KOREA. J. ORTHOD.
2003. : 33(3) : 211-22

Relationship between disk displacement of temporomandibular joint and dentofacial asymmetry

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The purpose of this study was to determine whether there is an association between disk displacement of the Temporomandibular Joint (TMJ) and dentofacial asymmetry in orthodontic patients.

The subjects consisted of 60 female orthodontic patients between the ages of 18 and 38 years (mean age 23.3 years) who had visited the Department of Orthodontics at Seoul National University Dental Hospital from January 2000 to April 2002. On the basis of magnetic resonance imaging (MRI) of their bilateral TMJs, the subjects were divided into four groups: bilateral normal group (twenty-one persons); disk displacement of right TMJ group (six persons); disk displacement of left TMJ group (nine persons); and disk displacement of both TMJs group (twenty-four persons).

Postero-anterior (PA) cephalograms and diagnostic models which had been taken before orthodontic treatment were measured. In the linear measurements, a line connecting the right and left Latero-Orbitale (Lo) represented the horizontal reference line (H). The vertical reference line (V) was constructed as a line bisecting and running perpendicular to H.

One-way analysis of variance (ANOVA) was used to test whether the mean values of measurements between groups were significantly different. In addition, Bonferroni's multiple comparison test was performed at a level of 0.05.

The results were as follows :

1. In the diagnostic model analysis, the overjet, right molar relationship, and left molar relationship were significantly different among the four groups.
2. In the PA cephalometric analysis, differences in the right and left vertical position of the lower first molar and Ag were significantly dissimilar among the four groups.
3. If the disk displacement of TMJ was present on one side, the ipsilateral ramus was shorter, resulting in asymmetry in the vertical position of Ag.

This study indicated that dentofacial asymmetry might be related to the disk displacement of TMJ.

Key words : TMJ disk displacement, MRI, PA ceph, Asymmetry

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Disk displacement of TMJ is defined as an abnormal relationship of the articular disk to the condyle, fossa, and articular eminence, and the disk is usually displaced anteromedially.[1] The superior lateral pterygoid muscle pulls the disk both forward and medially on the condyle. If the pull of this muscle is protracted, the posterior border of the disk may grow thinner. As this area is diminished, the disk tends to be displaced more in the anteromedial direction so that the condyle becomes positioned on the posterior border of the disk. This is known as disk displacement.[2]

Disk displacement can be regarded as loss of harmony among the functional components of TMJ. In the event of disk displacement, the retrodiscal tissue is pulled forward between the condyle and articular eminence. Subsequently, the compression of proximate vascular tissue can occur, altering the oxygenation, nutrition, and lubrication of condylar tissue through synovial fluid changes.[3] These localized changes can alter the growth of condylar cartilage and result in facial alterations.

Facial alterations can variously appear in either the sagittal, transverse, or vertical directions. Facial asym-metry is a transverse deviation, and in evaluating this condition PA cephalograms are frequently used. The establishment of a reference line is very important for this procedure; however, there are too many reference line systems in current application and no general consensus exists. Owen and Grummons & Kappeyne[4] used the Nc -ANS line as a vertical reference line. On the other hand, Ricketts *et al*[5] used a line passing through Nc and perpendicular to ZA line, while Mulick[6] used a line passing through Nc and perpendicular to the FR-FR line as a vertical reference line. There are many systems being applied to the horizontal reference line as well. Svanholt & Solow[7] used the Lo-Lo line as a horizontal reference line, whereas Owen and Grummons & Kappeyne[4] employed the ZA line.

In recent years, Trpkova *et al.*[8] investigated the amount of craniofacial asymmetry in female adolescents with unilateral or bilateral disk displacement of TMJ relative to those without any displacement, using MRIs of bilateral TMJ and PA cephalograms. They concluded that a greater amount of asymmetry was found in patients with bilateral disk displacement of TMJ compared with females with normal disk positioning, whereas females with unilateral disk displacement of TMJ did not differ significantly from the other two groups. However they used adolescents as the subject (Caucasian females between the ages of 10 and 17 years), and overall facial asymmetry may continue to change until growth terminates.

In this study, sixty adult females were the subjects. Because the growth of the subjects is regarded as terminated, changes in facial asymmetry were not expected. MRIs and PA cephalograms were analyzed, and, in addition, to examine the relationship between facial asymmetry and dental deviations in sagittal direction, diagnostic casts were measured.

It was hypothesized that there would be some differences in skeletal characteristics among those with normal disk position, those with unilateral disk displace-ment of TMJ, and those with bilateral disk displacement of TMJ. The purpose of this study was to determine whether there is an association between disk displace-ment of TMJ and dentofacial asymmetry in orthodontic patients.

MATERIALS AND METHODS

1. Sample Selection

Sixty female patients were selected from among 168 patients who had visited the Department of Orthodontics at Seoul National University Dental Hospital for orthodontic treatment, and had undergone an MRI of both TMJ between January 2000 and April 2002. They included individuals with clinically detectable TMJ signs & symptoms (joint sounds, capsular pain, masticatory muscle tenderness, limited mandibular range of motion, deviation on opening) and/or dentofacial morphologic abnormalities such as anterior open-bite, anterior cross-bite and facial asymmetry. Patients with missing teeth or ectopic eruptions were excluded. Those


Fig. 1. MRI analysis – normal (left : closed state, right : open stste).

patients with a history of previous orthodontic treatment or splint therapy were also excluded. None of the subjects had a history of infection, tumors, or trauma affecting the dentofacial area (such as juvenile rheumatoid arthritis). Males were not selected because of the limited number of available test subjects. The age of the subjects was between 18.1 and 38.9 years (mean age 23.3 years).

The MRIs of both TMJs, diagnostic models, and postero–anterior (PA) cephalograms of the subjects were evaluated before orthodontic treatment.

2. MRI ANALYSIS

Irrespective of TMJ status, all the subjects consented to bilateral high–resolution MRI scans in the sagittal (opened and closed) and coronal (closed) planes to evaluate the TMJs. Within the Department of Diagnostic Radiology at Seoul National University Hospital, the MRIs of both TMJs were obtained with Signa Horison (GE, Waukesha, WI) operating at 1.5T and a unilateral 3 inch surface receiver coil (GE). Initially, axial scout images were obtained at the level of the TMJs to identify the long axes of the condyles. Nonorthogonal sagittal sections were obtained perpendicular to the condyles and nonorthogonal coronal oblique sections were also obtained. Closed mouth images were obtained at maximum dental intercuspation and open mouth images were obtained at maximum unassisted vertical mandibular opening by using a Burnett bidirectional TMJ device (Medrad, Pittsburgh, PA). 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 along the sagittal plane by using a 3–mm slice thickness, 10–cm field of view, a number of excitations of 2, as well as an image matrix of 254 192 pixels. A T1–weighted 500/12 (TR ms/TE ms) pulse sequence was performed along the coronal plane under the same conditions.

The evaluation of each joint was obtained from consecutive sagittal MRI slices by the agreement of two experts. Each right and left joint was categorized respectively as normal, anterior disk displacement (ADD) with reduction, ADD without reduction, ADD without reduction and abnormal disk morphology (Figures 1, 2, 3, and 4).

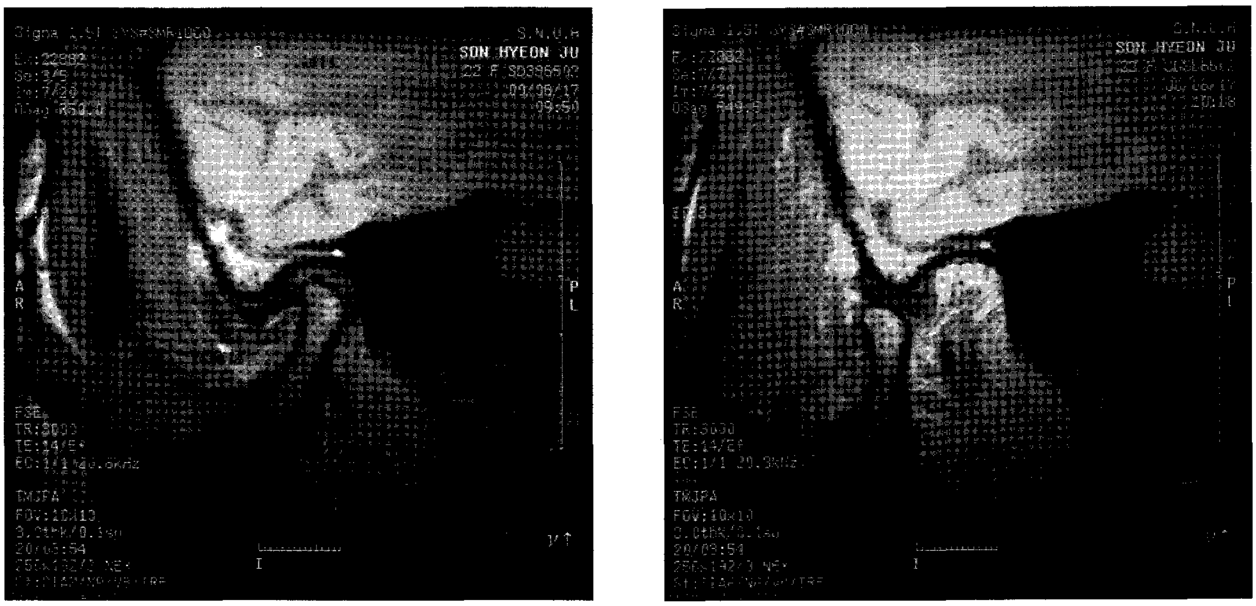

Fig. 2. MRI analysis – ADD with reduction (left : closed state, right : open stste).

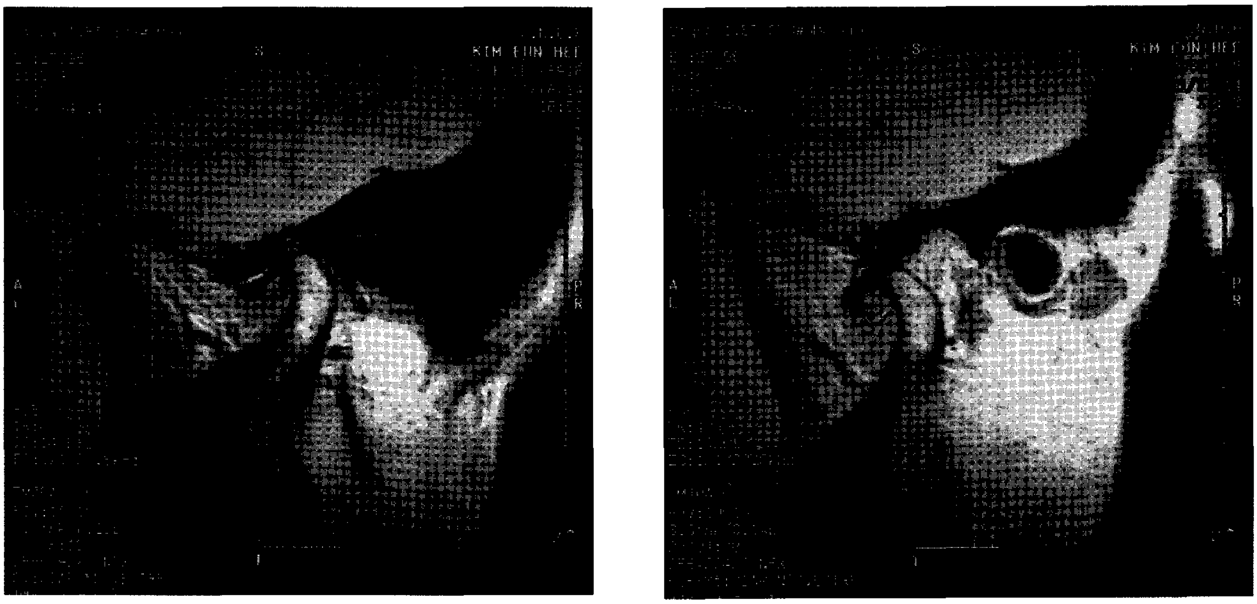

Fig. 3. MRI analysis – ADD without reduction (left : closed state, right : open stste).

3. DIAGNOSTIC MODEL ANALYSIS

Figure 5 represents the diagnostic model analysis. The overjet and the overbite were measured, as was the mesio-distal molar relationship (defined as the linear distance projected to the occlusal plane between the mesiobuccal cusp tip of the upper first molars and the mesiobuccal groove of the lower first molars). The right (RMR) and left (LMR) molar relationships were measured respectively. Differences between the two

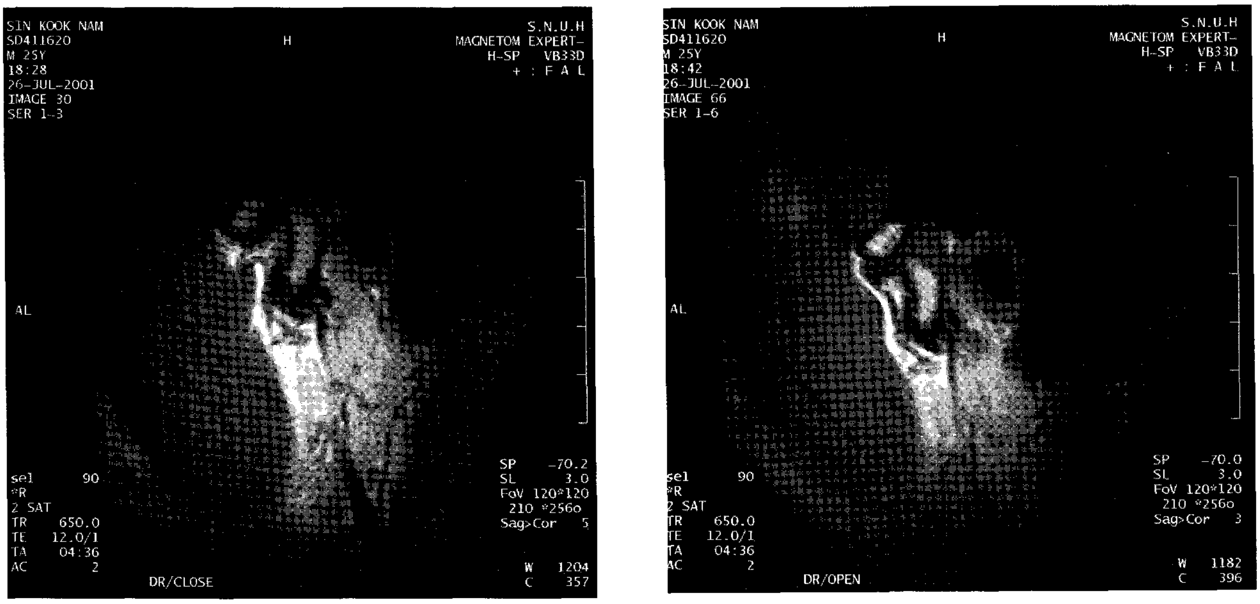

Fig. 4. MRI analysis – ADD without reduction and abnormal disk morphology (left : closed state, right : open stste).

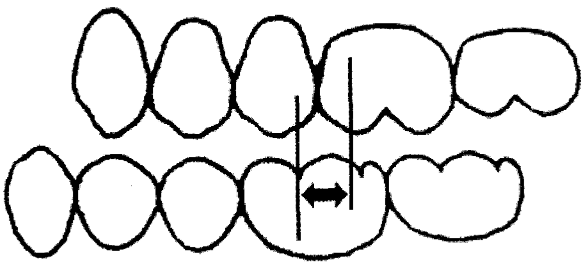

Fig. 5. Diagnostic model analysis (mesio-distal molar relationship).

measurements (*d*MR) were obtained by a subtraction of LMR from RMR. If the lower mesiobuccal groove was located mesially relative to the upper mesiobuccal cusp tip, this measurement was revealed as a positive value.

4. CEPHALOMETRIC ANALYSIS

Closed mouth postero-anterior cephalometric radiographs (PA cephalograms) were obtained for each subject with an Asahi CX-90SP (Asahi Roentgen Industrial Co., Kyoto, Japan). PA cephalograms were traced on acetate tracing film by the author, and traced cephalometric landmarks were digitized with Intuos 2 Graphics Tablet (WACOM Co., Ltd. Japan) and analyzed with custom-made computer software.

In the linear measurements, a line connecting the right and left Latero-Orbitale (Lo) represented the horizontal reference line (H). The vertical reference line (V) was constructed as a line bisecting and running perpendicular to H[7] (Figure 6).

The cephalometric landmarks are listed in Table 1. Differences between the right and left side as detected by linear and angular measurements are also defined in Table 2. From each sample, 16 paired linear measurements and one paired angular measurement were obtained as mentioned above. Differences between the right and left values for each measurement (except U1V and L1V) were used to calculate asymmetry according to the formula detailed below:

$$\frac{R - L}{R + L} \times 100$$

R signifies the value of measurements on the right side, while L signifies the value of measurements on the left side.

Table 1. Cephalometric landmarks (figure 7)

Landmarks	Description
Nc	Crista Galli, the constricted part of crista galli
ANS	Anterior nasal spine
U1	Maxillary central incisor, midpoint of the maxillary central incisors at the level of gingival crest
L1	Mandibular central incisor, midpoint of the mandibular central incisors at the level of gingival crest
Me	Menton, point on inferior border of symphysis directly inferior to mental protuberance and below center of trigonium mentali
Lo	Latero-orbitale, intersecting point between the external orbital contour laterally and the oblique line
Cd	Condylion, uppermost point of the condylar head
Zyg	Zygoma, most lateral and superior point of the shadow of the zygomatic arch
J	Jugal process, the point on the jugal process of the maxilla at a crossing with the tuberosity of the maxilla
U6	Upper first permanent molar, the buccal-most point on the crown of the upper first molar
L6	Lower first permanent molar, the buccal-most point on the crown of the lower first molar
Ag	Antegonion, The highest point in the antegonial notch (left and right)

Table 2. Measurements of asymmetry

Parameter	Description
*d*CdV	Difference between right and left side of distance from Cd to V
*d*CdH	Difference between right and left side of distance from Cd to H
*d*ZygV	Difference between right and left side of distance from Zyg to V
*d*ZygH	Difference between right and left side of distance from Zyg to H
*d*JV	Difference between right and left side of distance from J to V
*d*JH	Difference between right and left side of distance from J to H
*d*U6V	Difference between right and left side of distance from U6 to V
*d*U6H	Difference between right and left side of distance from U6 to H
*d*L6V	Difference between right and left side of distance from L6 to V
*d*L6H	Difference between right and left side of distance from L6 to H
dAgV	Difference between right and left side of distance from Ag to V
*d*AgH	Difference between right and left side of distance from Ag to H
*d*CdMe	Difference between right and left side of distance from Cd to Me
dAgMe	Difference between right and left side of distance from Ag to Me
*d*CdAg	Difference between right and left side of distance from Cd to Ag
*d*CdAgMe	Difference between right and left side of angle formed by the line connecting Cd and Ag and the line connecting Me and Ag
MD	Midline deviation

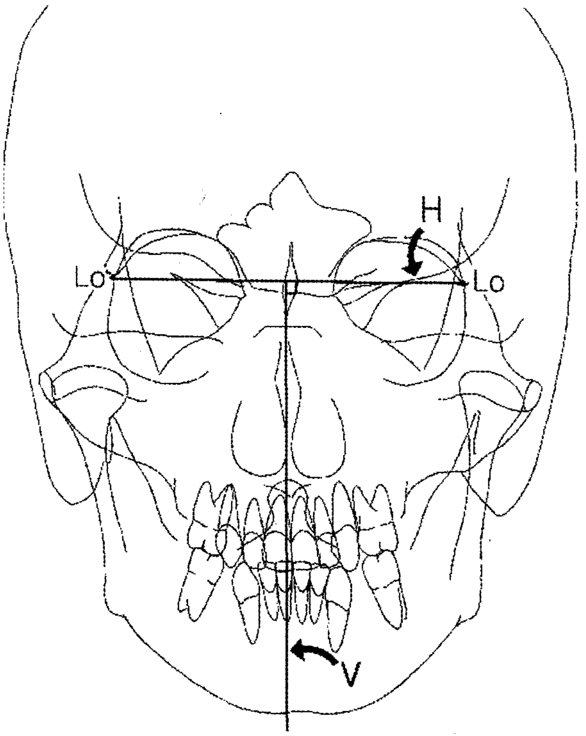

Fig. 6. Reference Lines in the Linear measurements.

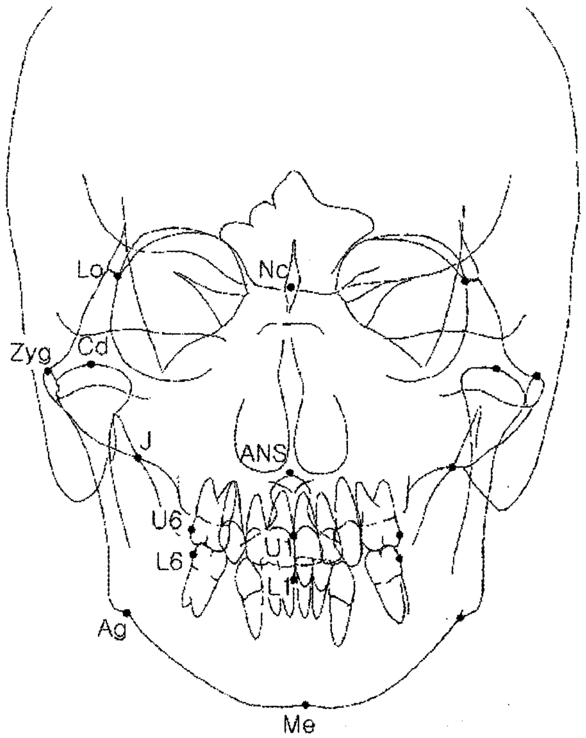

Fig. 7. Landmarks.

5. STATISTICAL ANALYSIS

According to the MRI analysis, the subjects were divided into four groups.

① Group I : This group consisted of subjects with bilateral normal TMJs.
② Group II : This group consisted of subjects with disk displacement of only the right TMJ.
③ Group III : This group consisted of subjects with disk displacement of only the left TMJ.
④ Group IV : This group consisted of subjects with disk displacement of both TMJs.

In this grouping, disk displacement of TMJ included 1) anterior disk displacement (ADD) with reduction, 2) ADD without reduction, and 3) ADD without reduction accompanied by abnormal disk morphology.

One-way analysis of variance (ANOVA) was used to test whether the mean values of measurements from each group were significantly different. Differences with a p-value of less than 0.05 were regarded as significant. Bonferroni's multiple comparison test was performed.

6. METHODS ERROR

Cephalometric measurement error was determined after repeated tracings of each PA cephalogram, obtained and measured according to a minimum one-week interval. Dahlberg's formula[9] was used to calculate the mean, standard deviation, and range of standard error for linear and angular measurements.

The mean error of cephalometric linear measurements was 0.6mm with ranges from 0.2mm (dJH) to 1.1mm (dAgMe). The mean error of cephalometric angular measurement was 0.8.

Table 3. Sample distribution to each groups according to the MRI analysis

	TMJ Status	Number (N (%))	Age (Years, Mean ± SD)
Group I	Bilateral normal TMJ	21 (35.0)	21.92 ± 3.53
Group II	Right TMJ DD*	6 (10.0)	24.78 ± 6.42
Group III	Left TMJ DD	9 (15.0)	26.11 ± 6.86
Group IV	Bilateral TMJ DD	24 (40.0)	23.08 ± 5.30
Total		60 (100.0)	23.30 ± 5.33

*DD : disk displacement

Table 4. Diagnostic model comparisons between 4 groups by ANOVA and Bonferroni's multiple comparisons

Variables⁺	Group	Mean ± SD(%)	F	Sig.	Multiple comparisons
Overjet	I	−0.29 ± 3.20	8.608	***	(I IV),(II IV)
	II	−0.33 ± 5.69			
	III	2.00 ± 3.04			
	IV	4.27 ± 2.42			
Overbite	I	−0.21 ± 2.21	0.780	NS	
	II	0.92 ± 2.75			
	III	0.67 ± 1.58			
	IV	−0.31 ± 2.46			
RMR	I	5.26 ± 4.16	9.215	***	(I IV)
	II	3.17 ± 3.92			
	III	2.72 ± 3.41			
	IV	0.08 ± 2.05			
LMR	I	4.29 ± 3.99	6.361	**	(I IV)
	II	3.83 ± 6.19			
	III	1.56 ± 2.40			
	IV	0.08 ± 1.92			
*d*MR	I	0.98 ± 2.80	1.369	NS	
	II	−0.67 ± 2.98			
	III	1.17 ± 2.44			
	IV	0.00 ± 1.64			

⁺RMR = right molar relationship, LMR = left molar relationship, *d*MR = difference between right and left molar relationship (*d*MR = RMR − LMR)
NS non-significant, ** $p<0.01$, *** $p<0.001$

Table 5. Comparison of each groups in asymmetry measurements by ANOVA and Bonferroni's multiple comparisons (Only statistically significant data are listed.)

Variables⁺	Group	Mean ± SD(%)	F	Sig.	Multiple comparisons
*d*L6H	I	−0.17 ± 1.04	6.221	*	(I II),(II III),(II IV)
	II	−2.50 ± 0.98			
	III	0.63 ± 2.00			
	IV	−0.10 ± 1.56			
*d*AgH	I	0.32 ± 1.31	8.698	***	(I II),(I III),(II III), (II IV),(III IV)
	II	−2.32 ± 1.97			
	III	2.37 ± 1.81			
	IV	0.27 ± 1.99			
*d*CdMe	I	0.10 ± 1.83	8.040	***	(I III),(II III),(II IV)
	II	−2.42 ± 2.39			
	III	2.68 ± 2.71			
	IV	1.60 ± 2.32			
dAgMe	I	−0.18 ± 3.06	4.320	**	(II III)
	II	−2.79 ± 4.51			
	III	3.05 ± 5.24			
	IV	1.41 ± 2.50			
*d*CdAg	I	0.54 ± 2.29	7.087	***	(I III),(II III),(II IV)
	II	−2.90 ± 3.24			
	III	4.28 ± 2.56			
	IV	2.12 ± 3.91			
*d*CdAgMe	I	0.68 ± 3.40	3.998	*	(II III)
	II	−2.36 ± 5.47			
	III	5.08 ± 6.34			
	IV	1.04 ± 3.70			

NS non−significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

RESULTS

The features of the four groups as determined by MRI analysis are listed on Table 3. Of the subject group, 65% of patients had some form of disk displacement of TMJ, 25% had unilateral disk displacement of TMJ (10% involving the right TMJ and 15% involving the left TMJ), and 40% had a bilateral disk displacement of TMJ.

Tables 4 to 5 contain the one−way ANOVA and Bonferroni's multiple comparisons outcome when means of difference measurements were compared among groups. As listed in Table 4, overjet ($p< 0.001$), right molar relationship ($p<0.001$), and left molar relationship ($p<0.01$) were significantly different amongthe four groups as indicated by diagnostic model analysis. However, overbite and *d*MR did not demonstrate any dissimilarity among the four groups. The means of right molar relationship and left molar relationship decreased from group I to group IV.

In the linear measurements, *d*L6H and *d*AgH differed significantly among the four groups, as did *d*CdMe, *d*AgMe, *d*CdAg, and *d*CdAgMe.

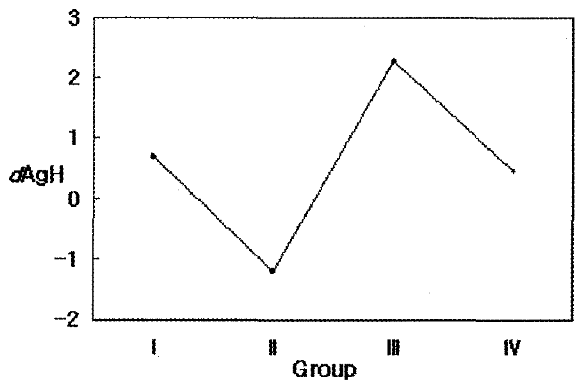

Fig. 8. the means of dAgH.

DISCUSSION

MRI has been known to be the most reliable procedure for highlighting soft tissues and the classification of disk displacement of TMJ without the utilization of ionizing radiation.[10,11] The accuracy of MRI for TMJ evaluation has been well demonstrated by earlier studies. Sagittal and coronal sections were 95% accurate in the assessment of disk position and form.[12]

In this study, subjects were categorized into four groups according to the MRI of bilateral TMJs (Table 3). Group I included 21 persons (35%). Groups II and III, with a unilateral disk displacement of TMJ group, included 15 persons (25%). Group IV included 24 persons (40%). The grouping demonstrated a relatively even distribution.

To determine whether an association existed between the disk displacement of TMJ and dentofacial asymmetry, emphasis was given to the analysis of PA cephalograms although diagnostic models were also analyzed. In regard to diagnostic model analysis, the overjet, right molar relationship, and left molar relationship showed differences among the four groups (Table 4). No important significance was observed because many factors (like crowding) exerted an influence on dentition. But the mean of *d*MR in group II was negative, implying that the right molar relationship showed a more pronounced Cl II tendency than the left molar relationship. On the contrary, group III produced a positive result, indicating that the left side appeared to have a greater Cl II tendency than the right side. This meant that there were associations between asymmetry in the vertical plane (PA cephalograms) and the sagittal plane (molar relationship on diagnostic model). Further study may be necessary in this area.

In the analysis of PA cephalograms, vertical asymmetries of the lower first molars and Ag existed. Moreover *d*CdMe, *d*AgMe, *d*CdAg, and *d*CdAgMe showed differences among the four groups (Table 5).

The vertical measurements of Ag from the four groups showed a distinct difference compared with other landmarks (Figure 8). Patients with bilateral normal TMJ or bilateral disk displacement of TMJ showed symmetries in regard to the vertical position of Ag. Conversely, patients with unilateral disk displacement of TMJ demonstrated asymmetries in regard to the vertical position of Ag. These results are different from those produced by other studies.[8]

Trpkova[8] investigated the amount of craniofacial asymmetry in female orthodontic patients with unilateral or bilateral disk displacement of TMJ relative to those without any disk displacement, using bilateral TMJ MRI and PA cephalograms. He concluded that if the disk displacement of TMJ was more advanced on one side, the ipsilateral ramus should have been shorter, thus resulting in significant asymmetry in this region.[8] However in his study, a greater amount of asymmetry was found in patients with bilateral disk displacement of TMJ compared with females with bilaterally normal TMJs, whereas females with unilateral disk displacement of TMJ did not differ significantly from the other two groups. He explained that asymmetry appeared to progress from bilateral normal TMJ to bilateral disk displacement of TMJ, and this finding could be justified by time differences in the onset of disk displacement of TMJ in patients with bilateral disk displacement of TMJ (which advances from one side to the other).

In the future, Trpkova's opinion may be verified if the number of MRI samples is sufficient. In order to achieve this confirmation, however, the grouping must be detailed according to the stages of disk displacement of TMJ.

The findings of this study tend to support the argument that disk displacement may be associated with altered craniofacial morphology. If disk displacement of TMJ exists, then disk displacement "pulls" the retrodiscal tissue forward between the condyle and articular eminence, resulting in potentially harmful effects. Compression of this normal vascular tissue may alter oxygenation, nutrition, and lubrication of condylar tissue through synovial fluid changes.[3] These localized changes may affect dynamic growth within this region, resulting in a loss of facial growth equilibrium as expressed in the various adaptive growth sites.

Indeed, through an experimental study on rabbits it has been shown that disk displacement of TMJ can significantly affect further mandibular growth, specifically ramus height.[13] However, a shorter ramus on the disk displacement side can be partially compensated for by growth at the base of the mandible, so that the overall height of the mandible (ramus and body) may not be reduced.

Nevertheless, it is basically impossible to conclude which one – dentofacial asymmetry or disk displacement of TMJ – happened first.

This study was a cross-sectional evaluation. It was impossible to determine the onset of disk displacement or to establish the effects of duration upon the disorder. At present, no longitudinal data involving MRI assessment of disk position is available to support the concept of growth alteration that may be occurring.

Patients with disk displacement of TMJ should be reevaluated later, and the rate of change in disk displacement of TMJ severity should be compared with the rate of change in craniofacial asymmetry. A follow-up investigation of patients with disk displacement of TMJ as documented by MRI is required to establish the long-term relationship between disk displacement of TMJ and craniofacial asymmetry.

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국문초록

측두하악관절 원판 변위와 치열 및 안면부 비대칭의 관계에 대한 연구

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본 연구의 목적은 교정환자에서 측두하악관절 원판 변위(disk displacement of TMJ)가 치열 및 안면부 비대칭과 관련이 있는가를 밝히는 것이다.

2000년 1월부터 2002년 4월까지 서울대학교병원 치과교정과에 내원한 환자 중 18 ~ 38세(평균 23.3세)인 여성 60명의 측두하악관절 자기공명영상(MRI)을 기초로 하여, 양측 TMJ가 모두 정상인 군 (21명), 우측 TMJ에만 원판 변위가 있는 군 (6명), 좌측 TMJ에만 원판 변위가 있는 군 (9명), 양측 TMJ에 모두 원판 변위가 있는 군 (24명)으로 나누고, 교정치료 전의 후전방 두부방사선계측사진과 교정진단모형을 계측하였다. 후전방 두부방사선계측사진의 분석에는 좌우 Latero-Orbitale(Lo)를 연결한 선분을 수평기준선으로 하고, 이 선분을 수직 이등분하는 직선을 수직기준선으로 하였다. 각 계측항목에 대해 일원배치분산분석(one-way ANOVA)과 후처치로서 다중비교분석(Bonferroni's multiple comparison test)을 시행하여, 다음과 같은 결과를 얻었다.

1. 교정진단모형에서 전치돌출도, 우측구치관계, 좌측구치관계가 각 군 사이에 유의한 차이를 보였다.
2. 후전방 두부방사선계측사진에서 하악제1대구치와 Ag의 수직적 위치의 좌우 차이가 각 군 사이에 유의한 차이를 보였다.
3. 측두하악관절 원판 변위가 편측에 존재하면, 이환측의 하악지 길이가 비이환측에 비해 짧았으며 좌우 Ag의 수직적 높이에도 차이를 보였다.

이상의 결과를 통하여, 측두하악관절 원판 변위의 편재와 치열 및 안면부 비대칭의 발현 양상은 관계가 있다고 판단된다.

주요 단어 : 측두하악관절 원판변위, 자기공명영상, 후전방두부방사선계측사진, 비대칭