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Morphologic and positional assessment of temporomandibular joint disk in facial asymmetric patients by magnetic resonance imaging

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The present study was conducted to examine the morphometrics and function of the disk on both sides among patients with facial asymmetry (FA) and to elucidate plausible correlations between internal derangement (ID) and FA. The sample was composed of 10 males and 27 females with FA. The disk status of all subjects was evaluated by bilateral high resolution magnetic resonance scans in the sagittal (closed and open) and coronal (closed) planes. Five types of disk displacement were identified accordingly. The disk function was diagnosed as normal disk function, disk displacement with reduction, and disk displacement without reduction. The disk shape on sagittal MRI in closed position was classified as bi-concave, biplanar, funnel/hemiconvex, and deformed. The disk position, translation and rotation were also measured. The difference between the shifted side and non-shifted side was analyzed by statistical analysis. Approximately 70% of the patients in the present study showed unilateral or bilateral ID. It was found that anterior disk displacements (ADD), especially rotational ADD, occurred more frequently in the shifted side, while normal disk position was observed mainly in the non-shifted side ($p < 0.01$). The disk of the shifted side showed significantly deformed configuration and inferior-anterior disk position. However, the disk of the non-deviated side showed hyper-mobility during jaw opening movement. These results demonstrate that in FA patients, the disks status of the shifted side is different from that of the non-shifted side, a phenomenon that could be correlated to facial asymmetry.

(**Key words**: Temporomandibular joint disk, Facial asymmetry, Magnetic resonance image)

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INTRODUCTION

Asymmetry in craniofacial skeleton is a common phenomenon. The directionality of cranial and craniofacial morphology can be partially denoted by the asymmetry of brain structure.[1] Even though faces with slight asymmetry are perceived as more attractive than symmetrical ones,[2] there is still no consensus regarding at which point the normal limit will become abnormal, which has been mainly judged by the clinician's sense of balance and the patient's perception of imbalance. One of the most prominent features for clinically diagnosed facial asymmetry (FA) is the shift of the chin to the shorter side and prominence of the gonial angle on the longer side.[3] Dental features include an open bite on the longer side, shifted mandibular midline from the longer side, crossbite on the shorter side, and tilts of the frontal occlusal plane.[4] The causes of facial asymmetry are still not clear and mainly listed as genetic imperfections, environmental factors, trauma with fractures and infections.

Recently, much attention has been paid on the impacts of internal derangement (ID) of the temporomandibular joint (TMJ) on facial morphology.[5,6] ID is a common intra-articular disorder with abnormal mutual position of the articular disk to the condyle, fossa and the articular eminence.[7] Prevalence of disk displacement (DD) is relatively high not only in populations with TMJ disorders[8] but also in asymptomatic preorthodontic adolescents.[9] Internal derangement of the TMJ being a cause of FA in children was first reported in 1985.[10] Experiment and clinical studies have reported that DD in the TMJ with an onset during the growth period can cause mandibular asymmetry.[11-16] Buranastidporn *et al*[17] found that the incidence of internal derangement in asymmetrical class III patients was higher than in symmetrical mandibular prognathism, and this difference was associated with a difference in TMJ morphology of both sides. However, there are few reports on the disk status of FA patients.[18] The aim of this study was to evaluate the morphology and function of the disk on bilateral sides in FA patients and to further elucidate the possible relationship between FA and ID.

MATERIAL AND METHODS

Sample selection

The samples were 37 pre-orthodontic patients (27 females and 10 males) between the ages of 12 and 44 years (mean 21.4 years old), with no history of infection, tumours, or other clinically significant pathology. Each subject's primary complaint was an asymmetric face, and the diagnosis of facial asymmetry was made by the measurement on postero-anterior (PA) cephalogram with the menton deviated more than 2 mm from the facial midline. Irrespective of the TMJ status, all subjects were consented to a bilateral high-resolution MRI in the sagittal (opened and closed) and coronal (closed) planes to evaluate the TMJ.

MRI evaluation

The MRIs were obtained with a Signa Horison (GE, Waukesha, Wisconsin, USA) operating at 1.5 T and a unilateral 3-in surface receiver coil (GE). Initially, the axial scout images were obtained at the level of the TMJ to identify the long axes of the condyles. Non-orthogonal sagittal sections were obtained perpendicular to the condyles, and non-orthogonal coronal oblique sections were also obtained. Closed-mouth images were obtained at maximum dental intercuspation, and open-mouth images were taken at maximum unassisted vertical mandibular opening by using a Burnett bidirectional TMJ device (Medrad, Pittsburgh, Pennsylvania, USA). T1-weighted 600/12 (repetition time [TR] ms/echo time [TE] ms) and proton-density 4000/14 (TR ms/TE ms) pulse sequences were performed in the sagittal plane by using a 3-mm slice thickness, a 10-cm field of view, 2 excitation, and an image matrix of 254 × 192 pixels. T1-weighted 500/12 (TR ms/TE ms) pulse sequence was performed in the coronal plane under the same conditions. One radiologist (S-C C) and one orthodontist (T-W K) interpreted all the MR images separately.

Disk position was analyzed and grouped[19-22] into 1 of 5 categories described as the following (Fig 1).

No disk displacement (NDD): In the sagittal plane of imaging, the disk has a biconcave shape. In the closed position, the junction of the posterior band with the bilaminar zone is located above the apex of the

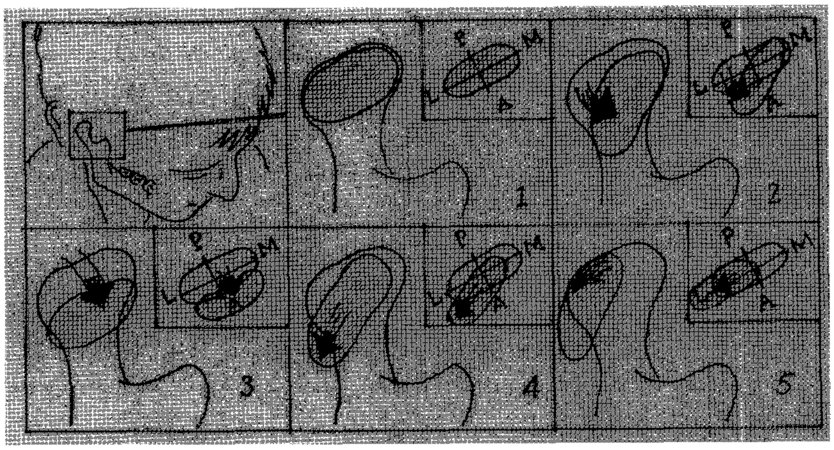

Fig 1. Five types of disk position. *1*, No disk displacement; *2*, partial anterior disk displacement; *3*, anterior disk displacement; *4*, rotational disk displacement; *5*, sideway disk displacement. This figure is cited partly from Tasaki et al (Tasaki MM, Westesson PL, Isberg AM, Ren YF, Tallents RH. Classification and prevalence of temporomandibular joint disk displacement in patients and symptom-free volunteers. Am J Orthod Dentofacial Orthop 1996;109:249-62).

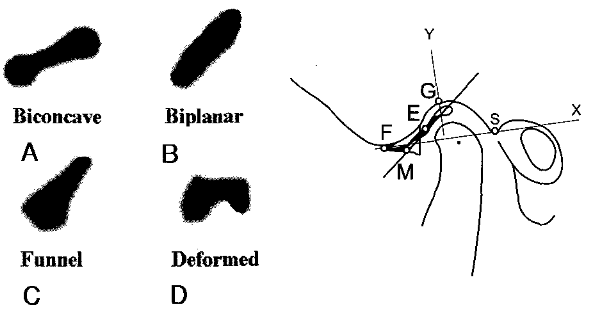

Fig 2. Disk types: *A*, Biconcave type; *B*, bi-planar type; *C*, funnel/hemiconvex type; *D*, deformed type. Diagram of TMJ associated anatomy: *E*, the midpoint of intermediate region of disk; *F*, most inferior point on the articular eminence; *G*, most superior point on the fossa; *S*, squamotympanic fissure point; Line *X*, drawn through point F and S; Line *Y*, drawn from point G and perpendicular to the Line *X*; *M*, the midpoint of anterior disk band; fossa width, the distance between point F and S. Fossa height, the distance from point G to Line *X*; disk position (Horizontal, H), the ratio of the distance between the projection of point E on Line *X* and point F to fossa width; disk position (Vertical, V), the ratio of the distance of point E and M on Line Y to fossa height.

condylar head (12 o'clock position ± 10%).[19] When the jaw opens, the condyle rotates under the disk and the disk-condyle complex translates anteriorly under the temporal tubercle. The disk remains interposed between the osseous components and moves anteriorly in a synchronized fashion. In the coronal plane of imaging, the disk has an arc-shaped configuration and is perfectly centered on the condylar head.[18]

Partial anterior disk displacement (PADD): Disk is anteriorly displaced in lateral or medial part of joint, while its position in medial or lateral part is sub-normal. These displacements exhibit no sideways components.

Anterior disk displacement (ADD): In the closed position, the posterior band of the disk is anterior to the condylar head in all sagittal sections.

Rotational anterior disk displacement (RADD): The disk is anteriorly displaced in all sagittal sections, together with a sideways component (medial or lateral) whether it is reduced or not.

Sideways disk displacement (SDD): In the coronal plane, it can be well documented. The disk is displaced to lateral or medial pole of the condyle. For it has no anterior displacement, the central sagittal view shows a normal disk position while in the more medial or lateral section it shows no disk image.

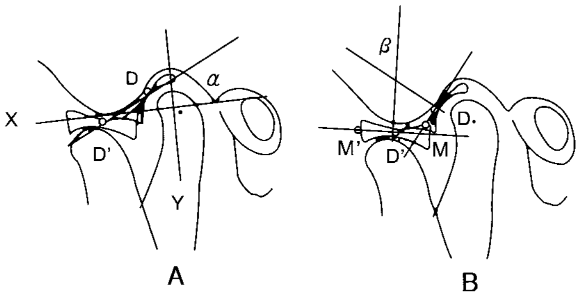

Fig 3. A: *D'*, The midpoint of the intermediate point of the disk on open position. Disk translation distance (Horizontal, H), ratio of the distance between point D and D' on Line *X* to the articular fossa width. Disk translation distance (Vertical, V), the ratio of the distance between point D and D' on Line *Y* to the fossa height. Disk translation angle (α), the angle between Line *X* and the line connecting Point D and D'. B: *M'*, the midpoint of the anterior disk band on open position. Disk rotation angle (β), the angle between the perpendicular lines of DM and D'M'.

Disk function was analyzed in the sagittal plane and categorized as normal (N), displaced with reduction (DDR) or without reduction (DDNR) following the criteria described previously.[5]

The classification of disk shape on sagittal MR image in closed position was modified from previous studies.[23,24] They are bi-concave, biplanar, funnel/hemiconvex, and deformed types (Fig 2).

Disk position in closed position was measured relative to the eminence width horizontally, and to the eminence height vertically as shown in Fig 2. Disk inclination was described by the angle between the long axis of the disk and Line *X*.

The same slices showing more condylar image on both closed and open position tracings were superimposed with a sufficiently identical image of the temporal bone. Translation of the disk and the disk rotation angle were measured as shown in Fig 3, A and B.

All the MR images were traced and scanned into the computer by a single investigator (B-S Z). Angular and linear measurements were measured by a software with a precision of 0.01° and 0.01 mm. The width and height of the articular eminence served as the horizontal axis (Line *X*) and vertical axis (Line *Y*) respectively. All the linear measurements were transferred to ratio forms relative to the width or height of the articular fossa in order to avoid the difference due to different anatomic dimensions.

Statistic analysis

The TMJs were categorized between shifted side and non-shifted side. The patients were classified into bilateral normal, unilateral DD and bilateral DD. To test the magnitude of the measurement error involved in this study, the MRI tracings of 20 randomly selected patients were measured again with a minimum 2-week interval. Dahlberg formula[26] was used to calculate the error for the measurements. With this method, all the measurements did not exceed acceptable limits. Proportion of different disk position and configuration were compared for shifted and non-shifted side by Fisher's exact test. Row mean scores difference was used to evaluate the proportion of normal disk position, DDR and DDNR between two sides by Cochran-Mantel-Haenszel Statistics. Paired Student *t*-tests were used for each measurement studied to evaluate the average differences between the shifted side and non-shifted side for disk position and disk movement. All p values less than 0.05 were considered as statistically significant.

RESULTS

The distributions of different types of disk displacement in shifted and non-shifted side in facial asymmetric patients are listed in Table 1. The proportion was significantly different between the shifted and the non-shifted side ($p < 0.01$), with the majority (70.3%) of the normal disk position (No DD) seen in the non-shifted side.

The proportions of different types of disk function (normal, DDR and DDNR) in the shifted and non-shifted side are listed in Table 2. There was more disk malfunction (DDR and DDNR) in the shifted side

Table 1. Prevalence of disk position in shifted and non-shifted side

Disk position	Number of joints in shifted side (n = 37)		Number of joints in non-shifted side (n = 37)		Significance (Fisher's exact test)
	Number	Percentage	Number	Percentage	
NDD	12	32.4	26	70.3	
PADD	2	5.4	2	5.4	
ADD	7	18.9	4	10.8	0.002 **
RADD	14	37.8	2	5.4	
SDD	2	5.4	3	8.1	

** $p < 0.01$; *NDD*, no disk displacement; *PADD*, partial anterior disk displacement; *ADD*, anterior disk displacement; *RADD*, rotational anterior disk displacement; *SDD*, sideways disk displacement.

Table 2. Proportions of normal disk position, disk displacement with reduction (DDR) and disk displacement without reduction (DDNR) in shifted and non-shifted side

Disk position	Number of joints in shifted side (n = 37)		Number of joints in non-shifted side (n = 37)		Significance (Cochran-Mantel-Haenszel test)
	Number	Percentage	Number	Percentage	
Normal	17	45.9	30	81.1	
DDR	12	32.4	5	13.5	0.000 ***
DDNR	8	21.6	2	5.4	

*** $p < 0.001$.

Table 3. Distribution of bilateral normal, unilateral DD and bilateral DD in FA patients

	Bilateral normal	Unilateral DD	Bilateral DD
Number (n = 37)	11	16	10
Percentage	29.7	43.2	27.1

than the non-shifted side and the difference was significant ($p < 0.001$).

The distribution of unilateral and bilateral disk displacement in facial asymmetric patients is shown in Table 3. About 70% of the sample had unilateral or bilateral DD.

The evaluations of the disk configuration in the shifted and non-shifted side are presented in Table 4. The proportion was significantly different between bilateral sides ($p < 0.01$). It seemed to have more biconcave type in non-shifted side and more deformed one in the shifted side.

As shown in Table 5, the disk position was significantly different between the shifted and non-shifted side in both horizontal ($p < 0.001$) and vertical directions ($p < 0.01$). The disk in the shifted side showed more inferior and anterior displacement.

With jaw movement from closed to maximum opening position, the disk translation angle and distance were showed in Table 6. The disk of the

Table 4. Distribution of different types of disk configuration in shifted and non-shifted side

Disk position	*Number of joints in shifted side (n = 37)*		*Number of joints in non-shifted side (n = 37)*		*Significance (Fisher's exact test)*
	Number	*Percentage*	*Number*	*Percentage*	
Biconcave	17	45.9	21	56.8	0.004 **
Biplanar	3	8.1	5	3.5	
Funnel	1	2.7	7	18.9	
Deformed	16	43.2	4	10.8	

** $p < 0.01$.

Table 5. Comparison of disk position in horizontal (H) and vertical (V) direction (ratio) between the shifted and non-shifted side with *t*-test

Variables	*Shifted side (n = 37)*		*Non-shifted side (n = 37)*		*Significance (Paired t-test)*
	Mean	*SD*	*Mean*	*SD*	
Disk position (H)	27.2	15.7	40.0	10.9	0.001 ***
Disk position (V)	21.3	36.1	46.4	36.1	0.003 **

** $p < 0.01$; *** $p < 0.001$.

Table 6. Comparison of disk translation angle (°), translation distance (horizontal and vertical, in ratio) and disk rotation angle (°) in shifted and non-shifted side

Variables	*Shifted side (n = 37)*		*Non-shifted side (n = 37)*		*Significance (Paired t-test)*
	Mean	*SD*	*Mean*	*SD*	
Disk translation angle (°)	35.7	13.4	20.6	14.6	*NS*
Disk translation distance (H)	43.2	14.3	47.3	17.3	*NS*
Disk translation distance (V)	34.9	11.5	60.0	25.8	0.002 **
Disk rotation angle (°)	35.7	13.4	46.5	20.1	0.030 *

NS, no significance; * $p < 0.05$; ** $p < 0.01$.

shifted side showed less movement vertically ($p < 0.01$) and less rotation ($p < 0.05$) than the opposite side.

DISCUSSION

MRI is the most reliable technique to highlight soft tissues and classify TMJ ID without using ionizing radiation.[19,20] The accuracy of MRI for TMJ evaluation has been well documented by earlier studies. It was reported that sagittal and coronal sections have 95% accuracy in the assessment of disk position and form.[27] Proton-density-weighted acquisition was used instead of T2 sequence because it can increase the signal intensity.[30] A small field of view (FOV) was framed to minimize the pixel size when small anatomical structures were analyzed.[22]

It is accepted that internal derangement of the TMJ is caused by the abnormal position of the articular disk to the condyle, fossa, and articular eminence. ADD is the most common type of internal derangement.[21] It was suggested recently that ADD may occur alone or with a medial or lateral disk shift over the condylar head.[20,27-29] Partial anterior displacements of the disk have also been described.[21,22] In the present study, we classified DD into normal, partial ADD, ADD, rotational ADD and sideways DD. Posterior DD (PDD) was not included in this study because the prevalence of PDD is relative low[31] and no PDD was found in this sample. In partial ADD, rotational ADD and sideways DD, we did not further clarify samples into lateral or medial sides during analysis because of the relatively small sample amount. However, it should be noted that there was a tendency of more laterally displaced component in partial ADD, which could be due to the anatomical organization difference between lateral and medial attachments of the disk. Lateral pterygoid muscle inserts into the medial part of the disk together with the pterygoid fovea, which may reinforce the disk-condyle attachment on this side. Most sideways DD in our sample occurred in a medial direction, which was in agreement with previous studies.[22,28]

In the FA patients, we found that about 50% of the TMJs had some kind of DD and 70% of them had a side component. Rotational ADD was an important aspect of DD in this sample, which was similar to other samples.[20,22,28] It might indicate that DD in a single region of the joint is more common than DD throughout the joint.

There was significantly more DD, especially rotational disk displacement in the shifted side, while normal disk status is prevailing in the non-shifted side. There were also more DDR or DDNR in the shifted side than the other side. These results indicated that TMJ of the shifted side and the contrast side differ not only in the DD type but also in the disk configuration and location, which was in agreement with the idea that position change of the disk was frequently accompanied by configurational change.[32,33] In the present study, we also found that the prevalence of deformed disk was significantly higher in the shifted side. The disk of the shifted side also showed more inferior-anterior displacement than the contra-lateral side. One possible explanation could be due to the high prevalence of DDNR in the shifted side, which is a severe type of DD and linked to degenerative changes.[8] In a longitudinal study of patients with unilateral non-reducing disk displacement, the occurrence of intra-individual side differences in ramal height occurs significantly more often than in reference individuals.[34] The difference between both sides was attributed to mandibular shortening of the disk displacement side caused by osteoarthrotic degeneration of the condyle.[34] On the other hand, when the TMJ is affected by intra-articular disease, growth is commonly impeded, resulting in mandibular hypoplasia on the ipsilateral side, although pathologic stimulation of the condyle growth layer with mandibular hyperplasia also occurs.[14] Therefore, non-reducing disk displacement causes mandibular height asymmetry in growing individuals not only due to osteoarthrotic degeneration but also via influences on mandibular growth.[14] ID is related to FA not only in growing subjects but also in adults.[11] Yamada *et al*[35] studied 129 orthognathic surgery patients by using helical computed tomography scan and found that TMJ pathologies such as condylar bony change and DD may be related to craniofacial morphology in subjects with jaw deformity.

In a study of 732 TMJs having signs and symptoms of ID, it was found that bilateral IDs are more frequent than unilateral ID with a 3:1 ratio,[22] while Tasaki *et al*[21] and Sanchez-Woodworth *et al*[36] found the same ratio to be 2:1. The ratio of 1:1 was obtained in other studies.[28,29] Our result differed from all of the above results, that is, more unilateral ID than bilateral ID, which might be a characteristic feature of the FA sample.

In this sample, 26 out of 37 patients (70%) had unilateral or bilateral ID. This finding supported the previous hypothesis that ID is related with FA.[11,15] Once a TMJ is internally deranged, an adaptive or degenerative osteo-cartilaginous process takes place in the mandible, temporal bone, and masticatory muscle. Schellhas *et al*[13] has described the slow and ordered structural changes as the compensated deformity of unilateral TMJ ID, the characteristic feature of which is facial asymmetry. Bilateral TMJ ID in this sample might be due to the different severity or asymmetric reaction of the bony structures to the intra-articular changes. Time differences in the onset of TMJ ID in patients with bilateral TMJ ID, on one side first and then on the other, could be one of the explanations also. A previous study implied that bilateral TMJ ID is likely to develop over a longer period than unilateral TMJ ID. Therefore, the bilateral TMJ ID can have an even greater influence on facial development.[15] Further investigations are needed to test this hypothesis.

There were 11 patients diagnosed as bilateral MRI normal. This could partly have resulted from the multiple causes of FA. According to Westesson's study,[12] the shorter side of the face demonstrates a smaller condyle head associated with DD, but the condyle is normal on the longer side. This absence of pathology measured by MRI could be due to the misleading information given by this technique. Disk displacement may not have occurred in the MRI session that was not done in the clinical examination position.[22] The accuracy of MRI in diagnosing ID ranges from 73% to 95%.[27,37] The prevalence of this study should not be applied to the general FA population for it was not selected on a random basis and cannot represent the whole population.

It's difficult to identify the posterior edge of the posterior band of the disk because of both morphologic changes of the displaced disk and signal intensity caused by the disk degeneration/adaptation.[33] The medial point is relatively clear and can be used as a more reliable point for registration of the disk location.[38] In this study, we selected the midpoint of the intermediate region of the disk as the reference point in measuring the disk position and translation. Point M (the mid point of the anterior band of the disk) was used to determine the angle of rotation. Linear and angular measurements were used objectively in this study for quantitative measurement other than other subjective methods such as the 12 o'clock position.[19] Standardization of the 12 o'clock position relative to the TMJ is difficult because of variations in head position during imaging. The midpoint of the head of the condyle was not used to estimate the disk location because it is influenced by many factors, such as the shape of the condyle, the depth of the fossa and the inclination of the condylar head.

The disk in the shifted side showed less translation and rotation compared to those of the non-shifted side. This might be explained by more DDNR observed in the shifted side. In the early stage of DDNR, it is typically associated with mandibular hypomobility[39] that can affect mandibular growth and shorter ramal height on the side of non-reducing DD could be caused not only by osteoarthrotic degeneration but also by an influence on growth,[14] while the disk of the non-shifted side shows hyper-mobility with longer translation distance vertically. This further translation of the disk during mandibular opening movement can maintain the correct condyle-disk relationship when the mandible is deviating to the shifted side.

It is likely that the disk status is related to FA to some degree. However, the precise relationship between ID and FA is not fully understood, which warrants further comprehensive studies to correlate the features of FA with detailed imaging findings.

CONCLUSIONS

This study examined the morphometric characteristics of bilateral disks of FA patients and evaluated the possible correlation between ID and FA. About 70% of the patients had unilateral or bilateral ID. The shifted side was found to have significantly more DD than the non-shifted side. The configuration of the disk was deformed in the shifted side. The disk of the non-shifted side showed compensative hyper-mobility during the jaw opening. Further studies are needed to explore the relationship between ID and FA.

- 국문초록 -

자기 공명 영상을 이용한 안면비대칭환자의
측두하악관절원반의 형태와 위치에 관한 연구

Bingshuang Zou · 김태우 · 최순철

본 연구는 안면비대칭이 있는 환자의 측두하악관절원반 형태와 위치를 평가하고 악관절내장증과 안면비대칭 간의 관계를

규명하기 위하여 시행되었다. 남자 10명 및 여자 27명으로 구성된 안면비대칭 환자 37명의 74개의 TMJ MRI를 사용하였으며, 대상 집단의 연령은 12세에서 44세까지의 범위로 평균 21.4세였다. 시상 및 두정 TMJ MRI를 최대감합위 및 최대개구위에서 채득한 후 부분전방변위, 전방변위, 회전 또는 측방 원반변위 등 원반변위의 종류를 기록하였으며, 원반의 모양, 위치, 그리고 원반의 변위 및 회전을 MRI tracing 상에서 판독하였다. 악관절내장증의 증상은 정상, 정복성 전방원반변위(ADDR), 그리고 비정복성 전방원반변위 (ADDNR) 집단으로 분류하였으며, 환자는 양측성 정상, 편측 혹은 양측 내장증 집단으로 분류하였다. 약 70%의 환자에서 편측성 또는 양측성 내장증을 보였으며, 통계분석 결과 ADD, 특히 회전성 ADD가 변위측에서 더 높은 빈도로 나타났으나 반대측에서는 원반의 위치가 정상인 경우가 많았다 ($p < 0.01$). 변위측의 원반은 모양의 변형 및 하전방 변위를 유의하게 더 나타냈다. 그러나 반대쪽은 개구시 원반이 수직방향으로 과운동성이 관찰되었다. 이 연구는 안면비대칭 환자에서 ADD의 종류가 원반의 모양, 경사, 변위 각도, 변위의 수직거리 및 회전각도와 연관이 있다는 것을 제시한다.

(**주요 단어**: 측두하악관절원반, 안면비대칭, 자기공명영상)

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