Mandibular lateral translation during symmetric mandibular movement

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Purpose: The purposes of this research were to investigate the mandibular lateral translation (Δ YMLT) during asymmetric mandibular movement and to clarify the relationship between the occurrence of Δ YMLT and temporomandibular joint (TMJ) status.

Materials and methods: Lateral deviation of the condyle during the mandibular functional movement of 1658 orthodontic patients was screened using computerized condylography. Maximum lateral deviation during opening/closing, mastication, and grinding movements were calculated.

Results: Occurrence of Δ YMLT in orthodontic patients was 26% and consisted of three types: Δ YMLT, over rotation MLT, and closed lock MLT. Occurring point of Δ YMLT in the condylar movement was in between 1 and 3.5 mm from reference position (RP). Maximum Δ YMLT tends to increase with age and Δ YMLT started at an early stage of growth and development. Subjects in the Δ YMLT group showed significantly more lateral deviation during mastication and bruxism than those in the non- Δ YMLT control group.

Conclusion: It is suggested that the Δ YMLT of the condyle occurs in the lower joint after disk displacement, and that the analysis of condylar tracking can be useful for early detection of dysfunction.

Keywords: Delta Y MLT, over rotation, closed lock, TMJ

Introduction

The importance of the study of mandibular movements has been described in the dental literature. These movements have been applied for occlusal reconstruction dominated by the temporomandibular joints (TMJ), with guidance mechanisms from teeth, and also for dynamic diagnosis regarding pathology of the craniomandibular system [1–3, 5, 9, 13, 14]. During lateral movements, the condyle on the working side moves laterally usually in a slightly upward direction. This movement, consisting mainly of a rotation around a vertical axis and a predominantly lateral translation, was originally

referred to as Bennett movement, and has been renamed mandibular lateral translation (MLT) [15]. The amplitude of this lateral translation is calculated to be approximately 0.5 mm [6]. Simultaneously, the balancing condyle slides medially and inferiorly on the distal aspect of the articular eminence. In addition, owing to the anatomy of the glenoid fossa and working direction of the muscle system, the laterotrusion movement creates a displacement in the vertical axis of the working condyle.

MLT phenomenon has been described in the pantographic studies of mandibular movements. It included immediate side shift (immediate MLT), early side shift (early MLT), distributed side shift (distributed MLT), and progressive side shift (progressive MLT). These MLT occur in asymmetric mandibular movement like laterotrusion. The physiological significance of MLT still remains to be clarified, although increasing MLT has been implicated in joint loosening and joint pathology [10, 14].

On the contrary, MLT during symmetric mandibular movements such as protrusion/retrusion or open/close movements associated with displacement of the articular disk was first described by Fushima et al. [4]. Clinical experience shows that there are quite a large number of patients with this phenomenon. To differentiate it from MLT in asymmetric mandibular movement, the MLT during symmetrical mandibular movement is referred to as delta Y MLT (Δ YMLT), because of the mandibular shift along the Yaxis in a coordinated 3D recording of the mandibular movement. Therefore, Δ YMLT can be defined as a mandibular translational lateral shift during symmetrical mandibular movement or symmetrical function.

This phenomenon suggested a close relation with condylar displacement accompanied by an articular disk displacement [4], thus indicating that Δ YMLT might be one of the signs for TMJ patho-physiology, although there is still not enough scientific evidence. During symmetric mandibular movement, there is no Δ YMLT in healthy non-symptomatic TMJ, although in asymmetric movement like laterotrusion, there is sometimes early progressive MLT, whereas the presence of immediate MLT remains questionable. Such early side shift in the balancing condyle is attributed to the translational condylar movement in lower joint space.

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When the mandible starts moving from an already displaced position with deranged disk-condyle assembly, it is possible to record $\Delta YMLT$ at the position in which re-establishment or normalization of disk-condyle relation in the lower joint during symmetric mandibular movement occurs. During clinical instrumental analysis using condylograph, $\Delta YMLT$ is a frequently encountered feature in the functional diagnosis, even in young growing orthodontic patients. These clinical experiences and observations led us to seek answers to basic questions such as whether the $\Delta YMLT$ can be considered as an indicator for the early stage of disk-condyle derangement, whether the $\Delta YMLT$ increases along with age, and whether the $\Delta YMLT$ might influence functional movements such as mastication and bruxism.

Therefore, the purposes of this investigation were: 1) to investigate the phenomenon of $\Delta YMLT$ during symmetric mandibular movement, 2) to examine the occurrence of $\Delta YMLT$ in different age groups, and 3) to clarify the relationship between the $\Delta YMLT$ in both asymmetric and symmetric functions.

Materials and methods

Subjects

One thousand six hundred and fifty-eight patients who visited the orthodontic clinic of Kanagawa Dental College were screened based on condylographic tracings for occurrence of

MLT during mediotrusion (asymmetric function) and opening/closing (symmetric function) movements.

On the basis of the condylographic tracing, we selected 168 subjects who showed $\Delta YMLT$ during open/close movement for further examination. The sample consisted of 63 males and 105 females with a mean age of 23.6 ± 12.4 years. In order to compare it with asymmetric dynamic functions (mastication, bruxism, and laterotrusion movement), 30 subjects who did not show $\Delta YMLT$ with fairly healthy TMJ were selected as control group.

Diagnostic condylography

Three-dimensional condylar paths of the patients were recorded during functional movements of the mandible and analyzed with a computerized condylography (Cadiax) system, which consisted of a cranial attachment and a mandibular face bow. A functional clutch was fixed to the labial surface of the lower dentition, and mandibular movements were confirmed to be free of any interference. The mandibular face bow was then connected to the clutch. Two-dimensional condylar movement in the sagittal plane was recorded on digitizers, which were attached to the cranial face-bow and placed over the TMJ region bilaterally.

Lateral deviation of the condyle in the mandibular functional movement was detected by the stylus attached

Fig. 1: Different types of MLT visualized condylographic tracing during opening/closing movements. (A) MLT with severely limited condylar movement (closed lock ΔY), (B) MLT with excessive condylar rotation in maximum opening position (over rotation ΔY), and (C) MLT without limitation and over rotation ($\Delta YMLT$) occurred in relatively close position to the reference position (RP)

Fig. 2: Measurement of MLTs using condylographic tracings during different functional movements

to the mandibular face-bow. After positioning the stylus on the hinge axis, condylar movements in both TMJ were recorded three-dimensionally from a reference position (RP) [12] established by using unforced chin point guidance.

To investigate the $\Delta YMLT$ of the condyle during opening, the condylar paths in the transversal plane were observed on the condylographic tracing. As shown in Fig. 1, there were different types of $\Delta YMLT$ which indicated medial (inward) and lateral (outward) deviation.

Classification of $\Delta YMLT$

The $\Delta YMLT$ was seen in different conditions of mandibular functional movement, which was evaluated by condylographic axis movement. It could be classified into three groups as follows (Fig. 1):

- 1) MLT with limitation (closed lock ΔY) which showed lateral translation with severely limited condylar movement during open/close movement.
- 2) MLT with over rotation (over rotation ΔY) which showed lateral translation with excessive condylar rotation in maximum opening position.
- 3) MLT without limitation and over rotation which showed lateral translation ($\Delta YMLT$) occurred in relatively close position to the reference.

Measurements of $\Delta YMLT$

In order to characterize the $\Delta YMLT$, the axis movement during opening and closing movement was analyzed based on the occurrence and magnitude of $\Delta YMLT$. The $\Delta YMLT$ with closed lock and $\Delta YMLT$ with over rotation were omitted from the measurement for further study, because their inclusion caused bias. Measurements of $\Delta YMLT$ were carried out based on the following criteria (Fig. 2):

- 1) Opening $\Delta YMLT$: starting point of lateral translation during opening condylar movement on the X and Z axis coordinates.
- 2) Closing $\Delta YMLT$: end point of lateral translation (right before starting closing $\Delta YMLT$) during closing condylar movement on the X, Y, and Z coordinates.

Tab. 1: Frequency of MLT in orthodontic patients

	Number of subjects	(%)
Total sample	1658	100
Without MLT	1217	73.4
With MLT	441	26.6
MLT group	441	
$\Delta YMLT$	168	10.1
Over rotation MLT	162	9.8
Closed Lock MLT	111	6.7

Tab. 2: Comparison of Δ YMLT values in different age groups

	Opening Δ YMLT point		Closing Δ YMLT point			Δ YMLT maximum
	X-axis	Z-axis	X-axis	Y-axis	Z-axis	
Before 10 ($n=20$) (Age, 8.1 ± 1.5)	1.51 ± 1.23	1.94 ± 1.57	0.96 ± 0.60	0.52 ± 0.23	1.67 ± 1.16	0.74 ± 0.29
11–20 ($n=108$) (Age, 16.0 ± 3.2)	1.77 ± 1.49	2.67 ± 2.09	1.55 ± 1.27	0.75 ± 0.55	2.96 ± 1.91	1.04 ± 0.69
21–30 ($n=116$) (Age, 25.3 ± 2.8)	1.91 ± 1.63	2.90 ± 2.23	1.83 ± 1.51	0.68 ± 0.36	3.15 ± 2.20	1.02 ± 0.59
31–40 ($n=21$) (Age, 34.9 ± 3.6)	3.16 ± 2.17	3.62 ± 1.50	2.67 ± 2.01	0.91 ± 1.21	3.49 ± 2.22	0.96 ± 0.45
Over 40 ($n=26$) (Age, 47.4 ± 6.4)	1.63 ± 1.06	1.97 ± 1.58	1.79 ± 1.27	0.88 ± 0.37	1.98 ± 1.24	1.20 ± 0.39

Tab. 3: Comparison of Δ YMLT values in young and adult subjects

	Opening Δ YMLT point		Closing Δ YMLT point			Δ YMLT maximum
	X-axis	Z-axis	X-axis	Y-axis	Z-axis	
Young (5–15 y)						
Right	1.84 ± 1.87	2.75 ± 2.14	2.02 ± 2.16	0.63 ± 0.37	2.94 ± 2.13	0.84 ± 0.36
Left	1.94 ± 1.77	2.56 ± 1.94	1.96 ± 2.02	0.60 ± 0.32	2.44 ± 1.95	0.79 ± 0.31
Adult (30–50 y)						
Right	2.07 ± 1.48	2.50 ± 1.67	2.14 ± 1.55	0.98 ± 1.17	2.58 ± 1.73	$1.08 \pm 0.44^*$
Left	2.59 ± 2.11	2.95 ± 1.82	2.24 ± 1.86	0.76 ± 0.32	2.77 ± 2.09	$1.11 \pm 0.43^*$

* Significantly different from young group at $P < 0.05$ level

- 3) Maximum Δ YMLT: measurement of the Y axis distance at the maximum point of lateral translation.
- 4) Lateral translation (Bennett): measurement of the Y axis distance in lateral translation of the working condyle during laterotrusion movement.
- 5) Angle of lateral translation (Bennett angle): measurement of the angle formed between the incisive movement ($S = 5$ mm) during laterotrusion of the balancing condyle and X axis.
- 6) Mastication MLT: measurement of the Y axis distance in lateral translation of the condyle during mastication movement.
- 7) Bruxism MLT: measurement of the Y axis distance in lateral translation of the condyle during simulated bruxism movement.

Magnetic Resonance Imaging (MRI)

In some cases, bilateral MRI was performed to diagnose the disk displacement patterns. MRI was performed utilizing the 0.5-T MRI system (RESONA; GE) with an 8-cm-diameter surface coil. T1-weighted multi-sliced images of spin echo (TR: 1000 ms; TE: 25 ms; NEX: 2; FOV: 15 cm; matrix: 160×224) were obtained in the sagittal plane both in the intercusp position (ICP) and in the maximum opening position of the mandible. In addition to the sagittal aspect, TMJ in ICP was also imaged in the coronal plane. Multi-slices were taken in 4-mm sections at 1-mm intervals. The slices were oriented perpendicular to the long axis of the condyle for sagittal images and parallel to the axis for coronal images.

The sagittal images were used to determine the antero-posterior position of the disk in the lateral, central and medial slices. The coronal images were used to determine latero-medial disk displacement. Disk displacement patterns were assessed according to the criteria described previously [4]. Disk displacement patterns were classified into 5 types: complete anterior displacement, antero-lateral displacement, antero-medial displacement, medial sideways displacement, and lateral sideways displacement.

Statistical analysis

Statistical analyses were performed with the SPSS program for Windows (SPSS for Windows, SPSS Japan, Tokyo, Japan). The

Tab. 4: Occurrence of Δ YMLT during asymmetric function

	No- Δ YMLT Control ($n=66$ side) mean SD	Δ YMLT Group ($n=336$ side) mean SD
Bruxism MLT (mm)	0.18 ± 0.16	$0.72 \pm 0.68^*$
Mastication MLT (mm)	0.67 ± 0.37	$1.59 \pm 0.83^*$
Bennett movement (mm)	0.36 ± 0.33	$0.74 \pm 0.61^*$
Bennett angle (degree)	4.33 ± 3.89	$9.16 \pm 7.59^*$

* Significantly different from No- Δ YMLT Control group at $P < 0.05$ level

Fig. 3: TMJ-MRI of Case 1 (12 years old). Sagittal slices (1, 2, and 3) of right TMJ showed anterior disk displacement without reduction. Left TMJ did not show clear anterior disk displacement in the lateral (1) and central (2) slices, while opening showed reduction of disk

Student's t-test was performed and the significance level was determined at $P < 0.05$.

Results

Frequency of Δ YMLT in orthodontic patients

One hundred and sixty-eight (168) patients of a total sample of 1658 (10.1%) showed Δ YMLT during opening and closing mandibular movement. The Δ YMLT with closed lock or over rotation were 6.7% and 9.8%, respectively (Tab. 1). Thus, in this study, 26.6% of the patients showed evidence of Δ YMLT shift phenomenon of the condyle during open/close symmetrical mandibular function. The Δ YMLT in opening and closing movements occurred in the range of 1.0–3.5 mm forward from RP position in any direction of x , y , and z (Tab. 2).

Comparison of Δ YMLT occurrence in different age groups

There was a tendency that side shift points of Δ YMLT on the X , Y and Z axis increased with age, while the values of the over 40 years old group decreased (Tab. 2). This increasing tendency of side shift points of Δ YMLT with age suggested progressive changing of the relation of the disk-condyle assembly. Maximum ΔY value also tended to increase.

Results from the independent comparison of young (5–15 y) group and adult (30–50 y) group also showed an increasing tendency for occurring points of Δ YMLT (Tab. 3). The maximum Δ YMLT value in the adult group was significantly larger in comparison with the young group.

Relation of Δ YMLT and MLT in mastication and bruxism

We compared the MLT during mastication and bruxism with the non- Δ YMLT control group (Tab. 4). Results showed that mastication MLT and bruxism MLT in the Δ YMLT group were significantly higher than in the non- Δ YMLT control group.

Bennett movement in the working side of the condyle and Bennett angle in the non-working side for the Δ YCLT group were also significantly increased compared with those of the non- Δ YMLT control group.

MRI and condylographic findings of Δ YMLT in young patients

In some cases, MRI was available to evaluate the relationship between the Δ YMLT and the TMJ condition. In case 1 (12 years old), different sagittal MRI slices indicated anterior disk displacement without reduction during opening position in the right TMJ and no anterior disk displacement with reduction in the left TMJ (Fig. 3). Coronal images of MRI showed antero-medial disk displacement in the right TMJ and medial sideways displacement in the left TMJ (Fig. 4).

Fig. 4: Coronal image of TMJ-MRI of Case 1 (12 years old). Right and left TMJ showed medially displaced articular disks. Together with a sagittal image (Fig. 2), it was diagnosed that right TMJ showed antero-medial disk displacement without reduction and left TMJ showed medial disk displacement with reduction

Fig. 5: Condylographic tracing of Case 1 (12 years old). Opening and closing movement represented $\Delta YMLT$ to the right side with limited movement in the right TMJ and non-limitation in left TMJ. The tracing suggested that the $\Delta YMLT$ follows the displaced disk on the side of TMJ with reducible disk

Fig. 6: TMJ-MRI of Case 2 (13 years old). Sagittal lateral slice (1) of the right TMJ showed anterior disk displacement, while central (2) and medial (3) slices did not show disk displacement. Left TMJ did not show clear anterior disk displacement in lateral (1) and central (2) slices, while medial slice (3) showed anterior disk displacement. Both TMJ exhibited with disk reduction in opening position

Condylographic tracing showed limited movement with steep SCI in the right TMJ and non-limited movement in the left TMJ. Both condyles exhibited $\Delta YMLT$ to the right side (Fig. 5).

Case 2 (13 years old) showed that anterior disk displacement was identified only in central and lateral slices of the sagittal images and lateral sideways displacement was sug-

gested in the coronal image of the right TMJ, indicating an anterior and lateral sideways disk displacement (Fig. 6). On the contrary, in the left TMJ, anterior disk displacement could be seen in the medial slice of the MRI, but not in the lateral slice. Medial sideways displacement of the disk was obvious in the coronal image of the MRI (Fig. 7). Therefore, this case was diagnosed as antero-lateral disk displacement on the right

Fig. 7: Coronal image of TMJ-MRI of Case 2 (13 years old). Right TMJ showed laterally displaced articular disks. Left TMJ showed a medially displaced disk. Together with the sagittal image (Fig. 5), it was diagnosed that the right TMJ showed antero-lateral disk displacement with reduction and left TMJ showed antero-medial disk displacement with reduction

TMJ and medial sideways displacement on left TMJ side. Both TMJs were reducible disk displacement. Condylographic tracing of open/close movement showed that the condyle moved slowly to the right side by approximately 1 mm, which suggested the occurrence of re-arrangement disk-condyle assembly in order to reduce the disk (Fig. 8).

These cases indicated that the directions of $\Delta YMLT$ and disk displacement were closely related to each other, that is, the $\Delta YMLT$ is one of the important indicators for detecting condylar displacement concomitant with disk derangement.

Discussion

The present study showed the occurrence of $\Delta YMLT$ in different age groups of the patients, influences of $\Delta YMLT$ on

the functional movements of the mandible such as mastication and bruxism, and several $\Delta YMLT$ aspects related to MRI findings. For those purposes, 1658 condylographic tracings from the patients were examined for the occurrence of MLT. Twenty-six percent of these patients showed MLT of three types: $\Delta YMLT$, over rotation MLT, and closed lock MLT; this indicated a relatively high MLT prevalence. The $\Delta YMLT$ were further analyzed in order to know in detail the physiological significance of mandibular translation during symmetrical movement. Side shift point of $\Delta YMLT$ in the condylar border movement was in between 1 and 3.5 mm from reference position (RP), which denoted a tendency for the distance between the RP and $\Delta YMLT$ position to increase with age, although the group of over 40 years old showed decrease in the distance. Maximum $\Delta YMLT$ also had a tendency to increase with age. These results indicated that the lower joint mobility or loosening progressed with age, speculating that tightness of the condylar-disk assembly slowly changed with age due to mandibular lateral shift. Previous research conducted by Fushima et al. [4] demonstrated that the type of condylar lateral translation during opening was related to the displacement pattern of the disk assessed by magnetic resonance imaging (MRI). Taken together with the present results, it can be assumed that the predictable phenomenon of $\Delta YMLT$ is a useful diagnostic indicator for disunion of the proper engagement of the condyle-disk assembly.

One of the striking findings in the present study was that $\Delta YMLT$ started at an early stage of growth and development, under 10 years old. Generally, a healthy TMJ with tight condylar-disk assembly does not show MLT, even if such a joint showed early MLT in asymmetric movement like laterotrusion. Whether this phenomenon in young subjects is due to TMJ loosening during the growing stage or to early expression of dysfunction with mandibular displacement is still not known. However, some young subjects showed disk displacement in the MRI study and close relation between the patterns of disk displacement direction and occurrence of $\Delta YMLT$; this

Fig. 8: Condylographic tracing of Case 2 (13 years old). Opening and closing movement represented $\Delta YMLT$ to the right side. During closing movement, closing $\Delta YMLT$ occurred at an approximately 1-mm forward position from RP. The tracing suggested that the $\Delta YMLT$ indicates the latero-medial therapeutic position of the mandible right before closing $\Delta YMLT$ point

suggested the transversal mandibular displacement accompanied by condyle and disk displacement. Cases presented here showed a tendency for limitation of movements on the condylographic tracing, suggesting the formation of lock joint prospectively. Since a transversal condylar lateral shift may change the inter-relationship between lateral pole and lateral ligament, it causes condylar closed lock during opening movement due to stretching of the lateral ligament in condylar rotational movement. Therefore, it can be elucidated that the Δ YMLT is one of the ways to relieve the situation of ligamentous lock of the condyle. On the basis of these findings, the phenomenon of Δ YMLT should be incorporated into the diagnosis of malocclusion as an early indicator of functional disturbances.

Another important aspect was the mandibular deviation during mastication and bruxism movements in comparison with the non- Δ YMLT control and the Δ YMLT groups. The Δ YMLT group showed significantly more lateral deviation during mastication and bruxism than those in the non- Δ YMLT control group. The Δ YMLT group also showed increased Bennett movement and Bennett angle in asymmetric laterotrusion movement. These findings suggested that the Δ YMLT can be used not only as an indicator of joint loosening, but also as an indicator for repositioning of displaced condyles. Fushima et al. [11] also suggested that the medio-lateral therapeutic position of the displaced condyle can be predicted based on MLT.

Lundeen and Gibbs [7] mentioned that the patients with more Bennett movement were the most difficult cases when trying to reduce posterior cusp interferences. The study of condylar movements during chewing has concluded that a mechanism that can coordinate the medial movement of the working condyle, with the upward, rearward lateral path of the non-working condyle and with the medial, upward path of the central incisor, could complete the functional programming articulator for reconstruction.

In contemporary dentistry, jaw tracking instruments are extensively used for differential diagnosis of craniomandibular disorders [4, 8, 11], although it is still necessary to clarify whether certain behaviors of condylar movement are related to a particular pathology of the TMJ. In this study, we used a computerized diagnostic condylograph in order to apply the condylar tracking path on the diagnosis of craniomandibular system. The importance of the condylograph in diagnosis regarding the physiology as well as the physio-pathology of the TMJ is due to its accuracy and capability to assess 3 dimensional dynamic movement of the condyle.

The phenomenon of Δ YMLT during symmetrical mandibular movement is one of the interesting functional behaviors of the masticatory organ, although it has been neglected in functional diagnosis in dentistry. Even though further research is needed to clarify more details, it was suggested that the lateral translation of the condyle occurs in the lower joint when the lower joint is loosened with disk displacement,

and that the analysis of condylar tracking is probably useful for early detection of dysfunction.

Take-home message

The phenomenon of Δ YMLT during symmetrical mandibular movement is one of the interesting behaviors of TMJ; this indicates functional status of the disk-condyle assembly, although it has been neglected in functional diagnoses in dentistry.

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