# Individualized Oblique-Axial Magnetic Resonance Imaging for Improved Visualization of Mediolateral TMJ Disc Displacement

**Yunn-Jy Chen, BDS**
Assistant Professor

**Luigi M. Gallo, Dr sc techn**
Senior Research Associate

Clinic for Masticatory Disorders and Complete Denture
Center for Dental and Oral Medicine and Maxillofacial Surgery
University of Zurich
Zurich, Switzerland

**Dieter Meier, PhD**
Institute of Biomedical Engineering and Medical Informatics
University of Zurich and Swiss Federal Institute of Technology
Zurich, Switzerland

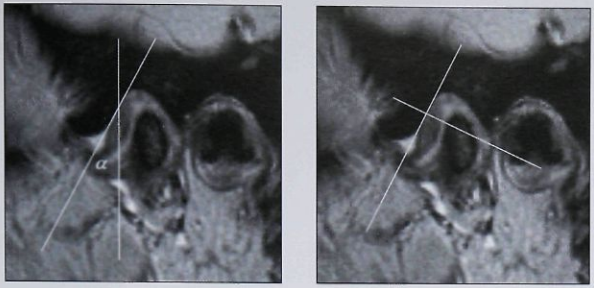
**Sandro Palla, Dr med dent**
Professor
Clinic for Masticatory Disorders and Complete Denture
Center for Dental and Oral Medicine and Maxillofacial Surgery
University of Zurich
Zurich, Switzerland

**Correspondence to:**
Dr L. M. Gallo
Clinic for Masticatory Disorders and Complete Denture
Center for Dental and Oral Medicine and Maxillofacial Surgery
University of Zurich
Plattenstrasse 11
CH-8028 Zurich, Switzerland
Fax: +41-1-634 4302
E-mail: luigi@zui.unizh.ch

**Aims:** *A new individualized oblique-axial orientation of magnetic resonance imaging scans of the temporomandibular joint (TMJ), corrected to be perpendicular to the tangent of the posterior slope of the articular eminence, has been proposed to improve the representation of the disc. The aim of this study was to evaluate the quality of the images obtained with this new type of scanning plane and to assess the factors that can affect the scans.* **Methods:** *Twenty-nine TMJs were scanned by the use of sagittal, conventional coronal, and individualized oblique-axial scanning planes. On the sagittal images, the angle $\alpha$ between the tangent of the posterior slope of the articular eminence and the vertical was measured, and the disc position was evaluated. For both imaging planes, 2 examiners, blind to the scanning techniques, counted the number of conventional coronal and oblique-axial scans in which the disc was visible and in which the medial and lateral disc borders were well demarcated and evaluated the mediolateral disc position.* **Results:** *The individualized oblique-axial technique was superior to the conventional coronal technique in depicting the disc and its medial and lateral demarcations (paired* t *test, $P < 0.05$). The possibility of correct diagnosis of the mediolateral disc position and the agreement between the observers in this evaluation were better with the oblique-axial technique than with the conventional technique ($P < 0.05$). This was particularly evident when the disc was anteriorly displaced.* **Conclusion:** *The individualized oblique-axial scanning planes should be used for a better representation of the disc/condyle complex mediolaterally if the disc is anteriorly displaced.*
J OROFAC PAIN 2000;14:128–139.

**Key words:** temporomandibular joint, mandibular condyle, temporomandibular joint disc, magnetic resonance imaging, comparative study

Autopsy,[1–12] arthrography,[5,11,13–16] and magnetic resonance imaging (MRI)[14,17–23] have been used to investigate disc shape and position, which seem to be important in the etiology of the internal derangement of the temporomandibular joint (TMJ).[1,24] Autopsy studies have found deformed discs in about 40% of analyzed specimens and partial or complete anterior disc displacements in 12% to 56% of specimens.[2,3,7,10] This low to moderate prevalence of anteriorly displaced discs found in autopsy studies has been confirmed also with MRI in humans: about one third of images of the TMJs of asymptomatic subjects[25,26] and 80% of those of symptomatic patients[21] had an anteriorly displaced disc. The prevalence of mediolateral disc displacement, however, is still controversial,[27] with 1 autopsy study reporting a medial displacement of the disc in 70% of 32 investigated joints.[3]




**Figs 1a and 1b** *(Left)* Sagittal image taken in the lateral third of the condyle with the angle α and *(right)* the individualized oblique-axial scanning plane perpendicular to the tangent of the posterior slope. The disc is anteriorly displaced.

This discrepancy in the knowledge about the prevalence of sagittal and lateral disc displacements is most likely due to the fact that the disc position can be reliably depicted with sagittal images, obtained by means of arthrography, arthrotomography, or MRI,[11,13,14,28–37] but not with coronal sections.[5,27,38,39] This can in turn be caused by methodologic limitations, ie, the partial volume effect, as well as by anatomic factors, ie, the position of the disc.[40] Indeed, the prerequisites for a reliable diagnosis of disc position are images with a clear representation of the disc and condyle, ie, with good contrast between these tissues and with clear disc borders (demarcations), conditions that are not always satisfied with conventional coronal images. To overcome this problem, an individualized oblique-axial MRI scanning plane (previously called *corrected coronal scanning plane*), perpendicular to the tangent of the posterior slope of the articular eminence, has been proposed.[40] In that preliminary study, the images obtained with the individualized oblique-axial scanning planes provided better disc representation for 5 of 7 joints than the conventional coronal images.

The aim of this study was therefore to evaluate in a larger sample whether the individualized oblique-axial scanning planes are superior to the conventional ones for the representation of the disc/condyle complex. This study also investigated the factors that could explain the differences between the 2 techniques.

## Materials and Methods

Twenty-nine TMJs of 20 subjects (8 males and 12 females, age 17 to 50 years, mean age 30 years) were imaged. Three subjects were asymptomatic, 11 had unilateral TMJ clicking, 2 had bilateral TMJ clicking, 3 had a unilateral closed lock, and 1 had bilateral TMJ subluxation.

### Imaging Technique

The images were recorded while the subject was biting in maximum intercuspation with a 1.5 Tesla MRI scanner (Philips Gyroscan NT), with bilateral TMJ coils of 8.0 cm diameter placed with their central opening directly over the TMJs. The scanning procedure started with a preliminary axial scan (axial localizer), which was used to determine the angulation of the condylar long axis. Next, a series of 14 sagittal images was taken perpendicular to the condylar long axis. One of these images, located in the lateral third of the condyle, was used to determine the steepness of the posterior slope of the eminence. A tangent to the cranial half of the posterior slope of the eminence was drawn on the computer screen, and the angle α between this line and a vertical line corresponding to the vertical axis of the scanner was calculated (Fig 1a).

Thereafter, a series of 14 conventional coronal images was recorded with the coronal plane parallel to the condylar long axis. Finally, a series of 14 oblique-axial images was produced with the planes perpendicular to the tangent of the posterior slope of the articular eminence and parallel to the condylar long axis (Fig 1b).

The scanning parameters for all sagittal, coronal, and oblique-axial images were: fast-field echo (FFE) pulse sequences (comparable to the Gradient Recalled Acquisition in the Steady State [GRASS] pulse sequences of the General Electric scanner and Fast Imaging with Steady-state Position [FISP] pulse sequences of the Siemens scanner), repetition time 500 ms, echo time 17 ms, flip angle 35 degrees, field of view (FOV) 130 mm, rectangular

FOV 50%, a 256 × 256 matrix, slicing thickness 2 mm, and 4 signal averages, for a scanning time of 3 minutes 50 seconds. All image files were transferred to a Pentium-class personal computer, converted into bitmap images, and interpolated from the resolution of 256 × 256 to 512 × 512 pixels with custom-developed software.

### Evaluation of the Images

The disc position in the anteroposterior direction was determined on the sagittal images according to the clock-face criteria outlined by Katzberg and Westesson.[41]

Two experienced dentists, blind to the scanning technique, were then asked to evaluate the coronal and oblique-axial images. Before the evaluation, both dentists were trained to interpret the images, displayed on the computer monitor, according to the criteria described below. They had to interpret 10 separate series twice, of which 5 were conventional coronal and 5 were oblique-axial images, which were not included in the evaluated series. The first evaluation was performed without detailed instruction, and the second one was done with detailed instruction.

After the training phase, all 58 series of coronal and oblique-axial images from the 29 TMJs were displayed in a random sequence on a computer monitor. For each series, the examiners counted the number of slices in which the disc was visible and in which the disc had a good demarcation (Fig 2) and diagnosed the mediolateral disc position. For this diagnosis the condyle was divided into 6 parts (Fig 3). The criteria were as follows:

1. *Normal disc position* when the medial end of the disc was located medially from the medial sixth of the condyle and the lateral end was located laterally from the lateral sixth of the condyle;
2. *Lateral disc displacement* when the medial end of the disc was located laterally to the medial sixth of the condyle;
3. *Medial disc displacement* when the lateral end of the disc was located medially to the lateral sixth of the condyle (Fig 3);
4. *Diagnosis uncertain* when both the disc and condyle were shown together but the medial or lateral end of the disc was not clearly enough shown to allow for a diagnosis (Fig 4); and
5. *Diagnosis impossible* when all images of the series did not show simultaneously the disc and condyle (Fig 5).

### Statistical Analysis

The examiners' agreement in counting the number of slices with the disc and the number of slices with a clear mediolateral disc demarcation was analyzed separately for both techniques by means of Pearson's correlation coefficient and by calculating the mean absolute differences. The degree of interexaminer agreement in the diagnosis of the mediolateral disc position was evaluated by means of kappa ($\kappa$) analysis.

The difference between the number of slices with disc depiction and the number with good mediolateral disc demarcation was compared between the 2 techniques by means of paired $t$ tests. The correlation between the number of slices with clear disc demarcation and the angle $\alpha$ was analyzed by means of Pearson's correlation coefficient, while the effect of the anteroposterior disc position on the diagnosis (whether normal/medial/lateral or uncertain/impossible) was checked by means of Chi-square ($\chi^2$) tests. Overall, a significance level of $P < 0.05$ was chosen.

## Results

### Training Effect

The Pearson's correlation coefficients between the 2 examiners in counting the number of slices showing the disc were 0.26 ($P > 0.05$) before the training and 0.85 ($P < 0.05$) after the training. The coefficients for counting the number of slices with a clear disc demarcation were 0.72 and 0.78, respectively (for both values $P < 0.05$). The mean absolute differences for the number of slices showing the disc were 2.5 before training and 0.8 after training, and the mean differences for the number of slices with good demarcation were 0.9 before training and 0.8 after training. Thus, the training had an effect only on the agreement of the number of slices showing the disc.

The interexaminer agreement for the diagnoses of the mediolateral disc position did not increase after the training and was low for both imaging techniques ($\kappa = 0.3$ before training and $\kappa = 0.25$ after training).

### Number of Slices Showing the Disc

Both examiners counted significantly more images as showing the disc with the individualized oblique-axial technique than with the conventional coronal technique (5.6 versus 4.4 for the first

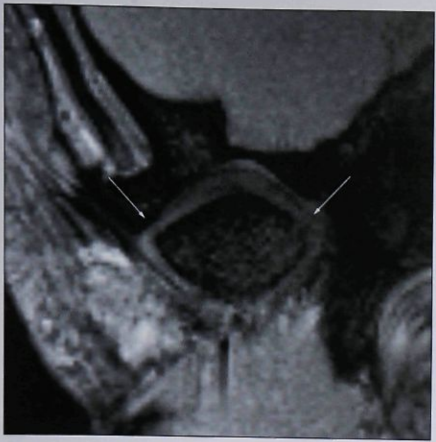


Fig 2 Criteria for clear demarcation of the disc: the medial and lateral end of the disc must be clearly depicted. Arrows indicate the medial or lateral end of the discs.

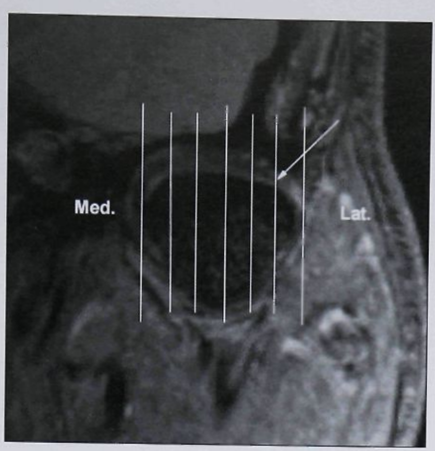



Fig 3 Criteria for diagnosis of mediolateral disc displacement: the image of the condyle can be divided into 6 parts, and the lateral end of the disc *(arrow)* is located medially to the lateral sixth of the condyle. This disc is therefore diagnosed as medially displaced. On the other hand, if the medial end of the disc is located laterally to the medial sixth of the condyle, then it is diagnosed as laterally displaced.

Fig 4 Criteria for uncertain diagnosis: the condyle and parts of the disc are shown, but the medial or lateral end of the disc is not shown clearly enough for a diagnosis to be made.

Fig 5 Criteria for impossible diagnosis: only the condyle without the disc is shown; therefore it is impossible to determine the mediolateral position of the disc.

**Table 1** Evaluation of the Conventional Coronal Images and the Oblique-Axial Images by the 2 Examiners

| | Examiner 1 | | | | Examiner 2 | | | |
|---|---|---|---|---|---|---|---|---|
| Joint no. | Conventional | | Oblique-axial | | Conventional | | Oblique-axial | |
| 1 | 6 | 2 | 6 | 4 | 5 | 1 | 4 | 3 |
| 2 | 3 | 2 | 4 | 2 | 3 | 2 | 5 | 2 |
| 3 | 5 | 0 | 6 | 4 | 4 | 1 | 4 | 2 |
| 4 | 6 | 2 | 7 | 4 | 5 | 3 | 5 | 3 |
| 5 | 4 | 3 | 6 | 4 | 3 | 2 | 6 | 4 |
| 6 | 5 | 0 | 7 | 4 | 2 | 1 | 6 | 4 |
| 7 | 3 | 2 | 6 | 4 | 3 | 1 | 6 | 3 |
| 8 | 4 | 1 | 4 | 2 | 4 | 2 | 4 | 1 |
| 9 | 6 | 2 | 7 | 5 | 5 | 2 | 6 | 3 |
| 10 | 4 | 1 | 5 | 2 | 4 | 2 | 4 | 2 |
| 11 | 6 | 2 | 7 | 4 | 3 | 2 | 6 | 4 |
| 12 | 6 | 2 | 7 | 6 | 6 | 3 | 7 | 5 |
| 13 | 5 | 2 | 7 | 5 | 3 | 2 | 7 | 4 |
| 14 | 4 | 1 | 5 | 2 | 4 | 1 | 5 | 2 |
| 15 | 2 | 11 | 5 | 3 | 2 | 1 | 5 | 3 |
| 16 | 4 | 2 | 4 | 2 | 3 | 2 | 4 | 2 |
| 17 | 3 | 1 | 4 | 3 | 3 | 1 | 4 | 3 |
| 18 | 6 | 2 | 5 | 2 | 6 | 3 | 4 | 2 |
| 19 | 5 | 2 | 5 | 3 | 6 | 4 | 5 | 2 |
| 20 | 2 | 1 | 4 | 3 | 2 | 1 | 4 | 3 |
| 21 | 5 | 2 | 6 | 4 | 5 | 3 | 6 | 4 |
| 22 | 7 | 4 | 6 | 3 | 7 | 4 | 6 | 3 |
| 23 | 4 | 2 | 5 | 3 | 4 | 2 | 5 | 3 |
| 24 | 4 | 1 | 5 | 3 | 4 | 2 | 4 | 3 |
| 25 | 3 | 1 | 5 | 3 | 2 | 1 | 5 | 3 |
| 26 | 6 | 2 | 6 | 4 | 6 | 4 | 6 | 4 |
| 27 | 4 | 0 | 6 | 3 | 3 | 1 | 6 | 3 |
| 28 | 3 | 1 | 6 | 4 | 3 | 1 | 5 | 3 |
| 29 | 4 | 1 | 6 | 4 | 3 | 2 | 6 | 3 |
| Mean | 4.4 | 1.6 | 5.6 | 3.4 | 3.9 | 1.9 | 5.2 | 2.9 |

In each column, the first number indicates the number of slices in which the disc was visible, and the second number indicates the number of slices in which the mediolateral borders were clearly demarcated.

examiner; 5.2 versus 3.9 for the second examiner; $P < 0.05$ for both examiners) (Table 1).

### Number of Images with Clear Disc Demarcation

Both examiners recorded significantly more images with clear disc demarcation with the individualized oblique-axial technique than with the conventional coronal technique (3.4 versus 1.6 for the first examiner; 2.9 versus 1.9 for the second examiner; $P < 0.05$ for both examiners) (Table 1).

### Diagnosis of Mediolateral Disc Position

With the conventional coronal scanning technique, the first examiner diagnosed 12 discs as normally positioned, 3 as medially displaced, and none as laterally displaced, while in 4 cases the diagnosis was impossible and in 10 it was uncertain (Table 2). The respective values for the oblique-axial images were 25, 4, 0, 0, and 0. The second examiner diagnosed 14 discs as normally positioned, 4 as medially displaced, and none as laterally displaced, while in 2 cases the diagnosis was impossible and in 9 it was uncertain with the conventional coronal technique. The respective values when the oblique-axial technique was used were 25, 3, 0, 0, and 1. Thus, both examiners had less difficulty in diagnosing the mediolateral position with the individualized oblique-axial technique. Furthermore, interobserver agreement in diagnosis of the mediolateral disc position increased with the individualized oblique-axial technique from fair agreement to excellent agreement ($\kappa = 0.69$ with the conventional coronal technique and $\kappa = 0.84$ with the individualized oblique-axial technique).

**Table 2** Sagittal and Mediolateral Disc Position, as Observed in the 2 Series of Images

| Joint no. | α (degrees) | Sagittal position | Mediolateral position: Examiner 1 Conventional | Examiner 1 Oblique-axial | Examiner 2 Conventional | Examiner 2 Oblique-axial |
|---|---|---|---|---|---|---|
| 1 | 30 | Anterior | Uncertain | Normal | Uncertain | Normal |
| 2 | 51 | Normal | Normal | Normal | Normal | Normal |
| 3 | 20 | Anterior | Uncertain | Normal | Uncertain | Normal |
| 4 | 35 | Normal | Uncertain | Normal | Uncertain | Normal |
| 5 | 48 | Normal | Medial | Normal | Medial | Normal |
| 6 | 23 | Normal | Uncertain | Normal | Normal | Normal |
| 7 | 45 | Anterior | Impossible | Normal | Impossible | Normal |
| 8 | 32 | Normal | Normal | Normal | Normal | Normal |
| 9 | 24 | Normal | Uncertain | Normal | Uncertain | Normal |
| 10 | 19 | Normal | Medial | Medial | Medial | Medial |
| 11 | 28 | Normal | Normal | Normal | Uncertain | Normal |
| 12 | 24 | Normal | Normal | Normal | Normal | Normal |
| 13 | 31 | Normal | Normal | Normal | Normal | Normal |
| 14 | 40 | Anterior | Uncertain | Normal | Uncertain | Normal |
| 15 | 41 | Anterior | Impossible | Normal | Uncertain | Normal |
| 16 | 40 | Normal | Normal | Normal | Normal | Normal |
| 17 | 25 | Normal | Normal | Normal | Normal | Normal |
| 18 | 47 | Normal | Normal | Normal | Normal | Normal |
| 19 | 40 | Anterior | Normal | Normal | Normal | Normal |
| 20 | 37 | Anterior | Impossible | Normal | Impossible | Normal |
| 21 | 31 | Anterior | Normal | Normal | Normal | Normal |
| 22 | 61 | Anterior | Impossible | Normal | Normal | Normal |
| 23 | 27 | Normal | Medial | Medial | Medial | Medial |
| 24 | 41 | Normal | Uncertain | Medial | Medial | Medial |
| 25 | 23 | Normal | Uncertain | Medial | Uncertain | Uncertain |
| 26 | 44 | Normal | Normal | Normal | Normal | Normal |
| 27 | 25 | Anterior | Uncertain | Normal | Uncertain | Normal |
| 28 | 46 | Normal | Uncertain | Normal | Normal | Normal |
| 29 | 33 | Normal | Normal | Normal | Normal | Normal |

### Steepness of the Posterior Slope of the Eminence

The mean of the angle α was 34.8 degrees (SD 10.5 degrees). Pearson's correlation coefficient ($r$) between the angle α and the number of slices taken with the conventional coronal technique and showing a clear disc demarcation was 0.585 ($P < 0.05$) for the first examiner and 0.371 ($P < 0.05$) for the second examiner.

### Effect of Disc Position

On the sagittal images, 10 of the 29 TMJs displayed an anteriorly displaced disc, and the other 19 joints showed normal disc position. With the conventional coronal images, the first examiner was unable to diagnose the mediolateral disc position for 8 of the 10 joints with anteriorly displaced discs (Table 3). This was also the case for 6 of the 19 joints with normal sagittal disc position. The second examiner was unable to diagnose the mediolateral disc position for 7 of the 10 joints with anteriorly displaced discs and for 4 of the 19 joints with normal disc position. Therefore, both examiners had significantly greater difficulty in diagnosing the mediolateral position of the disc from the conventional coronal images when the disc was anteriorly displaced ($\chi^2$ = 6.125, $P < 0.05$ for the first examiner and $\chi^2$ = 6.67, $P < 0.05$ for the second examiner; see Table 3).

With the oblique-axial images, both examiners were able to diagnose the mediolateral disc position for all 10 joints with anteriorly displaced discs (Table 3). The first examiner was also able to determine the mediolateral disc position of all 19 joints with normal sagittal disc position. The second examiner was unable to diagnose only 1 of the 19 joints. The effect of the sagittal disc position on the diagnosis of the mediolateral disc position became insignificant with the use of the oblique-axial images ($\chi^2$ = 0.545, $P > 0.05$ for the first examiner and $\chi^2$ = cannot be calculated, $P > 0.05$ for the second examiner; see Table 3).

Table 3 Effect of Anteroposterior Disc Position on the Diagnosis of Its Mediolateral Position with Conventional Coronal Images Versus Oblique-Axial Images

| | Conventional images | | Oblique-axial images | |
|---|---|---|---|---|
| | Displaced | Normal | Displaced | Normal |
| Examiner 1 | | | | |
| Possible diagnosis | 2 | 13 | 10 | 19 |
| Impossible diagnosis | 8 | 6 | 0 | 0 |
| Examiner 2 | | | | |
| Possible diagnosis | 3 | 15 | 10 | 18 |
| Impossible diagnosis | 7 | 4 | 0 | 1 |

The diagnoses of normal/medial/lateral were recorded as "possible" and those of uncertain/impossible were recorded as "impossible."

## Discussion

This study showed that oblique-axial images (Figs 6a to 6g) depicted the disc and condyle better than conventional coronal images (Figs 7a to 7g), especially when the disc was anteriorly displaced. It was also found that the individualized oblique-axial technique produced images with better disc demarcation than the images produced with the conventional coronal technique. As a consequence, the examiners had less difficulty in diagnosing the mediolateral disc position with the oblique-axial images. These findings can be explained by 2 phenomena: *(1)* the decrease of the partial volume effect and *(2)* a better depiction of the condyle and disc, when the disc is anteriorly displaced, with the images taken with the individualized oblique-axial technique.

During scanning, the TMJ region is divided into small cubes, volume elements called *voxels,* by means of the magnetic field gradients along the z, x, and y axes. The depth of a voxel is equal to the slice thickness (in this case, 2 mm), while its length and width correspond to the field of view divided by the matrix size (130 mm/256 = 0.51 mm). The MRI signal of a voxel is the total signal recorded within that volume. Therefore, if the voxel contains more than 1 tissue, the voxel signal is the total of the signal produced by the different tissues (Fig 8). This signal summation process, called partial volume effect, can influence the quality of the images, as shown in Fig 8. Indeed, by the use of the individualized oblique-axial technique, where the imaging plane is perpendicular to the posterior slope of the eminence and parallel to the long condylar axis, fewer voxels are affected by the partial volume effect than if the imaging plane is not perpendicular to the posterior slope of the eminence, as with the conventional coronal technique (Fig 9). Therefore, the reduction of the partial volume effect could have improved the demarcation between the disc and its surrounding tissues, making diagnosis easier. Of course, the likelihood of a voxel's containing different tissues also decreases if its size decreases. This is why the readability of images improves with thinner slices, as already reported by Westesson et al.[42] In that study, the authors also reported that better images were obtained with an oblique scanning orientation, without providing an explanation for their observation.[43]

This study also showed that the anteroposterior disc position influenced the possibility of diagnosing its mediolateral position on the conventional coronal images: diagnosis was more difficult when the disc was anteriorly displaced. When the disc is anteriorly displaced, the disc and condyle cannot be represented on the same image. Thus, the diagnosis of the mediolateral disc position is impossible. On the contrary, with the oblique-axial images, the anteriorly displaced disc can be depicted together with the condyle or at least the condylar neck, thereby facilitating the determination of the mediolateral disc position (Figs 9a and 9b). This is the reason why with the oblique-axial images the disc/condyle complex was shown simultaneously, even for the 10 joints with anteriorly displaced discs.

Schwaighofer et al[44] reported in an autopsy study that the diagnosis of disc position by means of conventional MRI coronal images was correct for 13 of 14 joints with normal disc position and for only 4 of 8 abnormal joints, 6 of which had an anterior disc displacement. This result seems to support our finding that with the conventional coronal scanning technique, the diagnosis of the mediolateral disc position is more difficult when the disc is anteriorly displaced. Considering the high percentage of anterior disc displacements in

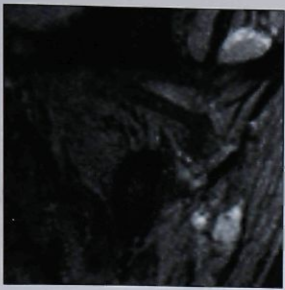


Fig 6a

Fig 6b

Fig 6c

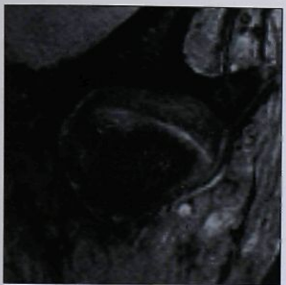


Fig 6d

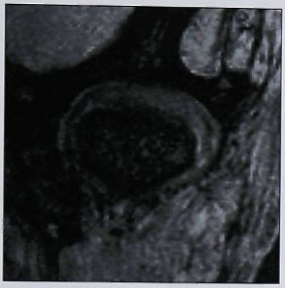


Fig 6e

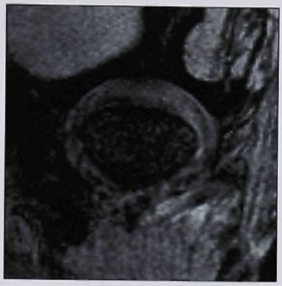


Fig 6f

**Figs 6a to 6g** Series of oblique-axial images. The disc can be seen, with clear medial and lateral ends. Some images also show a very clear demarcation between the disc and the tissues above it. A diagnosis of normal disc position can be easily made.

Fig 6g

asymptomatic individuals (up to 30%),[2,7,40] it is advisable to generally use the corrected technique to better observe the disc/condyle complex.

Roberts[45] stated that with MRI the patient should extend the head and neck during the scanning to get a better image. He related this phenomenon to a so-called *magic angle*. What actually happens is that the extension of the neck increases the angle between the posterior slope of the articular eminence and the conventional coronal scanning plane. As a consequence, the conventional coronal plane tends to move closer to perpendicular to the posterior slope of the eminence, exactly as is done with our scanning technique. Obviously, it is much more convenient for the patients (especially older individuals) when the technician changes the orientation of the scanning plane, instead of requiring patients to change head posture.

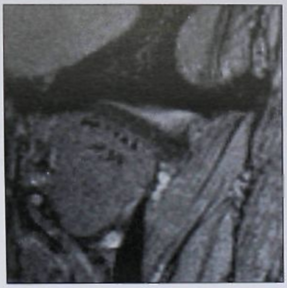


Fig 7a

Fig 7b

Fig 7c

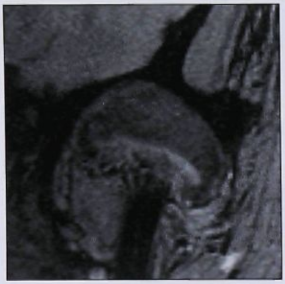


Fig 7d

Fig 7e

Fig 7f

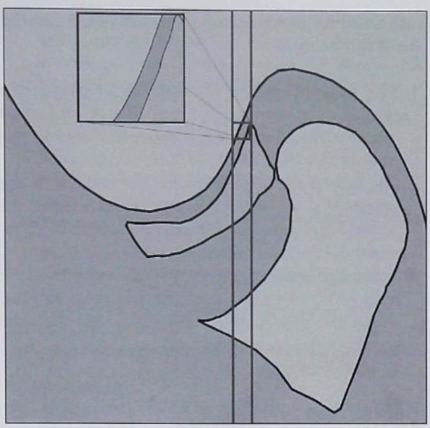
Fig 7g

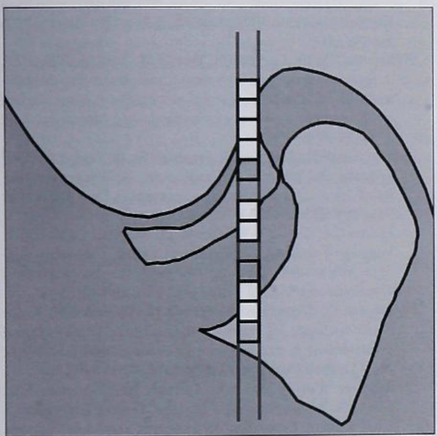
**Figs 7a to 7g** Series of conventional coronal images. These images were obtained from the same joint shown in Fig 6. This joint had a normal sagittal disc position. In Figs 7a and 7b, only the disc can be seen; therefore these images are not important for the diagnosis of the mediolateral position of the disc. In Figs 7c to 7e, the area of the posterior slope of the articular eminence is shown. Due to the small angle $\alpha$ the demarcation between the condyle and the disc is poor. In Figs 7f and 7g, parts of the disc are shown together with the condyle; however, the medial and lateral ends of the disc are not shown clearly enough to make a diagnosis.

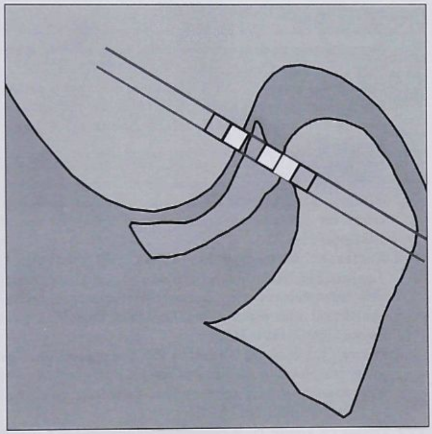
To date, there are still no widely accepted criteria for the diagnosis of the mediolateral disc position. The diagnostic criteria used in this study offer a possible way to interpret the images for this purpose. The individualized oblique-axial technique, combined with the diagnostic criteria, seems to provide a better way to judge the medial and lateral disc position. Comparisons with autopsy materials are necessary to validate these criteria.

It is well known that with MRI the interobserver variation in reading images is high and that calibration trials might help to decrease it.[46] In this study, a training phase was performed. Interexaminer agreement remained poor even after the training phase, a fact that could be explained by the small sample size. In fact, in the evaluation of the whole series, the agreement was excellent for the oblique-axial images and fair for the conventional coronal images.

Fig 8  Graphical representation of a TMJ with an anteriorly displaced disc. The parallel lines denote a slice of a conventional coronal image of the TMJ. The distance between the lines indicates the thickness of the slice. The area contained within the square is the lateral face of the smallest scanning volume unit, called a *voxel*. The images are constructed by mapping the signals of the voxels according to their spatial relationship into the corresponding pixels. The zoomed view shows that there is more than one type of tissue within the voxel. The signal of the corresponding pixel in this case is therefore the sum of the signals of the bone and disc. This signal summation is known as the partial volume effect, which causes poor demarcation between the disc and the surrounding tissues.







**Figs 9a and 9b**  *(Left)* Slice of a conventional coronal image of the TMJ in the area of the eminence in a joint with an anteriorly displaced disc. The white areas represent the voxels of this slice that are influenced by the partial volume effect. Since the disc is anteriorly displaced, it is impossible to obtain images that display both the disc and the condyle. *(Right)* Slice in the same area of the eminence obtained with the proposed individualized oblique-axial scanning plane, which is perpendicular to the tangent of the posterior slope of the articular eminence. Fewer voxels are affected by the partial volume effect when this technique is used. In addition, the disc and the condyle are shown together in the same images. This makes the diagnosis of the mediolateral disc position possible.

According to this study, the following conclusions can be drawn.

1. The individualized oblique-axial plane can reduce the partial volume effect and thus improve the demarcation between different tissues.
2. The size of the angle between the tangent of the posterior slope of the articular eminence and the vertical can influence images taken with the conventional coronal technique.
3. If the disc is anteriorly displaced, the individualized oblique-axial scanning plane technique shows the disc/condyle complex better than the conventional coronal technique.

## References


1. De Bont LG, Boering G, Liem RS, Eulderink F, Westesson P. Osteoarthritis and internal derangement of the temporomandibular joint: A light microscopic study. J Oral Maxillofac Surg 1986;44:634–643.
2. Westesson PL, Rohlin M. Internal derangement related to osteoarthrosis in temporomandibular joint autopsy specimens. Oral Surg Oral Med Oral Pathol 1984;57:17–22.
3. Dittmer D, Ewers R. Die Verlagerung des Discus articularis im menschlichen Kiefergelenk [Articular disk dislocation in the human TMJ]. Dtsch Zahnärztl Z 1991; 46:476–479.
4. Isberg-Holm AM, Westesson PL. Movement of disc and condyle in temporomandibular joints with and without clicking. A high-speed cinematographic and dissection study on autopsy specimens. Acta Odontol Scand 1982;40:165–177.
5. Kurita K, Westesson PL, Tasaki M, Liedberg J. Temporomandibular joint: Diagnosis of medial and lateral disk displacement with anteroposterior arthrography. Correlation with cryosections. Oral Surg Oral Med Oral Pathol 1992;73:364–368.
6. Pereira FJ, Lundh H, Westesson PL. Temporomandibular joint: Diagnosis of medial and lateral disk displacement with anteroposterior arthrography. Oral Surg Oral Med Oral Pathol 1994;78:279–287.
7. Pereira FJ, Lundh H, Westesson PL, Carlsson LE. Clinical findings related to morphologic changes in TMJ autopsy specimens. Oral Surg Oral Med Oral Pathol 1994; 78:288–295.
8. Pereira FJ. Macroscopic and Microscopic Findings in the Temporomandibular Joint. A Clinical and Autopsy Study with Reference to Age, Sex, Signs and Symptoms [thesis]. Malmö: Lund University, 1995:1–56.
9. Rohlin M, Westesson PL, Eriksson L. The correlation of temporomandibular joint sounds with joint morphology in fifty-five autopsy specimens. J Oral Maxillofac Surg 1985;43:194–200.
10. Solberg WK, Hansson TL, Nordstrom B. The temporomandibular joint in young adults at autopsy: A morphologic classification and evaluation. J Oral Rehabil 1985;12:303–321.
11. Tanimoto K, Hansson LG, Petersson A, Rohlin M, Johansen CC. Computed tomography versus single-contrast arthrotomography in evaluation of the temporomandibular joint disc. A study of autopsy specimens. Int J Oral Maxillofac Surg 1989;18:354–358.
12. Widmalm SE, Westesson PL, Kim IK, Pereira FJ Jr, Lundh H, Tasaki MM. Temporomandibular joint pathosis related to sex, age, and dentition in autopsy material. Oral Surg Oral Med Oral Pathol 1994;78:416–425.
13. Anderson GC, Schiffman EL, Schelihas KP, Fricton JR. Clinical vs. arthrographic diagnosis of TMJ internal derangement. J Dent Res 1989;68:826–829.
14. Donlon WC, Moon KL. Comparison of magnetic resonance imaging, arthrotomography and clinical and surgical findings in temporomandibular joint internal derangements. Oral Surg Oral Med Oral Pathol 1987;64:2–5.
15. Heffez L, Jordan S. A classification of temporomandibular joint disk morphology. Oral Surg Oral Med Oral Pathol 1989;67:11–19.
16. Isberg A, Stenstrom B, Isacsson G. Frequency of bilateral temporomandibular joint disc displacement in patients with unilateral symptoms: A 5-year follow-up of the asymptomatic joint. A clinical and arthrotomographic study. Dent Maxillofac Radiol 1991;20:73–76.
17. Cirbus MT, Smilack MS, Beltran J, Simon DC. Magnetic resonance imaging in confirming internal derangement of the temporomandibular joint. J Prosthet Dent 1987; 57:488–494.
18. Davant TS VI, Greene CS, Perry HT, Lautenschlager EP. A quantitative computer-assisted analysis of disc displacement in patients with internal derangement using sagittal view magnetic resonance imaging. J Oral Maxillofac Surg 1993;51:974–979.
19. De Leeuw R, Boering G, Stegenga B, de Bont LG. TMJ articular disc position and configuration 30 years after initial diagnosis of internal derangement. J Oral Maxillofac Surg 1995;53:234–241.
20. Helms CA, Doyle GW, Orwig D, McNeill C, Kaban L. Staging of internal derangements of the TMJ with magnetic resonance imaging: Preliminary observations. J Craniomandib Disord Facial Oral Pain 1989;3:93–99.
21. Paesani D, Westesson PL, Hatala M, Tallents RH, Kurita K. Prevalence of temporomandibular joint internal derangement in patients with craniomandibular disorders. Am J Orthod Dentofac Orthop 1992;101:41–47.
22. Sanchez Woodworth RE, Tallents RH, Katzberg RW, Guay JA. Bilateral internal derangements of temporomandibular joint: Evaluation by magnetic resonance imaging. Oral Surg Oral Med Oral Pathol 1988;65:281–285.
23. Schelihas KP. Internal derangement of the temporomandibular joint: Radiologic staging with clinical, surgical, and pathologic correlation. Magn Reson Imaging 1989;7:495–515.
24. Luder HU. Articular degeneration and remodeling in human temporomandibular joints with normal and abnormal disc position. J Orofac Pain 1993;7:391–402.
25. Katzberg RW, Westesson PL, Tallents RH, Drake CM. Anatomic disorders of the temporomandibular joint disc in asymptomatic subjects. J Oral Maxillofac Surg 1996; 54:147–153.
26. Kircos LT, Ortendahl DA, Mark AS, Arakawa M. Magnetic resonance imaging of the TMJ disc in asymptomatic volunteers. J Oral Maxillofac Surg 1987; 45:852–854.
27. Payne M, Nakielny RA. Temporomandibular joint imaging. Clin Radiol 1996;51:1–10.

28. Jend-Rossmann I, Jend HH, Siegert R. Significance of arthrography and computed tomography in the assessment of internal derangement of the temporomandibular joint. J Craniomaxillofac Surg 1987;15:265–269.
29. Liedberg J, Panmekiate S, Petersson A, Rohlin M. Evidence-based evaluation of three imaging methods for the temporomandibular disc. Dentomaxillofac Radiol 1996;25:234–241.
30. Panmekiate S, Petersson A, Rohilin M, Akerman S. Observer performance and diagnostic outcome in diagnosis of the disk position of the temporomandibular joint using arthrography. Oral Surg Oral Med Oral Pathol 1994;78:255–263.
31. Westesson PL. Reliability and validity of imaging diagnosis of temporomandibular joint disorder. Adv Dent Res 1993;7:137–151.
32. Muller J, Schmid C, Vogl T, Bruckner G, Randzio J. Vergleichende anatomische und MR-tomographische Untersuchungen an explantierten Kiefergelenken. Dtsch Zahnärztl Z 1992;47:303–308.
33. Hansson LG, Westesson PL, Katzberg RW, Tallents RH, Kurita K, Holtas S, et al. MR imaging of the temporomandibular joint: Comparison of images of autopsy specimens made at 0.3 T and 1.5 T with anatomic cryosections. Am J Roentgenol 1989;152:1241–1244.
34. Katzberg RW, Westesson PL, Tallents RH, Anderson R, Kurita K, Manzione JV Jr, Totterman S. Temporomandibular joint: MR assessment of rotational and sideways disk displacements. Radiology 1988;169:741–748.
35. Tasaki MM, Westesson PL. Temporomandibular joint: Diagnostic accuracy with sagittal and coronal MR imaging. Radiology 1993;186:723–729.
36. Westesson PL, Katzberg RW, Tallents RH, Sanchez Woodworth RE, Svensson SA. CT and MR of the temporomandibular joint: Comparison with autopsy specimens. Am J Roentgenol 1987;148:1165–1171.
37. Westesson PL, Katzberg RW, Tallents RH, Sanchez Woodworth RE, Svensson SA, Espeland MA. Temporomandibular joint: Comparison of MR images with cryosectional anatomy. Radiology 1987;164:59–64.
38. Brady AP, McDevitt L, Stack JP, Downey D. A technique for magnetic resonance imaging of the temporomandibular joint. Clin Radiol 1993;47:127–133.
39. Helms CA, Kaplan P. Diagnostic imaging of the temporomandibular joint: Recommendations for use of the various techniques. Am J Roentgenol 1990;154:319–322.
40. Chen YJ, Gallo LM, Palla S. New coronal scanning planes of the temporomandibular joint MRI [IADR abstract #935]. J Dent Res 1997;76:130.
41. Katzberg RW, Westesson PL. Normal anatomy. In: Katzberg RW, Westesson PL. Diagnosis of the Temporomandibular Joint. Philadelphia: W.B. Saunders, 1993:3–23.
42. Westesson PL, Kwok E, Barsotti JB, Hatala M, Paesani D. Temporomandibular joint: Improved MR image quality with decreased section thickness. Radiology 1992; 182:280–282.
43. Musgrave MT, Westesson PL, Tallents RH, Manzione JV, Katzberg RW. Improved magnetic resonance imaging of the temporomandibular joint by oblique scanning planes. Oral Surg Oral Med Oral Pathol 1991;71:525–528.
44. Schwaighofer BW, Tanaka TT, Klein MV, Sartoris DJ, Resnick D. MR imaging of the temporomandibular joint: A cadaver study of the value of coronal images. Am J Roentgenol 1990;154:1245–1249.
45. Roberts D. Information output and accuracy of current temporomandibular joint imaging strategies. In: Fricton JR, Dubner R (eds). Orofacial Pain and Temporomandibular Disorders. New York: Raven Press, 1995:277–323.
46. Orsini MG, Terada S, Kuboki T, Matsuka Y, Yamashita A. The influence of observer calibration in temporomandibular joint magnetic resonance imaging diagnosis. Oral Surg Oral Med Oral Pathol 1997;84:82–87.