The Relationship between Temporomandibular joint Pain and the Relative Signal Intensity of Retrodiscal Tissue on T1-, and T2-Weighted MRI Images

Jae-Kwang Jung, D.D.S.,M.S.D, Yun-Kyung Hur, D.D.S.,M.S.D.,PhD.,
Jae-Kap Choi, D.D.S.,M.S.D,PhD.,

Department of Oral Medicine, School of Dentistry, Kyungpook National University

Aims: The purpose of this study was to evaluate the relationship between temporomandibular joint pain and the relative signal intensity (RSI) of retrodiscal tissue on T1-, and T2-weighted MRI images.

Materials and Methods: This study was based on 122 TMJs of 61 patients who complain of TMJ pain in only one side but were revealed to have disc displacement in both TMJs according to MRI findings. The signal intensities of regions of interest (ROIs) in retrodiscal tissues were measured using T1-, and T2-weighted MRI images. The RSIs of retrodiscal tissues were referenced to the signal intensities of the ROIs of brain gray matter. The relationships between the RSI of retrodiscal tissue and joint pain, joint effusion, condylar degenerative change, and degree of disc displacement were examined. In addition, the relationships between joint pain and joint effusion, condylar degenerative change, and degree of disc displacement were examined.

Results: On T1-weighted MR images, the painful TMJs showed significantly higher retrodiscal tissue RSI than non-painful TMJs. In addition, there is an association between joint pain and the degree of disc displacement. However, on T2-weighted MR images, the RSIs of retrodiscal tissues didn't show any significant differences with regard to joint pain, joint effusion, condylar degenerative change, and degree of disc displacement.

Conclusions: The signal intensity of retrodiscal tissue can be used as a diagnostic marker for painful TMJ. However, the overall results suggest the signal intensity of retrodiscal tissue has a limited diagnostic significance in determining the pathologic status of TMJ.

Key words : temporomandibular joint pain, magnetic resonance imaging, signal intensity

Corresponding author : Jae-Kap Choi
Department of Oral Medicine, Kyungpook National University, School of Dentistry. 188-1, Samduk-dong 2ga, Jung-gu, Daegu 700-412, Korea
Tel: 82-53-600-7311
Fax: 82-53-426-2195
E-mail: jhchoi@knu.ac.kr

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Ⅰ. INTRODUCTION

According to the histological findings of a normal temporomandibular joint (TMJ) with no disc displacement and no pathologic inflammation, retrodiscal tissue consists mainly of loose, but highly vascularized and innervated connective tissue including elastic and collagen fibers. By contrast, TMJ disc consists of dense and poorly vascularized and innervated connective tissue. So, from the histological viewpoint, the retrodiscal tissue is not

appropriate for withstanding the load occurred during physiological function of jaw. However, in case of anterior disc displacement in TMJ, retrodiscal tissue gets located between the mandibular condyle and articular eminence and is consequently exposed to the ruinous load exerted by condyle head. This excessive strain can bring the inflammatory reaction on retrodiscal tissue. Several histological studies have supported the possibility of inflammation in retrodiscal tissue including the change of vascularity, the presence of inflammatory cells and so on. These inflammatory reactions in the retrodiscal tissue, which is richly innervated with nociceptive fibers, can play the most potential role in the development of joint pain associated with disc displacement[1].

The subsequent inflammatory reaction which causes pain of retrodiscal tissue can also enhance the histological changes in retrodiscal tissue. However, when considering that not every TMJ with disc displacement has joint pain, we can assume that the retrodiscal tissues of painful joints with disc displacement could be histologically different from retrodiscal tissues of joint without pain even in the similar joint status such as disc displacement. Several authors have reported about these histological differences including change of vessel wall, decrease of collagen fiber, infiltration of inflammatory cells, myxomatous changes[2-6].

As the result, in signal intensities on MRI images, there could be the consequent difference between joints with and without pain while those joints have similar disc displacement, effusion, deformity of condyle[7]. In other words, the measurement of signal intensity could be a valuable diagnostic marker which indicate objectively the presence of pain. Although joint pain is one of most common complaint in temporomandibular joint disorder (TMD), there are a few numerical methods which can objectively prove the presence of joint pain in patients with TMD. Until now, the presence of joint pain heavily depends on patient's complaint and the result of palpation test. So several researchers have assessed the usefulness of some other findings such as joint effusion on MRI[8,9], infrared thermography [10,11]. However, the usefulness of joint effusion and infrared thermography as pain marker still remains questionable and even disappointed[11]. In regard to palpation test, though palpation test with visual analogue scale (VAS) is known as most widely used clinical method and considered the best way to identify the pain[12,13], But the palpation test have had the weakness of heavily depending on subject's response and of not being the objective method.

That implies that its diagnostic validity could be occasionally challenged when it is considered that the response to palpation could be exaggerated or overlooked depending on patient's mood and secondary gain such as insurance or law suit purpose. So further objective methods in evaluation of pain have been needed.

The purpose of this study was to assess the change of MR signal intensity associated with presence of pain and to determine whether the changes in MR signal intensity can be considered as pain marker.

Ⅱ. MATERIALS AND METHODS

1. Subjects

Among the TMD patients who visited Department of Oral Medicine, Kyungpook National University Hospital from January 2009 to December 2010, a total of 61 patients were selected for this study according to the following inclusion and exclusion criteria. The inclusion criteria was as followings; (1) TMD patient with the complaint of unilateral joint pain, not both joint pain, (2) MRI evidence of anterior disc displacement in both TMJ. The patients with following conditions were excluded in this study; (1) an evidence of systemic inflammatory arthritis, (2) a history of significant TMJ injury such as condylar fracture, (3) those who could be concerned with secondary gain, (4) a sign of joint adhesion, and (5) an inappropriate MR image where the measurement of signal intensity is unable. The subjects consisted of 7 males and 54 chief

complaintfemales with the age from 13 years to 63 years (mean 33.68 ± 14.94 years)

2. History taking and Clinical examinations

From patient history and clinical examinations of the subjects, the following informations were collected; chief complaints, a history of trauma, psychologic status including probable secondary gain, a range of maximum opening, results of palpation test for both TMJs. In this study, only those patients who feel pain in TMJ spontaneously during function or at rest were selected for subjects.

3. Imaging conditions

MR imaging was performed with Sigma 1.5 Tesla MR Imaging system (General Electric, Milwaukee, WI, USA) using 7.62 cm surface coil of GE Medical system. T1 was used in the sagittal planes at the closed and open mouth position and T2 at the closed mouth position. The parameters of imaging for obtaining T1 and T2-weighted images are as follows: T1-weighted spin echo sequence (TR556 / TE17, 3 excitations, FOV 12×12 cm, 512×192 matrix), T2-weighted fast spin echo sequence (TR3000 / TE92, 3 excitations, FOV 12X12 cm, 512X192 matrix).

The disc position was classified into 1) anterior disc displacement with reduction (ADWR) and 2) anterior disc displacement without reduction (ADWOR) according to the diagnostic findings on T1-weighted images of closed and open jaw position.

Degenerative joint changes such as condylar flattening, subchondral sclerosis, surface irregularities, erosion, and osteophyte were investigated on the MR images and the TMJs were divided into two groups; Degenerative joint disease(DJD)-present group and DJD-absent group.

The presence of joint effusion was determined on T2-weight images. Joint effusion was defined by the presence of high signal intensity in the region of the upper or lower joint space. The TMJs were divided into two groups; Effusion-present group and Effusion-absent group.

The prevalence of TMJ pain was investigated for any correlations with regard to disc position, degenerative changes, and joint effusion.

4. Measurements of signal intensity

One hundred and twenty-two temporomandibular joints in 61 TMD patients were analyzed. The signal intensity of regions of interest (ROI) in retrodiscal tissues was measured using T1- and T2-weighted MR images respectively. Using the MRI console software, the regions of interest (ROI) of 1 mm in diameter was generated by a radiologist and placed over the retrodiscal tissue located at the 12 o'clock position relative to the most superior point of the condylar head. The radiologist didn't know any clinical information about the subjects. Another ROI of 4 mm in diameter was located in the gray matter most adjacent to the condyle head for reference[14] (Fig.1).

The relative signal intensity (RSI) was calculated with the following formula[15]; RSI of retrodiscal tissue = signal intensity of ROI in retrodiscal tissue/signal intensity of the ROI in the gray matter of the brain.

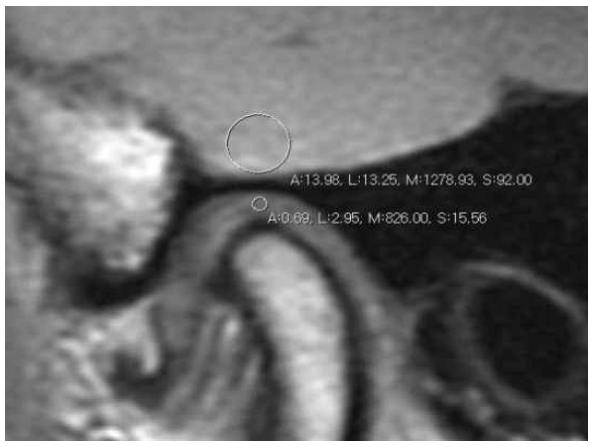

Fig. 1. The circular regions of interest in retrodiscal tissue and temporal brain are depicted on a sagittal T1-weighted MR image (original magnification×4).

Table 1. Association between the clinical and MRI findings and relative signal intensities (RSIs) of retrodiscal tissues on a sagittal T1-weighted MR image.

	Number of joints	RSI (mean ± SD)	*P* value
Joint pain			
present	61	0.84±0.27	<.01
absent	61	0.72±0.25	
Disc position			
ADWR	86	0.81±0.26	.098
ADWOR	36	0.72±0.27	
DJD			
present	78	0.81±0.26	.159
absent	44	0.74±0.28	
Joint effusion			
present	43	0.84±0.31	.077
absent	79	0.75±0.24	

Joint pain, Disc position, DJD, Joint effusion:(two sample t-test, $P < .05$)
ADWR, anterior disc displacement with reduction; ADWOR, anterior disc displacement without reduction; DJD, degenerative joint disease

The relationships between the RSI of retrodiscal tissue and disc position, degenerative joint changes, joint effusion, and joint pain were determined.

5. Statistical Analysis

For statistical analysis, the differences in mean RSI scores of retrodiscal tissue between groups with and without joint pain were investigated using two sample t-tests. The association of RSI with MRI findings including disc position, degenerative joint changes, joint effusion were tested for significance using the two sample t - test. Also the association between joint pain and MRI findings was tested for significance using Pearson Chi-Square test. PASW ® Statistics 18 software (SPSS Inc., Chicago, IL) was used to test statistical significance (P values<0.05).

Ⅲ. RESULTS

The mean RSI score of retrodiscal tissues obtained on T1-weighted images was significantly higher in the painful TMJs than that from non-painful TMJs ($p<0.01$). However, there was no significant difference in the mean RSI score of retrodiscal tissues obtained on T2-weighted images between two TMJ groups. (Tables 1, 2)

The comparisons of the mean RSI scores obtained on T1- as well as T2-weighted images didn't show any significant difference between present and absent groups with regard to disc position, joint effusion, degenerative joint changes. (Tables 1, 2)

When the prevalence of TMJ pain was investigated for any correlations with regard to disc position, degenerative changes, and joint effusion, there was a significant relationship only between TMJ pain and disc position. Otherwise, there were no correlations. (Table 3)

Table 2. Association between relative signal intensities (RSIs) of retrodiscal tissues on a sagittal T2-weighted MR image and the MRI findings, joint pain

	Number of joints	RSI (mean ± SD)	*P* value
Joint pain			
present	61	0.73±0.39	.401
absent	61	0.68±0.31	
Disc position			
ADWR	86	0.72±0.37	.603
ADWOR	36	0.68±0.29	
DJD			
present	78	0.73±0.36	.351
absent	44	0.67±0.32	
Joint effusion			
present	43	0.71±0.38	.953
absent	79	0.71±0.33	

Joint pain, Disc position, DJD, Joint effusion:(two sample t-test, $P < .05$)

Table 3. Association between joint pain and MRI findings

		pain		*P* value
		present	absent	
Disc position	ADWR	48	38	<.05
	ADWOR	13	23	
DJD	present	41	37	.451
	absent	20	24	
Joint effusion	present	25	18	.185
	absent	36	43	

Joint pain, Disc position, DJD, Joint effusion:(Pearson Chi-Square test, $P < .05$)

Ⅳ. DISCUSSION

According to the definition by International Association for the Study of Pain (IASP), pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage.[16] By this definition, pain is not just tissue damage by the noxious stimuli, but the complicated condition which can be intervened by both the subjective and psychologic condition. In other words, it means that pain could be misinterpreted by secondary gain or interest. In this study, in order to get rid of the possibility of distortion of pain complaint, we exclude all patients whose pain could be concerned with secondary gain. Furthermore, we included

those patients who showed spontaneous pain in the TMJ during physiologic function or at rest for this study. However, the patients who showed tenderness on palpation of TMJ, but didn't complain of subjective pain in TMJ were also excluded.

MRI is a useful procedure for studying retrodiscal tissue noninvasively. It have been reported that some of MRI findings in TMJ such as disc position and osteoarthrosis are useful for diagnosis of TMD and assessment of clinical symptoms. However, though there has been a lot of interest in retrodiscal tissue of TMJ from both clinicians and researchers who was considering this tissue as the potential source of joint pain in TMD patient with disc displacement, the researches about this topic have been not enough to confirm the potential roles in joint pain and even reported the conflicting results.

In regard to histological changes in retrodiscal tissue with joint pain, Holmlund et al.[3] reported that in 64% of joints with symptomatic disc derangement, histological evidence of inflammation such as hyperemia with perivascular inflammation was found in their retrodiscal tissue. Furthermore, Scapino reported that venous channels in the temporal part of the retrodiscal tissue were conspicuously dilated[4]. Whereas Hall et al.[17] also found thickened arterial walls, suggesting endothelial proliferation and possibly, restricted blood flow. Moreover, they reported that no significant inflammation was observed in any subjects, and even that there was no association between the amount of vascularity and the degree of dislocation.

As for studies about MR signal of retrodiscal tissue in TMJ with pain, Suenaga et al.[18,19] reported that on closed mouth, contrast-enhanced spoiled gradient-recalled acquisition steady state MR, TMJs with pain and dysfunction had higher signal intensity than those without. On open mouth T2-weighted MRI, Sano T et al.[14] reported that the average T2 signal is higher in painful joints than in nonpainful joints and this might reflect an increased vascularity of the joint tissue. Chiba et al.[1] reported that TMJ pain was more commonly reported in joints with high signal intensity in the retrodiscal tissue than with low signal intensity in the retrodiscal tissue on T2 weighted fat-suppressed MRI.

Lee et al.[15] found that the average of the relative signal intensity of retrodiscal tissue on T2 weighted MRI was significantly higher in the joint with pain than in a joint without pain.

Suenaga et al.[18] reported that the mean peak-signal-intensity ratio of the group with joint pain was significantly higher than that of the other groups. Moreover, with joint pain, anterior disk displacement without reduction was strongly associated with the mean signal-intensity ratio.

In contrast to previously researches, Sano[20] reported in the their study to discuss the significance of changes in the retrodiscal tissue on MRI of the painful TMJ in patients with TMD that decreased T1-weighted or proton signal in the retrodiscal tissue is related neither to TMJ pain nor histologically clarified.

Westesson et al.[21] reported that there was no appreciable correlation between the level of pain and the decreased signal intensity from the retrodiscal tissue on T1 weighted or proton density images, and when decreased signal intensity in the retrodiscal tissue is compared with the position of the disc, a strong relationship was found with a displaced disc without reduction, so called later stages. And this finding supported earlier suggestions by Manzione et al.[22] that the fibrosis of the retrodiscal tissue is part of the later modeling process.

As stated above, these results still remain contradictory. When it comes to the reason why these results have been conflicting, Sano[20] suggested that these results represented the different stages of the same process, namely alteration in the retrodiscal tissues as a result of altered function. He mentioned that this alteration meant that while the initial stages may be accompanied by increased vascularity, the more chronic changes are associated with decreased vascularity and greater likelihood of fibrosis[20].

We agree with his opinion from general point of

view but also would like to mention that joint pain could occur and recur in any stage, including even chronic disc displacement stage. This means that even in chronic stage with well-fibrosis, the repeated change of histological condition is possible if harmful load would be exerted on retrodiscal tissue.

Therefore, even in same disc displacement stage, the presence of pain could represent the different condition of retrodiscal tissue. So the present study employed subjects who had disc displacement in both side but joint pain only in one side to simulate the similar condition with respect to disc position. Table 2 showed no significant difference in RSI with respect to joint position or degenerative joint change which mean even more chronic stage than ADWOR, though Table 3 showed the significant difference in the prevalence of pain between disc positions. In this study, despite of similarities in variable joint conditions, the RSI of retrodiscal tissue on T1 showed a significant difference according to joint pain only, otherwise no significant difference with regard to other MRI findings. This result showed that the vascularity of the joint tissue could increase again following with the recurrent inflammatory response even in late stage of joint and support that the behavior control should continue to eliminate the harmful stimuli especially in vulnerable joint condition such as disc displacement. In addition, this result showed that the RSI of retrodiscal tissue on T1 weighted image could be a independent diagnostic marker of joint pain distinctive from joint effusion.

As for several studies about the association of MR findings and the histological appearance in the retrodiscal tissue with joint pain, the MR study by Takaku et al.[7] supports this interpretation. Through MRI study using the FISP-3D and histological study, they reported that high-signal intensities were observed in 30 joint spaces and in 19 of these joints, their retrodiscal tissues have hypertrophic changes, proliferation of synovial cells, and edematous subsynovial connective tissue[2]. They concluded that pathologic intracapsular changes are accurately depicted by FISP-3D, and this method is particularly useful for diagnosing changes in the disc and retrodiscal tissues. Whereas, Sakuma et al.[23] reported a study to evaluate whether decreased signal intensity on T1 weighted MR images of the retrodiscal tissue of the TMJ reflects increased density of collagen fibers. They concluded that reduced T1 signals of retrodiscal tissue do not necessarily reflect a dense distribution of collagen fibers. When compared with the study by Takaku[2], this study had not enough number of specimen to confirm their conclusion.

Before this experiment, we expected that more obvious difference of signal intensity would be found on T2 than T1 weighted images of MRI from a theoretical point of view that water has the longest T2 relaxation time and thus appears most obviously bright in T2 image[24]. However, contrary to our expectation, the RSI of retrodiscal tissue was significantly higher in the joint with pain than in a joint without pain on T1 weighted images of magnetic resonance imaging (MRI) in this study. This finding means that the presence of pain in joint with disc displacement doesn't occur only in the edematous condition out of our expectation. This finding is, however, coincident with the previous finding that not all of retrodiscal tissues with joint pain, even though severe, had the obviously edematous condition.

With regard to these equivocal result, Katzberg et al.[5] reported that a decrease of signal intensity on T1-weighted MR images has been described in the posterior attachment in chronically displaced discs, thought to represent the formation of a "pseudo" disc and with a fibrotic remodeling and that the increased signal on a T1-weighted MRI is compatible with myxomatous degeneration. Takaku at al.[2] reported that the severe myxomatous degeneration and split were showed in 26 of 43 symptomatic joints. We speculated that retrodiscal tissue in painful TMJ could be related to myxomatous degeneration as well as inflammation response and that these changes in retrodiscal tissue could be detected as the increase in RSI. But our

speculation remained unclear because of the limitation that in our study, the subsequent histological study on TMJ was not performed.

As for the previous studies measuring the MR signal intensity in TMJ, they could be methodologically divided into studies using signal intensity[14,15] and RSI as their values[15]. RSI is defined as the ratio of the signal intensity of retrodiscal tissues relative to various reference tissue. In this study, RSI was used to minimize the variation of brightness. However, there is no agreement on the placement and on the size of ROI, which could critically influence the result. This difference of the measurement method might bring the different results from previous studies[14,15].

For the association between the prevalence of joint pain and MRI findings in this study, there is a significant difference between ADWR and ADWOR with higher prevalence of joint pain in ADWOR. But no other MRI findings than disc position were related with the prevalence of joint pain. We speculated that this finding was due to the facts that joint disc couldn't be reduced during mouth opening and that this condition might bring more harmful tension force to retrodiscal tissue.

In summary, the increased RSI of retrodiscal tissue on T1-weighted image was significantly related with joint pain. It could be useful for the evaluation of joint pain and noninvasive assessment of retrodiscal tissue. And the disc position was significantly related with prevalence of pain.

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국문초록

원판후조직의 T1, T2 강조영상상의 상대적 신호강도와 관절통증의 상관관계

경북대학교 치의학전문대학원 구강내과학교실

정재광 · 허윤경 · 최재갑

이 연구의 목적은 측두하악관절에서 통증의 존재에 따른 T1,T2 강조 영상에서 원판후조직의 상대적 신호 강도의 연관성을 평가하는 것이다. 본 연구는 양측성 관절원판전위가 있으면서 편측성으로 관절통증을 가진 61명의 환자의 122개의 관절을 근거하여 행해졌다. 자기공명영상의 평가는 원판후조직의 신호강도의 측정과 관절원판의 위치, 삼출액, 퇴행성 변화와 같은 관절상태를 포함하였다. 원판후조직의 상대적 신호강도는 대뇌의 회질의 신호강도를 기준으로 구해졌다.

원판후조직의 상대적 신호강도와 관절통증, 개구량, 관절원판위치, 삼출액, 퇴행성 변화간의 상관성이 조사되었다. 그 결과, T1 강조 영상에서 상대적 신호강도가 비통증관절에 비해 통증관절에서 유의성있게 높게 나타났다. 또한 관절원판 전위의 심도와 통증 간에 유의성 있는 상관성이 있는 것으로 나타났다.

이러한 결과는 관절원판전위 환자에서 발생하는 악관절 통증이 원판후조직의 손상과 밀접한 관련성이 있음을 시사하는 것으로서 따라서 악관절의 T1 강조영상에서 관찰되는 원판후조직의 상대적 신호강도의 크기는 악관절 통증의 존재를 나타내는 진단학적 표시자로 사용될 수 있을 것으로 생각된다.

주제어 : 자기공명영상, 통증, 신호강도, 측두하악관절