# **Original Article**

# Computerized ultrasonic axiographic evaluation of condylar movement in patients with internal derangement of the temporomandibular joint

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# ABSTRACT

**Objectives:** To evaluate condylar movement during lateral excursion in individuals with internal derangement of the temporomandibular joint (TMJ) using ultrasonic axiography.

**Materials and Methods:** A total of 34 patients with internal derangement of the TMJ and 34 participants in the control group were examined. Mandibular functional movement was recorded by ultrasonic axiography. Three-dimensional condylar movement was measured in the working and balancing condyles.

**Results:** Significant differences in condylar movement were found between the two groups. In the group with internal derangement of the TMJ, the three-dimensional linear distances of the condylar path in a working condyle were greater than in the control group during lateral excursion. The speed of the balancing condyle in the returning path of lateral excursion was significantly greater in the group with internal derangement than in the control group.

**Conclusions:** The results of the present study indicate that internal derangement of TMJ may affect the working and balancing condylar movements during lateral excursion. (*Angle Orthod.* 2019;89:924–929.)

**KEY WORDS:** Temporomandibular joint; Jaw relation record; Internal derangement; Ultrasonic axiography; Computerized axiography; Condylar movement

#### INTRODUCTION

Because temporomandibular pain and/or dysfunction (TMD) symptoms are common, it is recommended that every orthodontic patient be screened for these problems.<sup>1</sup> Orthodontic treatment influences the patient's occlusal condition; it is important to identify any dysfunction in the masticatory system before treat-

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ment. For patients who have TMD symptoms or an unstable jaw position, orthodontists can consider resolving the TMD symptoms before any orthodontic treatment is begun. Internal derangement of the temporomandibular joint (TMJ) can be treated using an anterior repositioning splint, a full-arch maxillary stabilization splint,<sup>2,3</sup> or arthroscopic eminoplasty.<sup>4</sup>

However, patients who do not exhibit any symptoms of TMD before orthodontic treatment sometimes complain of symptoms during or after orthodontic treatment. For orthodontists, it is challenging to manage these patients who report that their TMD symptoms were a result of the orthodontic treatment. Unfortunately, there are few studies in the previous literature focused on the relationship between TMD and orthodontic treatment.<sup>5,6</sup> Thus, orthodontists need to be aware of the conditions in the masticatory system before any treatment is begun.

Mandibular border movements in the horizontal plane consist of the following four components: left lateral border, continued left lateral border with protrusion, right lateral border, and continued right lateral border with protrusion.<sup>7</sup> In healthy condyles, during lateral excursion, the working condyle shows mainly rotational movement and laterotrusive move-

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Figure 1. Flow chart of participant enrollment in the study.

ment less than 1 mm.<sup>8</sup> The balancing condyle shows a smooth gliding curved path and a small difference in inclination between the eccentric and returning paths. When compared with the normal healthy TMJ, patients with internal derangements have different condylar paths during lateral excursive movement.<sup>9</sup> Thus, the evaluation of condylar paths during lateral excursive movement before treatment can help clinicians be prepared for a clinical situation in which the development of TMD complications may occur later.

The paths of mandibular movements are possible with the help of computerized ultrasonic axiography. The development of lightweight, three-dimensional (3D) sensors attached to maxillary and mandibular teeth facilitates axiography and increases patient comfort. Previous studies have used computerized ultrasonic axiography to evaluate the condylar path inclination for growing patients.<sup>10,11</sup> The purposes of this study were to evaluate the condylar path, including the range of motion during lateral excursion, and to compare the paths between patients with internal derangement of the TMJ and healthy controls.

#### MATERIALS AND METHODS

The study included 68 adult patients divided into one of the following two groups: TMD patient group (n = 34; 20 women, 14 men; age 22.7  $\pm$  2.2 years) and control group (n = 34; 18 women, 16 men; age 23.5  $\pm$  3.1 years; Figure 1). The participants provided written informed consent as stipulated in the protocol approved by the institutional review board (CNUDH-2015-003) of Chonnam National University Dental Hospital in Korea.

The patient group was established by including consecutive patients referred to an oral medicine and TMD clinic because of temporomandibular pain and/or

Table 1. Der	nographic	Data of	the	Participants
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	Control Group		
Variables	$\text{Mean} \pm \text{SD}$	Mean $\pm$ SD	Significance
Number	34	34	ns
Male/female, no.	18/16	20/14	ns
Age, y	$23.5\pm3.1$	$22.7\pm2.2$	ns
Skeletal pattern			
Class I, no.	34	7	<i>P</i> < .01
Class II, no.	0	21	<i>P</i> < .01
Class III, no.	0	6	P < .01

<sup>a</sup> ns indicates not significant; *SD*, standard deviation. Chi-square test and independent *t*-test were performed to compare the variables between the two groups.

dysfunction (TMD patients). Inclusion required the presence of a TMD diagnosis of disc displacement in accordance with the Research Diagnostic Criteria for Temporomandibular Disorders (axis I group II).<sup>12</sup> A matched control group of consecutive healthy individuals (without a report of subjective TMD dysfunction) consisted of patients who visited a private clinic of one of the authors (Dr Choi) for annual dental check-ups. The patient and control groups were compared with regard to clinical findings of dysfunction. All participants had a full permanent dentition except for the third molars. Individuals with congenital malformations including rheumatoid arthritis and trismus and those under treatment with medications known to affect muscle activity or who had undergone orthodontic treatment were excluded from the study. The demographic data of the two groups are provided in Table 1.

The participants were instructed to perform right and left lateral movements of the mandible while seated upright with the head unsupported and facing forward. Each movement started and ended in maximum intercuspation. Condylar movements, including condylar paths on the working and balancing sides and 3D position of the working and balancing sides, were recorded for each patient using an ultrasonic recording device (axioquick recorder; SAM Prazionstechnik, Munich, Germany). The registration system is based on the measurement of real-time latency periods of sequentially transmitted ultrasound pulses between four transmitters attached to the mandible and eight receivers mounted on the head with a face bow. The axioquick recorder system uses a zero-reference plane determined by a posterior anatomic porion and an anterior orbitale to ensure identical Frankfort horizontal and axis orbital planes. This also establishes predetermined hinge axis reference points that are colinear and within clinical accuracy for recording articulator data. Thus, in this study, the hinge axis point selected was placed 10-mm anterior to the anatomic porion (external auditory meatus) according to the manual of Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-14 via free access



Figure 2. (A) Mandibular movements captured digitally. Horizontal movement occurs in the XY direction, frontal movement in YZ direction, and sagittal movement in XZ direction. (B) An axioquick recorder system was used to record condylar movements of the working and balancing sides.

the manufacturer. After the 3D acquisition of mandibular movements, the axiogram was generated with timing and digital data. The *x*-axis represented the anteroposterior direction, the *z*-axis represented the superoinferior direction, and the *y*-axis represented the right–left direction. The origin of the coordinates included the middle of the intercondylar axis (Figure 2).

The sample size of this study was not calculated a priori, but the post hoc power analysis by the G\*power program (version 3.1.9.2; Heinrich-Heine-University, Dusseldorf, Germany) showed more than 90% power for all measurements. Three orthogonal excursive ranges and the 3D linear distance of the working and balancing condular points were evaluated. The normality of variables was tested by the Kolmogorov-Smirnov test. The mean and standard deviation of the measurements were analyzed. One-way analysis of variance with Scheffe's multiple comparison tests and paired t-test were performed for statistical analysis. In addition, because one examiner (Dr Choi) performed and recorded the measurements, 10 participants were randomly selected in each group for repeated measurements. The method error was assessed by calculating the intraclass correlation coefficient. The intraclass correlation coefficient measurement showed a mean of 0.726 (intraclass correlation coefficient = 0.69-0.81). Statistical analysis was performed using

IBM SPSS Statistics for Windows Version 23.0 (IBM Corp., Armonk, N.Y.).

#### RESULTS

The mean values and standard deviations of the functional measurements on the working side and balancing side condyles are shown in Table 2. In the control group, the measurements of three directions in the condylar path and the 3D linear distance of the condylar path were significantly greater on the balancing side than on the working side (Figure 3). In the internal derangement group, significant differences were found in the measurements between the working and balancing sides. However, the values for the working side in the internal derangement group were greater than in the control group (Table 2). The speed of the balancing condyle in the returning path of lateral excursion was significantly greater in the group with internal derangement than in the control group (Table 3).

#### DISCUSSION

The purpose of the study was to evaluate condylar movement during lateral excursion in individuals with internal derangement of the TMJ using ultrasonic axiography. Internal derangement of the TMJ is

Table 2.	Comparison of the	Working and	Balancing Co	ndylar Movement I	During Lateral	Excursion Between the	Two Groups <sup>a</sup>
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	Balancing Condyle					Working Condyle				
	Inter Derangem	rnal ent Group	Control	Group		Inter Derangem	rnal ent Group	Control	Group	
Variables	Mean	SD	Mean	SD	P Value	Mean	SD	Mean	SD	P Value
X direction	6.79	2.55	4.63	1.62	.013	0.99	0.69	0.31	0.16	.000
Y direction	1.45	0.83	0.39	0.24	.000	1.05	0.69	0.33	0.20	.000
Z direction	5.92	1.79	3.99	1.13	.013	0.78	0.51	0.28	0.13	.001
Three-dimensional linear distance	9.23	2.84	5.83	1.38	.001	1.71	0.86	0.51	0.19	.000

<sup>a</sup> SD indicates standard deviation. Unit = mm.



Figure 3. Condylar path during left lateral excursion in the internal derangement group (A) and in the control group (B). In the internal derangement group (A), working (left) condyle (solid line) showed excessive lateral and rotational movements compared with the working condyle (dotted line) in the control group (B).

defined by displacement of the disc from its normal functional relationship with the mandibular condyle and the articular portion of the temporal bone.<sup>13</sup> The displacement of the articular disc does not cause mechanical obstruction<sup>14</sup> and may or may not be associated with pain, especially during function. Normal occlusion implies a stable relationship and mutual protection of the masticatory system during mandibular activity in addition to the relationship of the molars and canines based on Angle's classification. This occlusal relationship is functional and is ensured primarily by the correct static position of the condyle. It is essential to evaluate the occlusion in the static and dynamic states. Static occlusion refers to contact between the teeth when the jaw is closed and stationary, whereas dynamic occlusion refers to occlusal contacts in the functioning jaw. In other words, healthy occlusion refers to mutually protected occlusion in a dynamic state and occlusion without centric occlusion-centric relation discrepancy in the static state, when the condyle is in centric occlusion and centric relation. Because of the close relationship between the occlusal phase during masticatory movements and border movements of the mandible,15,16 emphasis is on lateral excursions in patients with internal derangements associated with the range of mandibular movement<sup>17,18</sup> and the condylar path.<sup>19</sup>

In a healthy condyle, the balancing condyle moves while the working condyle is involved only in rotation. Condylar movements facilitate the functional diagnosis

 Table 3.
 Comparison of the Speed of Balancing Condyle During

 Lateral Excursion Between the Two Groups<sup>a</sup>

	Control Group		
Speed, mm/sec	$\text{Mean}\pm\text{SD}$	$\text{Mean}\pm\text{SD}$	P Value
Eccentric path Returning path	$\begin{array}{r} 6.01\ \pm\ 3.43\\ 4.22\ \pm\ 1.55\end{array}$	$9.83 \pm 3.96$ $7.51 \pm 2.45$	.351 .023

<sup>a</sup> SD indicates standard deviation.

of the condyles.<sup>20</sup> However, the evaluation of condylar movement requires a recording system with six degrees of freedom,<sup>21,22</sup> and appropriate measurement tools were not reported until now. Previous studies only used an indirect method involving the range at the lower incisal point on the articulator. As condylar movement was estimated in terms of incisor movement, it was difficult to assess movement precisely on the working side, which is smaller than on the balancing side. In the present study, an ultrasonic recording device was used to record condylar movements on the working and balancing sides. The condylar movements were recorded in real time by sequentially transmitting ultrasound pulses between the four transmitters attached to the mandible and eight receivers mounted on the head.

Two types of condylar movement including toothguided and non-tooth-guided movement can be used to evaluate the condylar path. In non-tooth-guided movement, the incisal clutch was used, allowing the condyle to move in any direction regardless of the occlusion. On the other hand, a para-occlusal clutch was used for tooth-guided movement, which is affected by the occlusion. In the present study, the condylar path was recorded during tooth-guided movement. In the healthy condylar path, during lateral excursive movement, the working condyle shows mainly rotational movement and minimal laterotrusive movement (less than 1 mm).9 Evaluation of working side movement is critical for the management of TMD, particularly in pain control. The nonworking condyle showed a smooth gliding curved path and a small difference in inclination between the eccentric and returning paths.

When compared with the normal, healthy TMJ, a few different features were observed in patients with internal derangements.<sup>12</sup> In patients with internal derangements, the working condyle often showed excessive lateral and rotational movements. The starting position of the condylar movement often did

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not coincide with the ending position. The balancing condylar path may appear different at every measurement. In many cases, the velocity of the balancing condylar movement was uneven. Occasionally, a large difference was observed between the eccentric path and the returning path. In the present study, the 3D linear distances of the condylar path in the working condyle were greater in the group with internal derangement than in the control group during lateral excursion. The speed of the balancing condyle in the return path on lateral excursion was significantly greater in the group with internal derangement than in the control group. The possible reason for the differences between the two group might have been the difference in characteristics of the TMJ ligaments supporting the disc and condylar structures. Degenerative changes of the capsular ligament and discal ligament, such as loss of elasticity, may have caused excessive movement of the condyle and instability of the disc-condyle complex in the group with internal derangement. If patients experienced a state with reduction/without reduction, this may have led to hypermobility of the condyle to avoid premature contact or interference. Anatomic structures around the TMJ and individual occlusion can cause different condylar movements between the two groups. Yamasaki et al.19 and Saitoh et al.23 evaluated condylar movements during lateral excursions in children in the primary dentition, and they compared the movements with those of adults. They found that the balancing-side condyle of the children had a significantly smaller vertical excursion and a significantly larger anteroposterior excursion than that of adults, indicating the shallower and more anteriorly directed movements of the mandible during lateral excursions in children with primary dentition.

One of the limitations of this study was that the control group was not matched to have the same distribution of cephalometric patterns as the control group. Most of the TMD group (62%) was skeletally class II, whereas all of the control group was class I. In the present study, the control group was matched with the TMD group by sex, age, and number, whereas the cephalometric pattern was not considered. The aim was to compare condylar movements between two groups: one with TMD and one without. However, it would have been better if the two groups were also matched by including the same distribution of cephalometric measurements. There is still controversy concerning the association between class II malocclusion and TMD. However, according to the literature, TMD patients seem to have a higher prevalence of skeletal class II than the general population.<sup>24-29</sup> In addition, the clinical use of this computerized ultrasonic axiographic evaluation of condylar movement would be limited to those clinicians with the instrument in their office. The results of this study may encourage more clinicians to become interested in occlusion and TMJ.

# CONCLUSIONS

 Internal derangement of the TMJ may affect the working and balancing condylar movements during lateral excursion.

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