodontic treatment is shown to improve the occlusal relationship in TMD patients and promote the coordination and symmetry of muscle group activities. It can also correct anterior arch crowding and maintain condyle position [38]. In this study, the straight wire appliance was used to treat TMDs, and the results showed that the joint movement of patients was effectively improved, the TMJ clicking was relieved, and the QoL score was effectively increased. In contrast to this study, Mušanović et al. [39] pointed out that fixed orthodontic treatment in children aged 12-18 had no significant effect on the alleviation of TMJ clicking, which may be related to patients receiving such treatment being more cautious with their jaw movements to avoid TMJ-associated clicking. Walczyńska-Dragon et al. [40] reported significantly enhanced TMJ function, improved cervical motion, and reduced spinal pain in TMD patients after 3 months of occlusal splint orthodontic treatment, which is consistent with our findings. According to Almoznino et al. [41], the degree of QoL impairment in TMD patients was significantly higher, and was affected by factors such as previous orthodontic treatment, complications, pain, and muscle tenderness.

This work still has the following shortcomings that need to be improved. First, the sample size is small, resulting in limitations in mining deeper information. For this, we will expand the sample size and supplement and lengthen the follow-up time to conduct an in-depth prognosis analysis in future studies. Second, due to the limitation of equipment and research time, this work only discussed the application value of one single MRI technique in TMD diagnosis. Hence, we will use multiple MRI techniques in future research to obtain joint structure information in TMDs. Finally, this study only used MRI technology to conduct a preliminary analysis of the application of TMD-related diagnosis. The specific diagnostic value needs to be validated after expanding the research subjects in the future.

In conclusion, this study, conducted based on MRI to capture the joint details of TMDs, finds that MRI can accurately reflect the changes of the position, morphology and thickness of the articular disc during TMD progression, improve the accuracy of clinical diagnosis, and enhance the clinical treatment effect on TMDs. In addition, orthodontic treatment has been confirmed to alleviate the clinical symptoms of TMD patients and improve their QoL.

Disclosure of conflict of interest

None.

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