MAJOR PAPER

Usefulness of Dual Echo Volumetric Isotropic Turbo Spin Echo Acquisition (VISTA) in MR Imaging of the Temporomandibular Joint

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Purpose: We investigated the ability to detect the articular disk and joint effusion of the temporomandibular joint (TMJ) of a method of dual echo volumetric isotropic turbo spin echo acquisition (DE-VISTA) additional fusion images (AFI).

Methods: DE-VISTA was performed in the 26 TMJ of 13 volunteers and 26 TMJ of 13 patients. Two-dimensional (2D) dual echo turbo spin echo was performed in the 26 TMJ of 13 volunteers. On a workstation, we added proton density-weighted images (PDWI) and T₂ weighted images (T₂WI) of the DE-VISTA per voxel to reconstruct DE-VISTA-AFI. Two radiologists reviewed these images visually and quantitatively.

Results: Visual evaluation of the articular disk was equivalent between DE-VISTA-AFI and 2D-PDWI. The sliding thin-slab multiplanar reformation (MPR) method of DE-VISTA-AFI could detect all articular disks. The ratio of contrast (CR) of adipose tissue by the articular disk to that of the articular disk itself was significantly higher in DE-VISTA-AFI than DE-VISTA-PDWI ($P < 0.05$) in patients and volunteers with closed or open mouth. In volunteers, the CR between adipose tissue and the disk on DE-VISTA-AFI was marginally significant to that on 2D-PDWI at opened mouth ($P = 0.071$) and not significantly different ($P = 0.18$) from that at closed mouth. Joint effusion could be identified in DE-VISTA-AFI in all 8 joints that had joint effusion in DE-VISTA-T₂WI but in only 3 of those joints in 2D-T₂WI. The CR of joint effusion to adipose tissue on DE-VISTA-AFI did not differ significantly from that on DE-VISTA-PDWI. However, using DE-VISTA-T₂WI in addition to DE-VISTA-PDWI, we could visually identify joint effusion on DE-VISTA-AFI that could not be identified on DE-VISTA-PDWI alone.

Conclusion: DE-VISTA-AFI can depict the articular disk and a small amount of joint effusion by the required plane of MPR using the sliding thin-slab MPR method.

Keywords: *dual echo, MRI, temporomandibular joint, VISTA, 3D fast spin echo*

Introduction

The major symptoms of temporomandibular joint disorder (TMD) are pain or tenderness in or around the temporomandibular joint (TMJ), dys-

function, including TMJ clicking, and limited capability to open the jaw. Magnetic resonance (MR) imaging is considered the standard of reference for noninvasive diagnosis of displacement of the TMJ disk.¹ Studies comparing MR imaging findings with surgical and autopsy specimens report about 90 to 95% accuracy in detecting abnormalities in disk position when both coronal and sagittal images are

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evaluated.²⁻⁴ Another paper reports the 95% accuracy of MR imaging in assessing disk position and form and 93% accuracy in assessing osseous changes.⁵

Proton density-weighted images (PDWI) are necessary to detect the position and deformity of the articular disk,⁶⁻⁸ and T₂-weighted images (T₂WI) are necessary to detect the level of joint effusion, which is associated with pain.^{8,9} A dual echo technique is generally used for 2-dimensional (2D)-PDWI and -T₂WI scans.¹⁰ Sagittal and coronal sections of the TMJ in both closed- and opened-mouth positions are also required to determine displacement and reduction of the articular disk.^{11,12} However, 2D dual echo imaging is often technically difficult for planning.

Because 3-dimensional (3D) imaging is very time consuming using a spin echo method, a gradient echo method has been employed. The utility of 3D-T₂ turbo field echo (TFE) is reported for detecting lateral displacement of the articular disk using multiplanar reformation (MPR) at the TMJ.¹³ However, the mastoid air cells adjacent to the TMJ limit detection of the articular disk in those gradient echo sequences. Magnetic susceptibility effects due to structures containing air, such as mastoid air cells and the ethmoid sinus, can cause signal loss near the skull base when gradient echo methods are used.¹⁴ Three-dimensional imaging using a spin echo method can overcome this limitation by providing better images without the influence of susceptibility effects. However, conventional 3D-T₂ turbo spin echo (TSE) remains time consuming. Recently, use of the volumetric isotropic TSE acquisition (VISTA) sequence at clinical sites has enabled high speed imaging, even for spin echo 3D imaging.¹⁵⁻¹⁸

We hypothesized that the dual echo VISTA (DE-VISTA) method could be used to overcome the issues of prolonged scan duration and susceptibility effects at the TMJ. In addition, because DE-VISTA-PDWI and DE-VISTA-T₂WI have identical positional information, their data can be precisely added and calculated per voxel. Therefore, we created a DE-VISTA additional fusion image (AFI) with DE-VISTA-PDWI and DE-VISTA-T₂WI and investigated its ability to detect the articular disk and joint effusion of the TMJ.

Materials and Methods

Patients

Our institutional review board approved this study. We evaluated a total of 52 joints, 26 each in 13 asymptomatic male volunteers (aged 25 to 48

years, average age 32 years) and 13 consecutive patients with symptoms (2 men, 11 women; aged 14 to 74 years, average age 54 years) who underwent magnetic resonance (MR) imaging at our hospital from July 29, 2010 to February 6, 2012.

Imaging procedures

A 1.5-tesla MR imager (Intera Achieva Nova Dual R2-6, Phillips, Best, The Netherlands) was used with 2-channel sense-encoding (SENSE) flex coils as receivers.

We simultaneously obtained DE-VISTA-PDWI and T₂WI transaxial images within a range of 35 mm centering on the TMJ using 3D pilot scan techniques and dual echo sequence at both opened- and closed-mouth positions. Patient examinations at opened mouth were carried out using a bit block prepared by the ordering oral and maxillofacial surgeon.

Parameters for DE-VISTA imaging were: repetition time (TR)/echo time (TE) (first)/TE (second), 800/10/150 ms for 3D dual echo TSE (DE-VISTA); field of vision (FOV), 224 × 224 × 35 mm; acquisition matrix, 1 × 1 × 1 mm; reconstruction matrix, 0.5 × 0.5 × 0.5 mm; refocusing control pulse flip angle, 160°; scan orientation, transverse; phase direction, right to left (RL); SENSE parallel imaging technique; SENSE P reduction factor, 2; turbo factor, 38; driven equilibrium (DRIVE) technique; number of signals averaged (NSA), 2, and scan duration, 6 min 45 s at closed-mouth and 13 min 30 s at opened-mouth position.

We obtained 2D dual echo TSE images only in volunteers, and 7 slices was performed for each right (Rt) and left (Lt) TMJ each oblique sagittal and oblique coronal under the following conditions; slice thickness, 3 mm with a 0.3-mm gap; TR/TE, 1533 ms/19 ms (PDWI), 1533 ms/150 ms (T₂WI); acquisition matrix, 0.43 × 0.6 × 3.0 mm; reconstruction matrix, 0.29 × 0.29 × 3.0 mm; FOV, 150 mm; turbo factor, 10; DRIVE technique; and NSA, 2. The planned examination time for the dual echo sequences was 4 min 32 s each for oblique sagittal and oblique coronal images, and total examination time for closed- and opened-mouth positions was 18 min 8 s.

Image analysis

Using AZE Virtual Place[®] software (AZE, Tokyo, Japan), we created DE-VISTA-AFI by adding VISTA-PDWI and VISTA-T₂WI obtained by the dual echo sequence per voxel. Subsequently, we reconstructed 24 coplanar images, such as oblique sagittal and oblique coronal images of the right and left TMJ at closed- and opened-mouth

position, for each of the 3 methods, DE-VISTA-PDWI, DE-VISTA-T₂WI, and DE-VISTA-AFI. These images were obtained in planes perpendicular and parallel to the long axis of the condyle. The MPR images were one mm thick with 0.5-mm interval.

The articular disk

Two radiologists, both with more than 10 years' experience in MR imaging, visually compared DE-VISTA-PDWI, DE-VISTA-AFI, sliding thin-slab MPR of DE-VISTA-AFI, and 2D-PDWI of volunteers to evaluate the anterior and posterior bands of the articular disk. They visually compared DE-VISTA-PDWI, DE-VISTA-AFI, and sliding thin-slab MPR of DE-VISTA-AFI to evaluate the articular disk of patients. In consensus, they graded image quality using a 3-point scale, from 0 to 2: 0 points, articular disk cannot be identified; one point, either the anterior or posterior band of the articular disk can be identified; and 2 points, both the anterior and posterior bands of the articular disk can be identified. Initially, a part of the articular disk was detected by rotation MPR in the center of the TMJ, and the disk was then continuously detected over its length and breadth by sliding and rotation MPR, termed sliding thin-slab MPR of DE-VISTA-AFI. The sliding thin-slab MPR image was one mm in thickness. For interactive viewing, this slab can be moved through the whole stack of transaxial images.^{19,20} The radiologists evaluated the images for the presence of disk displacement status in DE-VISTA-AFI until consensus was reached.

For quantitative analysis, in volunteers, we placed a single one-mm² ROI at a similar site on adipose tissue by the articular disk and the articular disk itself in 2D-PDWI, DE-VISTA PDWI, and DE-VISTA-AFI. The same copied ROI was placed on DE-VISTA PDWI and DE-VISTA-AFI. In patients, a single one-mm² ROI was placed on adipose tissue by the articular disk and the articular disk itself in DE-VISTA-PDWI and DE-VISTA-AFI at the same site with the copied ROI. We then measured the contrast ratio (CR) as: CR = signal of adipose tissue/signal of articular disk itself.

Joint effusion

Two radiologists visually reviewed and recorded the presence or absence of joint effusion in volunteers in DE-VISTA-T₂WI, DE-VISTA-AFI, DE-VISTA-PDWI, and 2D-T₂WI. They visually reviewed and recorded the presence or absence of joint effusion in patients in DE-VISTA-T₂WI, DE-VISTA-PDWI, and DE-VISTA-AFI.

For quantitative analysis, in volunteers with joint effusion on DE-VISTA-T₂WI, a single one-mm² ROI was placed on the joint effusion and adipose tissue in DE-VISTA-T₂WI, DE-VISTA-PDWI, DE-VISTA-AFI, and 2D-T₂WI. Two-dimensional T₂WI in volunteers demonstrated joint effusion in only 3 of 8 joints that showed joint effusion in DE-VISTA-T₂WI. For the other 5 joints, a single one-mm² ROI was placed on a similar site identified with joint effusion in VISTA-T₂WI. CR was measured as: CR = signal of joint effusion/signal of adipose tissue.

Statistical analysis

In volunteers, we used one-way analysis of variance (ANOVA) with Tukey-Kramer *post hoc* test to compare CR (adipose tissue/disk) in DE-VISTA-PDWI, DE-VISTA-AFI, and 2D-PDWI for quantitative analysis of the articular disk and to compare CR (joint effusion/adipose tissue) in DE-VISTA-T₂WI, DE-VISTA-AFI, DE-VISTA-PDWI, and 2D-T₂WI for quantitative analysis of joint effusion. In patients, where only 2 groups were compared, 2-tailed paired t test was used. In all analyses, $P < 0.05$ was considered significant. All statistical analyses were performed with JMP software (version 9.0.2, Institute, Inc, SAS, Cary, NC, USA).

Results

MR imaging was performed successfully in the planned scan time in all patients and volunteers.

The articular disk

Visual evaluation

At closed-mouth position in volunteers, a grade of one point was given to 4 joints on DE-VISTA-PDWI, 3 joints on DE-VISTA-AFI, and 6 joints on 2D-PDWI. Three joints that received a grade of 2 points only on the sliding thin-slab MPR of DE-VISTA-AFI were otherwise evaluated with one point on other images (Fig. 1). One joint graded one point on DE-VISTA-PDWI was evaluated with 2 points on DE-VISTA-AFI and 2D-PDWI.

At opened-mouth position in volunteers, a grade of one point was given to 3 joints on DE-VISTA-PDWI and DE-VISTA-AFI and 7 joints on 2D-PDWI. Two joints that received a grade of 2 points only on the sliding thin-slab MPR image of DE-VISTA-AFI were otherwise evaluated with one point on other images. One joint graded with one point on DE-VISTA-PDWI and DE-VISTA-AFI was given 2 points on 2D-PDWI. At opened-mouth position, the posterior band of this joint could not

Fig. 1. Temporomandibular joint (TMJ) of a 25-year-old male volunteer at closed-mouth position using sliding thin-slab multiplanar reformation (MPR) method. The articular disk cannot be identified in DE-VISTA-PDWI (dual echo volumetric isotropic turbo spin echo acquisition proton density-weighted images) oblique sagittal image (a), DE-VISTA-AFI (DE-VISTA additional fusion image) oblique sagittal image (b), and 2-dimensional (2D)-PDWI oblique sagittal image (c). It was possible to identify the articular disk using sliding thin-slab MPR of DE-VISTA-AFI. White arrow indicates the disk with rotation MPR in the center of the TMJ, termed sliding thin-slab MPR, of the oblique sagittal (d) and oblique coronal (e) images of DE-VISTA-AFI.

Table 1. Visual evaluation of the articular disk in volunteers

Points in DE-VISTA-PDWI	Points in DE-VISTA-AFI	Points in thin-slab MPR of DE-VISTA-AFI	Points in 2D-PDWI	Number of joints identified at closed-mouth position	Number of joints identified at opened-mouth position
2	2	2	2	19	18
1	2	2	2	1	0
1	1	2	2	0	1
1	1	2	1	3	2
2	2	2	1	3	5

Zero points, the articular disk cannot be identified; one point, either the anterior or posterior band of the articular disk can be identified; 2 points, both the anterior and posterior bands of the articular disk can be identified.

In all joints that could not be identified the articular disk on 2D-PDWI (2-dimensional proton density-weighted images), DE-VISTA-PDWI (dual echo volumetric isotropic turbo spin echo acquisition proton density-weighted images), and DE-VISTA-AFI (DE-VISTA addition fusion images), the anterior and posterior bands of the articular disk could be identified by the sliding thin-slab multiplanar reformation (MPR) of DE-VISTA-AFI.

be identified because of motion artifact at DE-VISTA-AFI and DE-VISTA-PDWI, but both the anterior and posterior bands of the articular disk of this joint could be identified on 2D-PDWI and sliding thin-slab MPR. The articular disks of all 52 joints (26 joints each for closed- and opened-mouth

position) could be detected by sliding thin-slab MPR of DE-VISTA-AFI (Table 1).

At closed-mouth position in patients, 2 joints on DE-VISTA-PDWI and DE-VISTA-AFI were graded with one point. On sliding thin-slab MPR of DE-VISTA-AFI, all 26 joints received 2 points.

At opened-mouth position in patients, all 26 joints received 2 points on DE-VISTA-PDWI, DE-VISTA-AFI, and sliding thin-slab MPR of DE-VISTA-AFI (Table 2).

Disk displacement status in the total 26 joints of volunteers was evaluated at DE-VISTA-AFI as: 22 joints, normal superior disk position with normal function (84%); 3 joints, disk displacement with reduction (12%); and one joint, disk displacement without reduction with articular disc deformity

(4%) (Fig. 2). Although the case showing disk displacement without reduction currently was asymptomatic, history-taking revealed that he had previously been symptomatic; the mandibular condyle of the affected side was smaller than that of the opposite side. Thus, only one slice of 2D-PDWI could show the deformed and displaced articular disk that was detected overall by sliding thin-slab MPR of DE-VISTA-AFI. Disk displacement status in the total 26 joints of patients was evaluated at DE-

Table 2. Visual evaluation of the articular disk in patients

Points in DE-VISTA-PDWI	Points in DE-VISTA-AFI	Points in thin-slab MPR of DE-VISTA-AFI	Number of joints identified at closed-mouth position	Number of joints identified at opened-mouth position
2	2	2	24	26
1	1	2	2	0

Zero points, the articular disk cannot be identified; one point, either the anterior or posterior band of the articular disk can be identified; 2 points: both the anterior and posterior bands of the articular disk can be identified.

In all joints that could not be identified the articular disk on DE-VISTA-PDWI (dual echo volumetric isotropic turbo spin echo acquisition proton density-weighted images) and DE-VISTA-AFI (DE-VISTA addition fusion images), the anterior and posterior bands of the articular disk could be identified by the sliding thin-slab multiplanar reformation (MPR) of DE-VISTA-AFI.

Fig. 2. Temporomandibular joint (TMJ) of a 40-year-old male volunteer with asymmetric condyles and very small left condyle. DE-VISTA-AFI (dual echo volumetric isotropic turbo spin echo acquisition additional fusion image) oblique sagittal image (a) and 2-dimensional proton density-weighted (2D-PDWI) oblique sagittal image (d) at closed-mouth position show anterior displacement and deformity of the articular disk. DE-VISTA-AFI oblique sagittal image (b) and 2D-PDWI oblique sagittal image (e) at opened-mouth position show no reduction. This articular disk was deformed, and we could not distinguish between the anterior and posterior bands, so it was graded with one point. The oblique coronal image of DE-VISTA-AFI (c) shows that his condyles were asymmetric, and the left condyle was very small. Small white arrow indicates the articular disk.

Fig. 3. Temporomandibular joint (TMJ) of a 61-year-old male patient with anterolateral disk displacement with reduction. DE-VISTA-AFI (dual echo volumetric isotropic turbo spin echo acquisition additional fusion image) oblique sagittal image (a) and oblique coronal image (b) show anterolateral displacement of the disk at closed-mouth position. DE-VISTA-AFI oblique sagittal image (c) and oblique coronal image (d) at opened-mouth position show the normal position of the disk. Joint effusion was observed at the joint space. White arrow indicates the disk. Oblique coronal image was necessary to detect the laterally displaced disk.

VISTA-AFI as: 7 joints, normal superior disk position with normal function (27%); 11 joints, disk displacement with reduction (42%) (Fig. 3); and 8 joints, disk displacement without reduction (31%) (Fig. 4). Figure 4 shows anterolateral disc displacement with oblique sagittal and oblique coronal DE-VISTA-AFI.

Quantitative analysis (Table 3)

In volunteers (13 cases, 26 joints), ANOVA indicated an overall difference between the 3 images in regard to CR between adipose tissue and disk ($P < 0.05$). CR between adipose tissue and disk was higher on DE-VISTA-AFI than DE-VISTA-PDWI when compared at closed- and opened-mouth positions ($P = 0.036$, closed; $P = 0.017$, opened). At both closed and opened mouth, CR between adipose tissue and disk did not differ significantly between VISTA-PDWI and 2D-PDWI (closed mouth, $P = 0.74$; opened mouth, $P = 0.83$). CR between adipose tissue and disk on DE-VISTA-AFI had statistically marginal significance to CR on 2D-

PDWI at opened-mouth position ($P = 0.071$). However, CR on DE-VISTA-AFI did not differ significantly from that of 2D-PDWI ($P = 0.18$) at closed mouth.

In patients (13 cases 26 joints), CR between adipose tissue and disk was higher on DE-VISTA-AFI than DE-VISTA-PDWI when compared at closed and opened mouth ($P < 0.0001$).

Joint effusion

Visual evaluation

Visual evaluation identified joint effusion in 8 joints of volunteers and 12 joints of patients in DE-VISTA-T₂WI. Joint effusion in those 20 joints was also identified in DE-VISTA-AFI, but it was difficult to distinguish between adipose tissue and joint effusion in DE-VISTA-PDWI. Joint effusion at the TMJ of volunteers could be identified in DE-VISTA-AFI in all 8 joints that demonstrated joint effusion in DE-VISTA-T₂WI but in only 3 of those joints in 2D-T₂WI. DE-VISTA-AFI could depict a

Fig. 4. Temporomandibular joint (TMJ) of an 18-year-old female patient with disk displacement without reduction. DE-VISTA-AFI (dual echo volumetric isotropic turbo spin echo acquisition additional fusion image) oblique sagittal image (a) and oblique coronal image (b) show anterior displacement of the disk at closed-mouth position. DE-VISTA-AFI oblique sagittal image (c) and oblique coronal image (d) (e) at opened mouth show no reduction of the disk. Joint effusion was observed at the joint space. White arrow indicates the disk.

Table 3. Comparison of the ratio of contrast (CR) between adipose tissue by the disk and the articular disk itself

		2D-PDWI	DE-VISTA-PDWI	DE-VISTA-AFI
Volunteer	Closed mouth	mean 2.30 (1.35–4.33)	mean 2.16 (1.41–3.55)	mean 2.52 (1.47–3.72)
	Opened mouth	mean 2.55 (1.07–4.08)	mean 2.16 (1.29–3.17)	mean 2.57 (1.37–3.59)
			$P=0.036$	$P=0.071$
Patient	Closed mouth		mean 2.22 (0.96–4.10)	mean 2.66 (1.05–5.20)
	Opened mouth		mean 2.00 (1.05–3.11)	mean 2.40 (1.17–4.00)
			$P<0.0001$	$P<0.0001$

In volunteers (13 cases, 26 joints), CR was higher on DE-VISTA-AFI (dual echo volumetric isotropic turbo spin echo acquisition additional fusion images) than DE-VISTA-PDWI (DE-VISTA proton density-weighted images) ($P=0.036$, closed mouth; $P=0.017$, opened mouth). CR on DE-VISTA-PDWI did not differ significantly from that on 2-dimensional (2D)-PDWI ($P=0.74$, closed mouth, $P=0.83$, opened mouth). CR on DE-VISTA-AFI was marginally significant compared to that on 2D-PDWI at opened-mouth position ($P=0.071$) but not significantly different at closed mouth ($P=0.18$).

In patients (13 cases, 26 joints), CR was higher on DE-VISTA-AFI than on DE-VISTA-PDWI ($P<0.0001$).

small amount of joint effusion (Fig. 5).

Quantitative analysis (Table 4)

ANOVA indicated an overall difference in CR (joint effusion/adipose tissue) among the 4 images ($P<0.0001$). CR (joint effusion/adipose tissue) in

all joint effusion of volunteers was higher on DE-VISTA-AFI than DE-VISTA-PDWI but did not differ significantly on DE-VISTA-AFI and DE-VISTA-PDWI ($P=0.65$). It was significantly higher in DE-VISTA-T₂WI than DE-VISTA-AFI ($P=$

Fig. 5. Temporomandibular joint (TMJ) of a 30-year-old male volunteer. **(a)** 2-dimensional proton density- (2D-PDWI) and T_2 -weighted (T_2 WI) images at closed mouth position. **(b)** DE-VISTA-PDWI (dual echo volumetric isotropic turbo spin echo acquisition proton density-weighted images), T_2 WI, and addition fusion image (AFI) at closed-mouth position. **(c)** 2D-PDWI and T_2 WI at opened-mouth position. **(d)** DE-VISTA-PDWI, T_2 WI, and AFI at opened-mouth position. The relationship between the articular disk and synovial fluid was clearer on DE-VISTA-AFI than DE-VISTA-PDWI. The articular disk was clearer on DE-VISTA-AFI than 2D-PDWI at closed and opened mouth. White arrow indicates the disk; white arrowhead indicates joint effusion.

0.0008), DE-VISTA-PDWI ($P < 0.0001$), and 2D- T_2 WI ($P = 0.0024$) but did not differ significantly between 2D- T_2 WI and DE-VISTA-PDWI ($P = 0.42$), between 2D- T_2 WI and DE-VISTA-AFI ($P = 0.98$).

Discussion

Our study indicated that DE-VISTA may be used to quantify detection of the articular disk and effu-

sion of the temporomandibular joint. Compared to conventional 2D-PDWI, which had a slice gap, the 3D images of DE-VISTA-PDWI, DE-VISTA- T_2 WI, and DE-VISTA-AFI were continuous. Thus, we could obtain MPR, which had a thinner slice thickness and lacked gaps, and use the sliding thin-slab MPR method to detect the articular disk. Therefore, it was possible to identify the disk by rotating MPR in the center of the TMJ in cases whose conventional MPR did not depict the disk.

Table 4. Comparison of the ratio of contrast (CR) between joint effusion and adipose tissue in 8 joints of volunteers with joint effusion could be identified in DE-VISTA-T₂WI (dual echo volumetric isotropic turbo spin echo acquisition T₂-weighted images)

	DE-VISTA-PDWI	DE-VISTA-AFI	DE-VISTA-T ₂ WI	2D-T ₂ WI
CR (Joint effusion/ adipose tissue)	mean 1.19 (0.89–1.51)	mean 1.49 (1.17–1.86)	mean 2.60 (1.83–3.35)	mean 1.59 (0.41–2.88)
	$P < 0.0001$		$P = 0.0008$	$P = 0.0024$

CR between joint effusion and adipose tissue did not differ significantly on DE-VISTA-AFI (DE-VISTA additional fusion images) and DE-VISTA-PDWI (DE-VISTA proton density-weighted images) ($P = 0.65$). It was significantly higher in DE-VISTA-T₂WI than DE-VISTA-AFI ($P = 0.0008$), DE-VISTA-PDWI ($P < 0.0001$), and 2D-T₂WI (2-dimensional T₂-weighted images) ($P = 0.0024$). CR did not differ significantly between 2D-T₂WI and DE-VISTA-PDWI ($P = 0.42$), between 2D-T₂WI and DE-VISTA-AFI ($P = 0.98$).

Because 2D images were performed with 3-mm slice thickness and 0.3-mm slice gap, the present MPR method performed with thin slices and no gaps was useful in identifying small and deformed articular disks and small amounts of joint effusion.

The most distinguished feature of DE-VISTA is its ability to establish high TSE factors and shorten imaging scan time by exciting the nonselective refocusing pulse, which also shortens echo spacing and reduces motion artifacts.^{15–18} In our study, the total scan time of DE-VISTA at closed- and opened-mouth positions was 13 min 30 s. Diagnosis of disk dislocation cannot be established solely on the basis of oblique sagittal MR imaging findings. An oblique coronal section was also necessary to diagnose TMD.^{11,12} The scan time of 2D dual echo images (2D-PDWI and 2D-T₂WI) totaled 18 min 8 s. DE-VISTA can be arranged by simple planning and effectively shortens acquisition time.

In visually evaluating knee ligaments and menisci with 3.0T MR imaging, readers performed better with conventional 2D acquisition than 3D-FSE acquisitions.²¹ Also in our examination, CR between adipose tissue by the articular disk and the articular disk itself at DE-VISTA-PDWI did not exceed that at 2D-PDWI, but the ratio was equivalent between DE-VISTA-AFI and 2D-PDWI. It was higher in DE-VISTA-AFI than DE-VISTA-PDWI in both volunteers and patients. DE-VISTA was TSE method, and the J coupling effect caused high adipose signals.²² Therefore, we considered it easier to identify the articular disk on DE-VISTA-AFI than DE-VISTA-PDWI. The diagnosis of disk displacement status was better in sliding thin-slab MPR of DE-VISTA-AFI than 2D-PDWI. Thus, DE-VISTA-AFI provides sufficient information to diagnose TMD.

Although a TR of 800 ms is short for DE-VISTA-T₂WI, it depicted good joint effusion con-

trast because it contained DRIVE and was sufficient to evaluate the presence of joint effusion. Driven equilibrium consists of applying a resonant 90° radiofrequency (RF) pulse at the precise time when the transverse magnetization is refocused by the last spin echo 180° RF pulse and properly adjusted field gradients. This driven equilibrium pulse transforms the residual transverse magnetization (long T₂) into longitudinal magnetization.²³ Compared to 2D-T₂WI, it was possible to identify a small amount of joint effusion in DE-VISTA-T₂WI. In all cases that demonstrated effusion of the TMJ in DE-VISTA-T₂WI, it was possible to identify joint effusion in DE-VISTA-AFI. CR between joint effusion and adipose tissue was higher in DE-VISTA-AFI than DE-VISTA-PDWI, but not statistically significantly different. The intensity of joint effusion, which was almost equal to that of adipose tissue on DE-VISTA-PDWI, was enhanced by the addition of DE-VISTA-T₂WI on DE-VISTA-AFI. These results show that the evaluation of joint effusion accumulation is easier using DE-VISTA-AFI than DE-VISTA-PDWI alone.

When added together, DE-VISTA-PDWI and T₂WI are not rescaled with dual echo, and on the whole, the signal of DE-VISTA-T₂WI, which is the second echo, is weak. Noise of additional imaging was unnoticeable.

We considered it easier to identify the articular disk and joint effusion using DE-VISTA-AFI than both DE-VISTA-PDWI and DE-VISTA-T₂WI.

Diagnosis using 3D images enables evaluation by reconstruction of arbitrary cross sections by thin slice, even after each inspection is terminated. There is some possibility that diagnosis using such 3D images may become common in the future by dissemination of filmless diagnostic images and advancement of image diagnostic systems. Therefore, this research would be worthwhile.

Our study is limited because of single-institution bias, the relatively small number of volunteers and patients, and the lack of surgical findings—limitations that may be solved by using DE-VISTA for TMD at another hospital. It is also necessary to process additional fusion images at a work station. Time will solve with more experience in their use. Another limitation is that in-plane matrix resolution was less in the DE-VISTA image than 2D-PDWI or T₂WI images. The primary purpose of MR imaging for TMD was detection of the articular disk and joint fluid. For those purposes, DE-VISTA had necessary and sufficient conditions. Three-tesla MR imaging may improve this limitation.

Conclusion

The additional fusion image obtained by DE-VISTA can depict both the articular disk by the required plane of MPR using sliding thin-slab MPR as well as a small amount of joint effusion.

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