RESEARCH

Temporomandibular joint and 3.0 T pseudodynamic magnetic resonance imaging. Part 1: evaluation of condylar and disc dysfunction

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Objectives: This study describes an improved method for examining and diagnosing temporomandibular joint (TMJ) dynamics by 3.0 T pseudodynamic MRI.

Methods: Clinical observation and conventional static MRI of volunteers (one without and eight with TMJ arthrosis) were followed by 3.0 T pseudodynamic MRI in positions ranging from the mouth closed to mouth fully opened. Condylar head (Cd), articular disc anterior border (Da) and articular disc posterior border (Dp) were digitized on sagittal images to determine trajectory and velocity patterns.

Results: Patients were divided into three groups based on the presence or absence of dysfunction: Group 1, no dysfunction on the right or left side of the TMJ; Group 2, dysfunction on the right or left side of the TMJ; and Group 3, dysfunction on both the right and left sides of the TMJs. In 75% of patients (12 of 16 joints), pseudodynamic TMJ analysis was useful for determining a functional abnormality. Using a points system based on three trajectory and seven velocity patterns, discs with adhesion and perforation had significantly fewer points than discs with anterior displacement (with and without reduction) and discs with no abnormality ($P = 0.019 < 0.05$).

Conclusions: Trajectory and velocity patterns based on 3.0 T pseudodynamic MRI identified the affected side and determined the extent of morbidity in the Cd as well as the Da and Dp. The typical abnormal movement pattern of discs with anterior displacement (with and without reduction) and pathological structural changes of the articular disc (such as adhesion and perforation) could be identified.

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Introduction

Pseudodynamic 1.5 T MRI is not used as a routine MRI examination technique for assessment of temporomandibular joint (TMJ) disorders, but such imaging can help to assess movement of the condylar head (Cd)¹ and articular disc.^{2,3} Cine-MRI diagnosis is useful for post-therapeutic evaluation of an adherent TMJ disc.⁴ The movement of the Cd and articular disc in TMJs

with adhesion and perforation abnormalities is not well understood. Static MRI cannot effectively determine the border between the posterior band of the articular disc and its posterior attachment.⁵ Some studies have used the central, thin part of the articular disc as a measurement marker;³ however, there is a lack of detailed research on the movement of Cd together with the movement of the anterior (Da) and posterior (Dp) borders of the articular disc.

Pseudodynamic MRI differs from the natural opening of the TMJ.⁶ Studies using pseudodynamic MRI have reported that condylar velocity patterns of normal subjects move synchronously with bilateral Cds.^{7,8}

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Cineradiography⁹ and videofluorography¹⁰ can capture physiological mouth opening and show that Cd velocity patterns peak relatively near the articular eminence.

3.0 T MRI with a super-high magnetic field provides imaging of the human body and head, but the equipment used lacks a specialized dual surface coil for clear TMJ images. Although some studies have used a surface coil for TMJ imaging,¹¹ the efficacy of 3.0 T TMJ pseudodynamic imaging is unclear. This paper describes an improved method for examining and diagnosing TMJ abnormalities using 3.0 T pseudodynamic MRI.

Materials and methods

Clinical findings

Database images of nine volunteers (six males and three females; between 24 and 35 years of age, median 26.5 years) were used in the study. Ethical approval was obtained from the ethics committee of the University of Tokushima Medical and Dental Hospital in Japan. Volunteers received information about the study and informed written consent was obtained. One volunteer had no symptoms of TMJ dysfunction, whereas the other eight had clinically diagnosed abnormalities related to TMJ arthrosis as defined by the Japanese Society for TMJ criteria.¹¹

Clinical examination revealed the presence of TMJ pain and sounds (clicking or crepitus) with jaw movement. It also revealed the side of the TMJ affected by pain or sounds as well as limitation and deviation during mouth opening. Clinical findings that could not be differentiated between the right and left sides of the TMJ (*e.g.* limitation and deviation during mouth opening) were categorized as bilateral.

Static MRI

Reports on 3.0 T imaging methods for the TMJ served as a reference.¹² Images were taken with 3.0 T MRI equipment (Signa 3.0 T, GE Yokogawa Medical Systems, Ltd., Tokyo, Japan) using a 3 inch dual surface coil (GE Yokogawa Medical Systems). Scan parameters of the 3.0 T static MRI sequences are shown in Table 1. MR

images were selected from a database of 3.0 T TMJ images. Digital Imaging and Communications in Medicine (DICOM) database images (512 pixels $\times$ 512 pixels $\times$ 16 bit) were converted to tagged image file format (TIFF) images with OSIRIS (Version 4.19, University of Geneva, Switzerland) and used for measurements.

The volunteers were instructed to lie supine and their heads were positioned perpendicular to the scanning table in the Frankfort horizontal plane. The median sagittal plane of the head was also perpendicular to the scanning table. The Cd was palpated and 21 3-plane localizer static MR images (7 axial, 7 sagittal and 7 coronal; thickness 8 mm; interval 1 mm) were taken. The largest and clearest axial image was used as a measurement localizer image to set individual planes for cutting the Cd.

Seven individualized proton density images and seven T_2 weighted sagittal images were obtained for the right and left sides of the TMJ (thickness 2 mm; interval 0.2 mm) in the mouth closed and mouth fully opened position. The fourth image provided the midpoint of the Cd long axis.

Static MRI findings indicated the presence or absence of a TMJ abnormality and its location. Joint effusion, osteoarthritis, disc displacement and disc shape were all considered when determining the TMJ status. More than one high-signal line (*e.g.* spot intensity) in the upper or lower joint space was considered to be joint effusion. Osteoarthritis was indicated by the presence of pathological bone changes such as eburnation (subchondral sclerosis) or erosive bone change with or without deformity of Cd and osteophytes. Articular disc position (disc displacement with or without reduction) was assessed in the mouth closed and mouth fully opened positions. Disc abnormalities such as folding were identified.

Pseudodynamic MRI

Scan parameters of the 3.0 T pseudodynamic MRI sequences are shown in Table 1. Pseudodynamic images were taken parallel to sagittal sections of the head in the mouth closed position to avoid different cross-sections of Cd, articular eminence and glenoid fossa from the mouth closed position to mouth fully opened positions.

Table 1 Scan parameters of 3.0 T MRI sequences

	<i>Static MR</i>						<i>Pseudodynamic MR</i>
	<i>Three-plane localizer</i>	<i>Proton density Sagittal</i>	<i>T₂ weighted Sagittal</i>	<i>Proton density Coronal</i>	<i>T₂ weighted Coronal</i>		
Flip (degrees)	30	90	90	90	90	90	
Echo	1/1	1/1	1/1	1/1	1/1	1/1	
TE	1.348	12.86	85.2	12.91	85.72	10.01	
TR (ms)	4.992	2800	5900	2100	4800	1800	
Thick/space	8.0/2.0	2.0/0.2	2.0/0.2	2.0/0.2	2.0/0.2	2.0/1.0	
FOV (cm)	24 $\times$ 24	14 $\times$ 14	14 $\times$ 14	14 $\times$ 14	14 $\times$ 14	14 $\times$ 14	
Matrix	256 $\times$ 128	448 $\times$ 256	512 $\times$ 320	448 $\times$ 256	512 $\times$ 320	448 $\times$ 224	
NEX	1.0	2.0	2.0	2.0	2.0	1.0	
Time (s)	17	180	240	180	240	40	

TE, echo time; TR, repetition time; FOV, field of view; NEX, number of excitations

Figure 1 Co-ordinate points for pseudodynamic measurement. Em, lowest articular eminence; Cd, highest protrusion of the condylar head, where the perpendicular line from the posterior mandibular ramus meets the condylar head; Da, articular disc anterior border, where the posterior border of the anterior attachment showing low signal intensity is separated from the surrounding area in the anterior band of the articular disc; Dp, articular disc posterior border, where a bow tie configuration is derived from a temporal part of posterior attachment and a condylar part of posterior attachment

Seven sagittal images of the right and left sides of the TMJ (thickness 2 mm; interval 1 mm) were taken, and the fourth image coincided with the midpoint of the Cd long axis. Flaps (FL400 L, Hanshin Technical Laboratory, Ltd., Hyogo, Japan) were added from mouth closed position to mouth fully opened positions. Serial images were taken for 40 s per flap.

Measurement points: Co-ordinate points for the pseudodynamic measurements are shown in Figure 1. Image J software¹³ was used for the measurements. The average of the pixel co-ordinate values at three time measurements was converted to 0.2734 mm/pixel. Co-ordinate values were determined for the lowest articular eminence (Em) and corrected for head rotation.

Analysis by trajectory and velocity patterns: We studied trajectory patterns connecting the Cd, Da and Dp measurement points for each flap insertion, and velocity patterns were measured at these points (Figure 1). Some volunteers could insert no more than four flaps because of limited jaw movement. Normal and abnormal trajectory and velocity patterns were compared and categorized.

Results

Normal TMJ trajectory and velocity patterns

Figure 2 shows (a) trajectory and (b) velocity patterns at Cd, Da and Dp measurement points on the left side of a normal TMJ (case 1).

Abnormal TMJ trajectory patterns

Based on the measurement of points Cd, Da and Dp in the mouth closed position and during flap insertion, trajectory patterns of abnormal TMJs were divided according to the degree of positive or negative trajectory and length of the trajectory (Figure 3). There were three basic patterns: Type I (relatively curved), Type II (relatively short and straight) and Type III (zigzag). Type I was subdivided according to whether or not there was positive trajectory from flap 0 to 1 to create subtype I-a (downward trajectory from flap 0 to 1) and subtype I-b (upward trajectory from flap 0 to 1).

Figure 2 Normal (a) trajectory and (b) velocity patterns (Case 1, left temporomandibular joint)

Figure 3 Trajectory patterns I-a, I-b, II and III; Cd, condylar head; Dp, posterior border of the articular disc; Type I, relatively curved; subtype I-a, downward trajectory at flap 0 to 1; subtype I-b, upward trajectory at flap 0 to 1; Type II, relatively short and straight; Type III, zigzag

Abnormal TMJ velocity patterns

Based on the measurement of points Cd, Da and Dp in the mouth closed position and during flap insertion, velocity patterns of abnormal TMJs were divided according to peaks, troughs and velocity duration (Figure 4).

Normal and abnormal trajectory and velocity patterns for all volunteers were compared (Table 2). TMJ morbidity was graded based on the movement of Cd, Da and Dp. A point system was devised to determine the extent of TMJ morbidity.

Grades were based on the following scientific weighting:

Grade 1, 3 points: normal, Cd and Da, trajectory (I-a) and velocity (1A);

Grade 2, 2 points: normal, Dp, trajectory (I-b) and velocity (1A, 2A or 3A);

Grade 3, 1 point: abnormal, Cd, Da and Dp, trajectory (I) and velocity (except 1A, 2A, or 3A); and

Grade 4, 0 points: abnormal, Cd, Da, and Dp; trajectory (II or III).

Pseudodynamic MRI analysis was not considered to be effective (meshed area) if a joint scored ≥ 6 . Because only one case with no symptoms scored ≥ 6 (black area), pseudodynamic MRI analysis was considered to be effective if a joint scored ≤ 5 . The extreme right column shows the scored values from the pseudodynamic analysis.

Trajectory and velocity patterns for Cd, Da and Dp were analysed, and the TMJs of eight volunteers with TMJ arthrosis were divided based on the presence or absence of dysfunction. Group 1: no dysfunction on the right or left side of TMJs; Group 2: dysfunction on the right or left side of TMJs; and Group 3: dysfunction on the right and left sides of TMJs.

Clinical, static MRI and pseudodynamic MRI in abnormal TMJ

Table 3 shows the clinical, static MRI and pseudodynamic MRI findings in all volunteers. In the six TMJs marked with an “*”, the relationship between pseudodynamic and clinical findings was revealed not by

morphological analysis alone, but by functional analysis. In the six other TMJs marked with a “†”, the pathology was clearer and the relationship between the pseudodynamic and clinical findings could be explained better by combining functional with morphological analysis. In the four TMJs marked with a “**” and “×”, including two “**” in which morphological analysis showed abnormalities not detected by functional analysis, the latter “×” could not explain the relationship between pseudodynamic and clinical findings. In the present experiment, functional analysis by MRI was effective in 12 of 16 (75%) TMJs.

The Kruskal–Wallis test revealed that discs with adhesion and perforation (four TMJs) had significantly fewer points than discs with anterior displacement with and without reduction (five TMJs) and discs with no abnormality (four TMJs) ($P = 0.019 < 0.05$).

Discussion

Analyzing TMJ dynamics by trajectory and velocity patterns

Normal TMJ dynamics: In normal TMJs, Cd and Da showed the subtype I-a trajectory pattern (relatively curved, without a downward trajectory between flap 0 and 1) that moved synchronously on the right and left sides. Cd and Da showed the subtype 1A velocity pattern (chevron shape, one intermediate peak) with the peak of Cd passing through the articular eminence. This pattern seemed to capture the natural opening pattern of the temporomandibular joint the same as cineradiography⁹ and videofluorography.¹⁰

In the pseudodynamic MR images in our study, the border between the posterior band of the articular disc and its posterior attachment at flap 0 was obscured. This posteroinferior limit of the articular disc and posterior attachment was used as the Dp measurement point. As a result, between flaps 0 and 1 there was an upward trajectory (subtype I-b) and acceleration (subtypes 2A and 3A). Subtypes 2A and 3A of the velocity pattern were treated as normal patterns resembling the subtype 1A velocity pattern.

Another factor influencing this upward trajectory of Dp and acceleration of Cd, Da and Dp may have been the addition of flaps to insertion steps 0 and 1 because of the overbite and overjet (vertical and horizontal distance between upper and lower anterior incisal teeth in the mouth closed position) of the volunteers.

The articular disc cannot be regarded as a single rigid body because of differences in movement between the anterior and posterior borders.

Abnormal TMJ dynamics: Significant changes in TMJ dynamics could not be analysed in abnormal TMJs using only Cd trajectory patterns. Many abnormal TMJs showed abnormal velocity patterns that were useful for analysing their articular disc dynamics. There were more abnormal Da and Dp velocity patterns than

Figure 4 Velocity patterns 1A/2A/3A, 1B/2B/3B, 4A/5A/6A/7 and 4B/5B/6B/7. Type 1, chevron shape with one peak; Type 2, U-shape with one trough; Type 3, convexo-concave shape with one peak and one trough; Type 4, convexo-concave shape with a total of three asperities of velocity; Type 5, without peak or trough in velocity and move or stop gradually; Type 6, without peak or trough in velocity and becomes temporally stable; Type 7, without peak or trough in velocity and stable; 0-1 flap, initial step; 1-2 flaps, early steps; 2-3 flaps, intermediate steps; 3-4 flaps, late steps; 4-5 flaps, final steps

trajectory patterns; hence, velocity patterns were more useful for analysing these dynamics. After evaluation, eight cases with TMJ disorder could be divided into three dysfunctional groups (see Results section).

Comparison of the clinical, static and pseudodynamic MRI findings showed that pseudodynamic MRI analysis was useful in 12 of the 16 (75%) joints. Analysis of morphological and functional findings by

static and pseudodynamic MRI explained the clinical findings and roughly described the pathology.

Significance of TMJ pseudodynamic analysis: Typical anterior disc displacement with reduction was suspected following pseudodynamic MRI analysis in cases 3 (left side), 4 (left side), 5 (right side) and 9 (left side). The trajectory pattern was normal in case 4 (Figure 5). A

Table 2 Correlation between normal and abnormal trajectory patterns and velocity patterns (all cases, right and left temporomandibular joints)

	Trajectory patterns						Velocity patterns						Pseudodynamic analysis	
	Right			Left			Right			Left			Right	Left
	Cd	Da	Dp	Cd	Da	Dp	Cd	Da	Dp	Cd	Da	Dp	Total points	Total points
Case 1	I-a	I-a	I-b	I-a	I-a	I-b	1 A	1 A	5 A	1 B	1 A	3 A	7	6
Case 2	I-a	I-a	I-b	I-a	I-a	I-b	1 B	1 A	1 A	1 A	1 A	1 A	7	9
Case 3	I-a	I-a	I-b	I-a	I-b	III	1 A	1 A	1 A	3 B	1 A	3 B	9	2
Case 4	I-a	I-a	I-b	I-a	I-a	I-b	3 A	1 A	3 A	3 A	4 B	3 A	6	4
Case 5	I-a	I-a	I-a	I-a	I-a	I-b	2 B	7	3 B	2 A	2 B	2 A	3	4
Case 6	I-a	II	II	I-a	I-a	I-b	5 B	3 B	3 B	2 B	3 B	6 B	1	3
Case 7	I-a	I-a	I-a	I-a	I-a	II	5 A	5 A	5 A	5 A	5 A	5 A	3	2
Case 8	I-a	III	II	I-a	II	I-b	3 B	4 B	6 A	1 A	1 A	6 A	1	4
Case 9	II	II	II	II	II	II	3 B	1 A	7	3 B	3 B	3 B	0	0

Key to Table 2

Grade	Point	Definition	Explanation	Cd	Da	Dp
1	3	Normal	Cd and Da: trajectory (I-a) and velocity (1A)	4	6	
2	2		Dp: Trajectory (I-b) and velocity (1A, 2A or 3A)			7
3	1	Abnormal	Cd, Da and Dp: trajectory (I) and other velocity	12	7	5
4	0		Cd, Da and Dp: trajectory (II or III)	2	5	6

Pseudodynamic analysis

	Normal TMJs without any clinical symptoms
	More than 6 points : not effective by pseudodynamic analysis
	Less than 5 points : effective by pseudodynamic analysis

TMJ, temporomandibular joint; Cd, condylar head; Da, anterior border of the articular disc; Dp posterior border of the articular disc. Trajectory patterns: I, relatively curved; I-a, downward trajectory at flap 0 to 1; I-b, upward trajectory at flap 0 to 1; II, relatively short and straight; III, zigzag; Velocity patterns: Type 1, chevron shape with one peak; Type 2, U-shape with one trough; Type 3, convexo-concave shape with one peak and one trough; Type 4, convexo-concave shape with a total of three asperities of velocity; Type 5, without peak or trough in velocity and move or stop gradually; Type 6, without peak or trough in velocity and becomes temporally stable; Type 7, without peak or trough in velocity and stable

sudden decrease in movement of the condyle and disc and the ensuing sudden increase in velocity (a deceleration and acceleration pattern) were observed hemilaterally. When there was a sudden deceleration of the condyle and disc on one side, the contralateral condyle and disc showed sudden acceleration, especially at the Da. We could distinguish hemilateral anterior disc displacement with reduction that did or did not affect the opposite side. In cases 4 (left side) and 9 (left side), disc displacement with reduction was observed only by pseudodynamic MRI.

On the right side of case 6 (Figure 6), typical anterior disc displacement without reduction (with folded articular disc) was suspected based on the pseudodynamic MR images, and the right Cd trajectory patterns were subtype II (relatively short and straight, not passing through Em). "Folded" Da and Dp remained anterior to Em. Cd, Da and Dp velocity patterns on both right and left sides showed all deceleration patterns that appeared in Cd (subtypes 5B and 2B), Da (subtypes 3B and 3B) and Dp (subtypes 3B and 6B). The trajectory pattern on the left side appeared normal.

Table 3 Relationship between clinical, static and pseudodynamic MRI for all volunteers

No.	Clinical						Static MR						Pseudodynamic MR					
	Right			Left			Right			Left			Right			Left		
	Pain	Sound	Movement	Pain	Sound	Movement	Joint effusion	Disc displacement	Bone change	Joint effusion	Disc displacement	Bone change	Total points	Disc displacement	Disc change	Total points	Disc displacement	Disc change
Case 1	—	—	—	—	—	—	—	—	—	—	—	Concavity	7	—	—	6	—	—
Case 2	—	Clicking	—	—	Clicking + crepitus	—	+	—	—	—	—	—	7**	—	—	9[×]	—	—
Case 3	—	Clicking	Deviation at opening	—	Clicking	Deviation at opening	+	—	—	+	ADDwR	—	9**	—	—	2[†]	ADDwR	—
Case 4	—	—	Deviation at opening	—	—	Deviation at opening	—	—	—	—	—	—	6[×]	—	—	4[*]	ADDwR	—
Case 5	—	—	Deviation at opening	—	—	Deviation at opening	+	ADDwR	Concavity	+	—	Concavity	3[†]	ADDwR	—	4[†]	—	—
Case 6	—	—	—	—	Clicking	—	+	ADDwoR Folding	—	—	—	—	1[†]	ADDwoR Folding	—	3[*]	—	—
Case 7	—	—	Deviation at opening	—	—	Deviation at opening	+	—	—	+	—	Knife shaped	3[†]	—	Adhesion	2[†]	—	Adhesion
Case 8	—	—	—	Pain	Clicking	—	—	—	—	—	—	—	1[*]	—	Perforation	4[*]	—	—
Case 9	—	—	Limitation of mouth opening	—	—	Limitation of mouth opening	—	—	—	—	—	—	0[*]	—	Adhesion	0[*]	ADDwR	—

Disc adhesion and perforation (four temporomandibular joints (TMJs)) < ADDwR + ADDwoR (five TMJs) < disc with no abnormality (four TMJs); Kruskal–Wallis test; $P = 0.019 < 0.05$; ADDwR, anterior disc displacement with reduction; ADDwoR, anterior disc displacement without reduction. *relationship between pseudodynamic and clinical findings not revealed by morphological analysis alone; †relationship between pseudodynamic and clinical findings can be explained better by combining functional and morphological analysis; ×functional analysis cannot explain the relationship between pseudodynamic and clinical findings; **morphological analysis shows abnormalities not detected by functional analysis

Figure 5 Anterior disc displacement with reduction (ADDwR) (Case 4): (a) trajectory pattern and (b) velocity pattern

Deceleration on the one side was caused by movement of the other side. Other types of displacement (medial, lateral, posterior, rotational and sideways)¹⁴ were not observed in this study.

MRI diagnosis has been used for post-therapeutic evaluation of an adherent TMJ disc,⁴ but the presence of a characteristic movement of the condyle or articular disc with disc adhesion before treatment has not been reported. In our study, disc adhesion was suspected in Cases 7 (right and left side) and 9 (right side) following pseudodynamic MRI analysis.

In Case 7, the trajectory patterns were almost normal, but the Cd, Da and Dp velocity patterns were subtype 5A (acceleration) in which the condyle “dragged” the articular disc, because Cd, Da and Dp moved nearly the same distance, accelerating as the

mouth opened. Static MR images showed joint effusion on the right and left sides of Case 7.

In Figure 7 (Case 9), the trajectory patterns were abnormal subtype II (relatively short and straight). The right Cd did not exceed Em, and the Dp trajectory pattern was relatively short and straight. However, the velocity patterns of the right Dp were subtype 7 (stable) in which Dp moved independently from Cd, and Da moved nearly the same distance without accelerating as the mouth opened. Co-ordination between the condyle and articular disc was lost; the condyle could not “drag” the Dp, with the latter behaving as if there was disc adhesion between the posterior attachment and posterior slope of the articular eminence. In Case 9, the left Cd did not exceed Em and the trajectory pattern of Dp was relatively short and straight. The velocity

Figure 6 Anterior disc displacement without reduction (ADDwR) (Case 6): (a) trajectory pattern and (b) velocity pattern

Figure 7 Disc adhesion (Case 9): (a) trajectory pattern and (b) velocity pattern

pattern on the left side in Case 9 showed a typical deceleration and acceleration pattern of anterior disc displacement with reduction. Da disc adhesion was not considered for this velocity pattern.

Obscurity of the temporal posterior attachment has been reported as a characteristic MRI finding in patients with disc perforation.¹⁵⁻¹⁷ In over half of perforation or disruption cases mouth opening is not restricted.¹⁵ Disc adhesion could be associated with obscurity of the temporal posterior attachment, and in such cases mouth opening would be restricted. It was difficult to distinguish adhesion and perforation only by the latitude of anterior condylar movement. Obscurity of the temporal posterior attachment was rare in 3.0 T pseudodynamic

MRI analysis (only one abnormal TMJ in this study, *i.e.* the right side of Case 8).

In Figure 8 (Case 8), the right Cd trajectory pattern was relatively curved and exceeded Em, with no recognizable abnormality. The velocity pattern of the right Cd and Da temporarily decelerated (subtypes 3B and 4B) compared with the chevron pattern (subtype 1A) of the opposite left Cd and Da. The right and left Da may have been “dragged” by the movement of Cd. The right and left Dp trajectory patterns were subtype II (relatively short and straight), and their velocity patterns were subtype 6A (stable, acceleration and then stable). Because Dp moved independently of Cd and Da remained in the same position from mouth closed to mouth half-opened, disc

Figure 8 Disc perforation (Case 8): (a) trajectory pattern and (b) velocity pattern

adhesion in Case 8 was thought to be more advanced than in Cases 7 and 9, with possible perforation. The left side of Case 8 showed a relatively high number of points (4 points) even though Dp was subtype 6A, similar to the opposite right side Dp. The left side of this TMJ may not have been severely damaged. Instead, movement on the left side of the TMJ may have been restricted by stable acceleration and movement of Dp on the right side.

Discs with adhesion and perforation had significantly fewer points than discs with anterior displacement (with and without reduction) and discs with no abnormality ($P = 0.019 < 0.05$), which may constitute the rationale of this point system. Pathological conditions of the articular disc other than disc displacement were evaluated by pseudodynamic MRI analysis. In particular, stable or acceleration Dp patterns (subtypes 7, 6A and 5A) may be associated with pathological conditions in the temporal posterior attachment such as adhesion and perforation of the articular disc.

3.0T static MRI permits clearer imaging than 1.5T imaging, including the contour of subtle changes such as anterior and posterior borders of the articular disc. It also allows for a slightly improved diagnosis of disc displacement. Although 3.0T static MRI does not significantly reduce the examination time, it may produce clearer images that make 1.5T static images unnecessary. T_2 static images were necessary for diagnosing joint effusion. As with static images, movement images were necessary for diagnosing lateral or rotational disc displacement in cases where the mediolateral border contour of the disc was obscured. Supplementary images of the long axis of the condyle and anteroposterior frontal sections were also necessary.

In conclusion, analysis of morphology and function using MRI revealed the relationship of an abnormality with clinical findings. Patients were divided into three TMJ functional diagnosis patterns: no dysfunction, dysfunction on one side and dysfunction on both sides.

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In 75% (12 of 16 joints) of cases, pseudodynamic TMJ analysis was useful for determining functional abnormality. Using a point system that combined trajectory and velocity patterns, discs with adhesion and perforation had significantly fewer points than discs with anterior displacement (with and without reduction) and discs with no abnormality ($P = 0.019 < 0.05$). 3.0T pseudodynamic MRI analysis of trajectory and velocity patterns helped identify the affected side and determine the extent of morbidity in Da, Dp and Cd that could not be revealed using previous methods, thereby showing potential clinical application. Pseudodynamic MRI analysis indicated typical anterior disc displacement with and without reduction and revealed pathological structural changes in the articular disc (adhesion and perforation).

Further investigation is required to distinguish articular disc adhesion and perforation based on trajectory and velocity patterns. The pathology shown by Cd, Da and Dp in TMJs and determining whether the true pathology lies in the articular disc or in surrounding tissues such as the joint capsule, ligament and masticatory muscles require further evaluation.

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