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<Original Article>

Effect of Anterior Guidance Change on the Condylar Path in Skeletal Class I Young Adult Women Using a Splint with Flat or Steep Anterior Guidance

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• Abstract

Purpose: To investigate the effects of anterior guidance (AG) change on the working (WCP) and non-working condylar paths (NWCP), and lower incisor path (LIP) using a splint with flat (FAG) or steep AG (SAG).
Materials and Methods: The samples consisted of six young adult women (mean age=23.5±3.3 years). Inclusion criteria were skeletal Class I and normodivergent pattern, normal overbite/overjet, minimal slide from retruded cuspal position to intercuspal position, no temporomandibular disorder signs and symptoms, mutually protected occlusion, and minimal tooth wear. After the values of natural AG (NAG) were obtained as a reference for each patient, two types of splints (15° flatter and steeper than NAG) were made. After insertion of the splints with FAG or SAG, the WCP, NWCP, and LIP were recorded five times for each patient using an ultrasonic AQR (SAM, Munich, Germany) and statistical analysis was subsequently performed.
Result: NAG exhibited postero-superior movement in the WCP and did not show a noticeable immediate side shift (ISS) or difference between the eccentric (EP) and returning paths (RP) in the NWCP. FAG was associated with an irregular and excessive WCP, an increase in ISS, and a difference between EP and RP in the NWCP. SAG showed minimal WCP movement and a decrease in the extent of difference between EP and RP in the NWCP. LIP showed significant differences in EP and in RP ($P<0.001$, all; FAG<NAG<SAG).
Conclusion: Since AG change can affect the WCP, NWCP, and LIP, it is necessary to establish proper AG during orthodontic treatment.

• Key words : Condylar path, Flat anterior guidance, Lower incisor path, Natural anterior guidance, Splints, Steep anterior guidance

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Introduction

The recent trend of an increasing proportion of adult orthodontic patients has led to an increased number of patients presenting with signs and symptoms of temporomandibular disorder (TMD)[1]. Although the evidence has not shown that static occlusal factors cause TMD[2,3], skeletal anterior open bite, overjet greater than 6 to 7 mm, slides greater than 4 mm from the retruded cuspal position (RCP) to the intercuspal position (ICP), unilateral posterior crossbite, five or more missing posterior teeth, and defects in the anterior guidance, occlusal curvature, and vertical dimension are malocclusion factors that have been considered to be related with TMD[1,4-7].

In several previous studies on the relationship between the anterior guidance (incisal and canine guidance) and the condylar path, Gray[8] proclaimed that both anterior guidance and posterior support contribute significantly to the comfortable functioning of the masticatory system. Hobo and Takayama[9] suggested that if the canine guidance was not consistent with the working condylar path, there would be sagittal displacement of the working path to compensate for the lack of harmony. Lotzmann et al.[10] theorized that establishment of an idealized, symmetrical anterior guidance could lessen the mandibular deviation and harmonize the tooth-guided and non-guided paths. In addition, Nishigawa et al.[11] reported that altered occlusal guidance reproducibly and reversibly increased the lateral border movement area in two subjects who had unilaterally restricted lateral border movements. Hobo[12] and Ogawa et al.[13] found that the anterior guidance was related to the amount and direction of the condylar movement on the working side.

The main purposes of the splint therapy are to stabilize the mandible and to help the patient develop a desirable condylar path by establishing new anterior guidance[14]. Additionally, the splint can be used as a simulation tool to measure the change of anterior guidance compared to the natural anterior guidance. However, to the authors' knowledge, there have been only a few studies with regard to change in the three-dimensional (3D) position and movement path of the condyle due to adjustment of the anterior guidance with a splint. Therefore, the purpose of this study was to investigate the effects of anterior guidance change on the condylar path, lower incisor path, and 3D position of the condyle using splints with flat anterior guidance or steep anterior guidance. The null hypothesis was that there was no difference in the working and non-working condylar paths, lower incisor path, and 3D position of the condyle between flat anterior guidance and steep anterior guidance.

Materials and Methods

The samples consisted of six young adult women (mean age=23.5±3.3 years). Inclusion criteria were as follows: young female adult (between 18 and 30 years of age), Class I skeletal pattern (0°<ANB<4°), normodivergent pattern (24°<FMA<30°), normal inclination of the maxillary and mandibular incisors (105°<U1-FH<115°, 90°<IMPA<95°, respectively), normal overbite/overjet (more than 2.0 mm, less than 3.5 mm, respectively), minimal slide from the RCP to the ICP (less than 0.5 mm), no TMD signs and symptoms, mutually protected occlusion, and minimal tooth

Table 1. Natural incisal and canine guidance of each patient

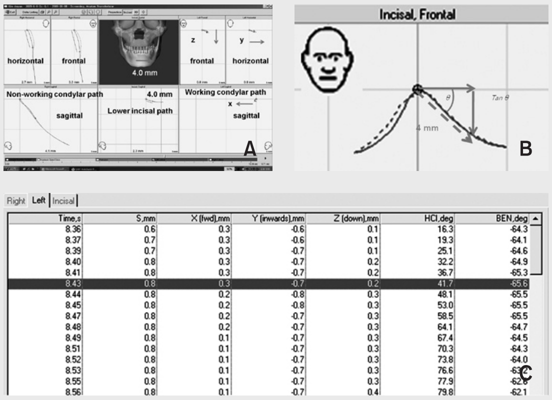
Patient	Natural incisal guidance (protrusive movement)	Natural canine guidance (lateral excursive movement)			Comparison of the natural incisal and canine guidance (P-value)
		Right side	Left side	Comparison of the natural right and left canine guidance (P-value)	
1	49°	48°	45°	0.2850	0.0273*
2	47°	45°	45°		
3	45°	40°	40°		
4	49°	50°	46°		
5	48°	45°	46°		
6	54°	50°	50°		
Mean±SD	48.67°±3.01°	46.33°±3.83°	45.33°±3.20°	-	-

The Man-Whitney test was performed. *P<0.05.

wear. The skeletodental patterns of the sample were as follows: ANB, 2.6º±1.1º; FMA, 26.8º±2.4º; U1-FH, 110.2º±2.9º; IMPA, 93.0º±1.8º; overbite, 3.2 mm±0.3 mm; overjet, 3.1 mm±0.2 mm.

After the values of natural anterior guidance (incisal and canine guidance) of each patient were obtained as a reference (Table 1), two types of splints (one 15º flatter and one 15º steeper than natural incisal and canine guidance) were made for each patient on a SAM3 articulator (SAM, Munich, Germany) (Fig. 1). The splint with flat anterior guidance was made with transparent resin and the splint with steep anterior guidance was made with pink and transparent resin mixture for easy identification. Each splint was 2-mm-thick at the most posterior tooth.

After these splints with flat anterior guidance and steep anterior guidance were inserted into the mouth of each patient and ten minutes had elapsed for muscle deprogramming, the condylar path (working and non-working sides), the lower incisor path, and the 3D position of the working condyle were recorded five times for each patient using an ultrasonic AxioQuick Recorder (AQR) with paraocclusal clutch (SAM) (Fig. 2). These devices enable us to track the condylar path and lower incisor path on the computer monitor without interfering with the tooth-guided movement. Since the tooth contact range does not exceed 4 mm during mastication, all measurements were recorded within a 4 mm-range of tooth contact using these three types of canine guidance. This research was conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki. After Shapiro-Wilk normality test, one-way analysis of variance (ANOVA) with Scheffe's multiple comparison tests and paired t-test were performed for statistical analysis.



Time,s	S,mm	X (fwd),mm	Y (inwards),mm	Z (down),mm	HCI,deg	BEN,deg
8.36	0.6	0.3	-0.6	0.1	16.3	-64.3
8.37	0.7	0.3	-0.6	0.1	19.3	-64.1
8.39	0.7	0.3	-0.7	0.1	25.1	-64.6
8.40	0.8	0.3	-0.7	0.2	32.2	-64.9
8.41	0.8	0.3	-0.7	0.2	36.7	-65.3
8.43	0.8	0.3	-0.7	0.2	41.7	-65.6
8.44	0.8	0.2	-0.8	0.3	48.1	-65.5
8.45	0.8	0.2	-0.8	0.3	53.0	-65.5
8.47	0.8	0.2	-0.7	0.3	58.5	-65.5
8.48	0.8	0.2	-0.7	0.3	64.1	-64.7
8.49	0.8	0.1	-0.7	0.3	67.4	-64.5
8.51	0.8	0.1	-0.7	0.3	70.3	-64.3
8.52	0.8	0.1	-0.7	0.3	73.8	-64.0
8.53	0.8	0.1	-0.7	0.3	76.6	-63.2
8.55	0.8	0.1	-0.7	0.3	77.9	-62.6
8.56	0.8	0.1	-0.7	0.4	79.8	-62.1

Figure 2. (A) The left graph is the right non-working condylar path, and the right graph is the left working condylar path, (B) The lower incisor path, (C) The working condylar path was measured in the three-dimensional planes. X-axis: the sagittal axis, Y-axis: the transverse axis, Z-axis: the vertical axis.

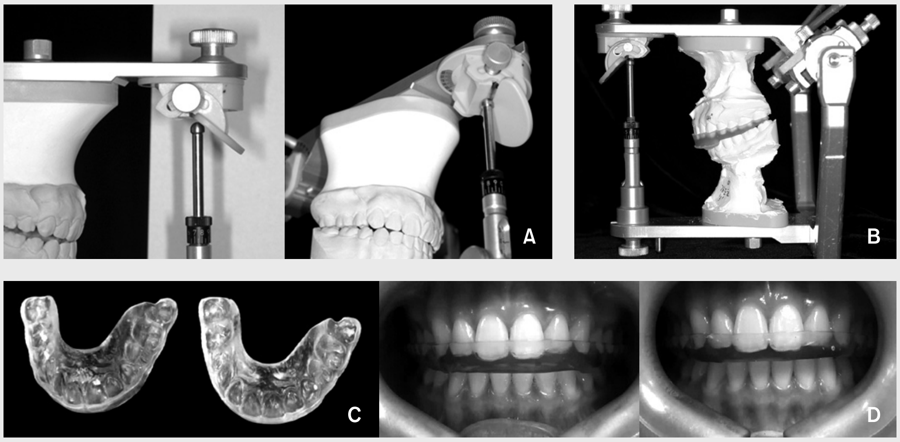


Figure 1. (A) Adjustment of the incisal table of the SAM3 articulator (SAM, Munich, Germany) to obtain the values of natural incisal and canine guidance, (B) Fabrication of the splint with steep and flat anterior guidance, (C) The splint with steep (left, pink and transparent resin mixture) and flat anterior guidance (right, transparent resin), (D) Insertion of the splint with steep (left) and flat anterior guidance (right) in each patient.

Result

The working condylar path in the natural canine guidance appeared to move to the postero-superior direction slightly. However, the flat canine guidance showed an irregular and excessive working condylar path while the steep canine guidance produced minimal working condylar movement compared to the natural canine guidance (Fig. 3).

In the non-working condylar path, the natural canine guidance did not yield a noticeable immediate side shift or a difference between the eccentric and returning paths. However, the flat canine guidance resulted in an increase in the immediate side shift and a difference between the eccentric and returning paths. The steep canine guidance caused a decrease in the range of motion and in the extent of difference between the eccentric and returning paths (Fig. 4).

The values of right and left canine guidance measured on the mounted cast (right side, 45.3°; left side, 46.3°; Table 1) were similar to the values of the lower right and left incisor paths measured on AQR (right side, 45.6°; left side, 47.5°; Table 2). The lower incisal path did not differ significantly between the eccentric and returning paths in the natural, flat, or steep anterior guidance (all P>0.05; Table 2).

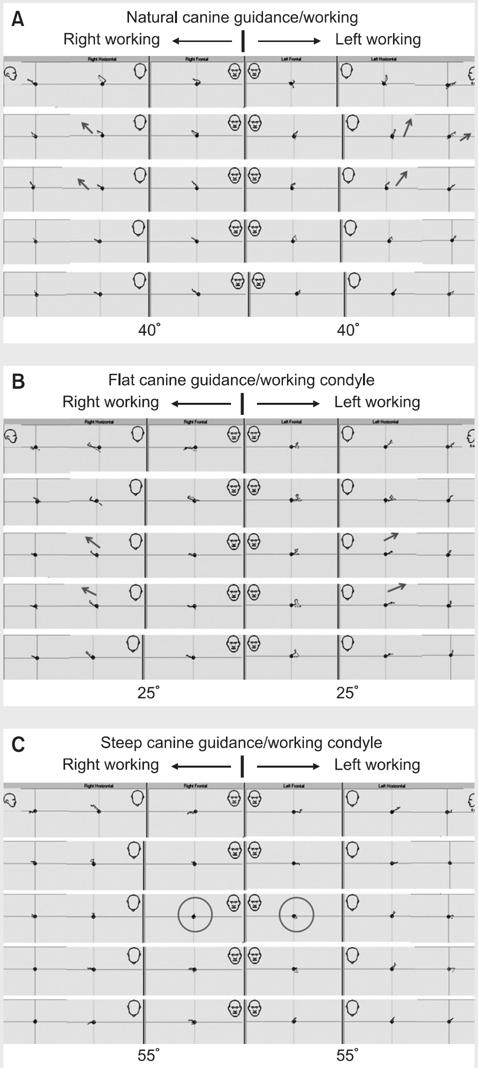


Figure 3. The working condylar path. (A) Natural canine guidance, (B) Flat canine guidance, (C) Steep canine guidance. The arrows indicate the direction and amount of movement.

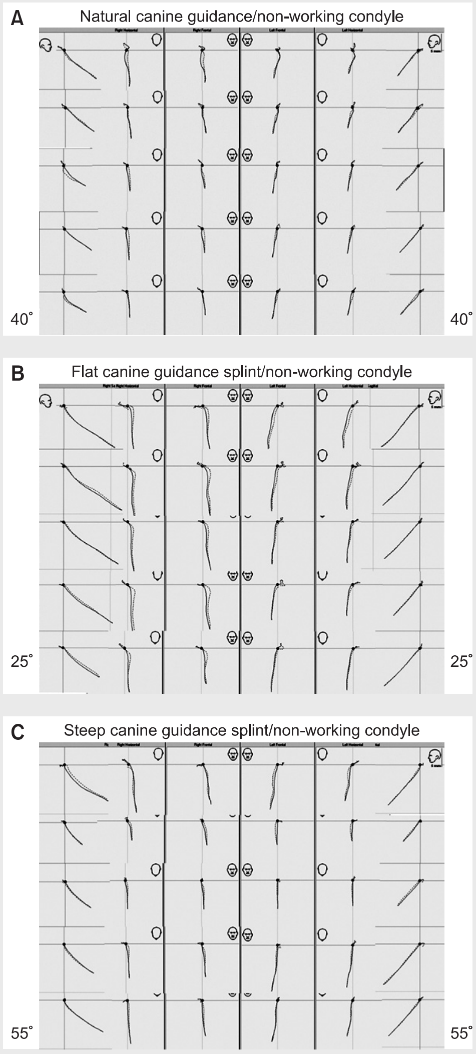


Figure 4. The non-working condylar path. (A) Natural canine guidance, (B) Flat canine guidance, (C) Steep canine guidance.

However, the lower incisor paths showed significant differences in the eccentric path and in the returning path among the three sets of anterior guidance (all P<0.001; flat anterior guidance<natural anterior guidance<steep anterior guidance; Table 3).

In terms of the 3D-coordinates of the working condyle position measured within a 4 mm lateral excursion, statistically significant differences were not found among the natural, flat, and steep canine guidance except for in the z-axis of the returning path of the right working condyle (P<0.05, flat anterior guidance<[natural anterior guidance, steep anterior guidance]; Table 2).

Since a positive or negative value indicates the direction of movement of the working condyle in the 3D-coordinates, it is necessary to confine the absolute values of the working condyle movement to determine the absolute change of the working condyle movement. However, the absolute values of the working condylar movement were not significantly different among the three groups except for in the z-axis of the returning path of the left working condyle (P<0.01, [flat anterior guidance, steep anterior guidance]<natural anterior guidance; Table 4).

Among the three types of canine guidance, the steep one seemed to produce minimal working condylar movement and the flat one showed relatively excessive and irregular working condylar movement (Fig. 5A). In the non-working side, when the canine guidance was flat, there was a tendency for the non-working condylar path to become over-extended. The reverse phenomenon was seen when the canine guidance was steep (Fig. 5B). Within the 4 mm-range of tooth contact, irrespective of the steepness of the canine guidance, the working condylar paths did not show significant differences in direction and distance.

In the non-working side, differences between the eccentric and returning paths in the frontal view appeared to be the largest when the canine guidance was flat. Immediate side shift also increased with the flat splint (Fig. 6A). When comparing the eccentric and returning paths in the sagittal view of the non-working sides, the returning angles were flatter than the eccentric angles in most cases (Fig. 6B).

The definition of a case with favorable working and non-working condylar paths can be determined based on the

Table 2. Comparison of the three-dimensional position of the working condyle in the eccentric and returning paths among the three groups

Working		Natural			Flat			Steep			P-value[a]		Multiple comparison	
		Eccentric	Returning	P-value[b]	Eccentric	Returning	P-value[b]	Eccentric	Returning	P-value[b]	Eccentric	Returning	Eccentric	Returning
Left side (mm)	x	-0.02±0.24	-0.07±0.24	0.7406	-0.10±0.10	-0.01±0.23	0.3716	-0.02±0.20	0.08±0.40	0.4241	0.7172	0.8490	-	-
	y	-0.10±0.22	-0.16±0.16	0.2463	-0.18±0.24	-0.22±0.33	0.6718	-0.11±0.21	-0.01±0.26	0.2640	0.8267	0.3118	-	-
	z	-0.24±0.22	-0.19±0.18	0.6756	0.17±0.14	-0.06±0.12	0.0793	-0.10±0.12	-0.09±0.13	0.8437	0.3712	0.6461	-	-
Right side (mm)	x	0.01±0.23	-0.03±0.19	0.7461	-0.06±0.17	0.07±0.27	0.2184	0.01±0.31	0.07±0.40	0.4725	0.8327	0.7878	-	-
	y	-0.24±0.25	-0.28±0.21	0.3239	-0.27±0.22	-0.29±0.28	0.7654	-0.18±0.16	-0.07±0.20	0.2257	0.5832	0.2196	-	-
	z	-0.17±0.32	-0.25±0.18	0.5405	-0.06±0.20	0.08±0.22	0.0763	0.03±0.24	-0.02±0.11	0.4196	0.2205	0.0182*	-	(1,3)<(3,2)

x-axis: the sagittal axis, y-axis: the transverse axis, z-axis: the vertical axis.
1: natural anterior guidance, 2: flat anterior guidance, 3: steep anterior guidance.
[a]One-way ANOVA test with Scheffe's multiple comparison test were performed, [b]Paired t-test was performed. *P<0.05.

Table 3. Comparison of the lower incisal path in the eccentric and returning paths among the three groups

Lower incisal path	Natural anterior guidance			Flat anterior guidance			Steep anterior guidance			P-value[a]		Multiple comparison	
	Eccentric	Returning	P-value[b]	Eccentric	Returning	P-value[b]	Eccentric	Returning	P-value[b]	Eccentric	Returning	Eccentric	Returning
left side (°)	45.63±5.60	45.30±5.37	0.1082	29.68±5.56	28.90±5.45	0.1447	53.46±1.74	52.88±2.32	0.1823	0.0000**	0.0000**	2<1<3	2<1<3
right side (°)	47.52±6.67	47.10±6.74	0.3457	36.75±4.60	36.60±4.92	0.5948	58.25±5.73	57.72±6.02	0.1224	0.0000**	0.0001**	2<1<3	2<1<3
P-value[b]	0.4842	0.4920	-	0.0196*	0.0160*	-	0.0668	0.0668	-				

1: natural anterior guidance, 2: flat anterior guidance, 3: steep anterior guidance.
[a]One-way ANOVA test with Scheffe's multiple comparison test were performed, [b]Paired t-test was performed. *P<0.05, **P<0.001.

Table 4. Comparison of the absolute values in the three-dimensional position of the working condyle in the eccentric and returning paths among the three groups

Working		Natural			Flat			Steep			P-value[a]		Multiple comparison	
		Eccentric	Returning	P-value[b]	Eccentric	Returning	P-value[b]	Eccentric	Returning	P-value[b]	Eccentric	Returning	Eccentric	Returning
Left side (mm)	x	0.18±0.14	0.17±0.14	0.9009	0.10±0.10	0.18±0.13	0.2943	0.17±0.09	0.24±0.32	0.4837	0.4333	0.8204	-	-
	y	0.20±0.11	0.31±0.13	0.1271	0.26±0.12	0.33±0.20	0.4864	0.18±0.15	0.18±0.17	1.0000	0.5674	0.2730	-	-
	z	0.26±0.19	0.32±0.14	0.5334	0.20±0.09	0.10±0.07	0.0278	0.12±0.09	0.13±0.09	0.8437	0.2254	0.0046*	-	(2,3)<1
Right side (mm)	x	0.19±0.15	0.15±0.10	0.4341	0.14±0.10	0.24±0.12	0.0426	0.21±0.21	0.25±0.31	0.5841	0.7588	0.6777	-	-
	y	0.18±0.14	0.31±0.14	0.1686	0.31±0.13	0.36±0.16	0.5978	0.19±0.15	0.17±0.11	0.8167	0.1972	0.0738	-	-
	z	0.20±0.16	0.25±0.18	0.6233	0.16±0.11	0.19±0.11	0.7014	0.14±0.18	0.09±0.06	0.3505	0.7749	0.1221	-	-

x-axis: the sagittal axis, y-axis: the transverse axis, z-axis: the vertical axis.
1: natural anterior guidance, 2: flat anterior guidance, 3: steep anterior guidance.
[a]One-way ANOVA test with Scheffe's multiple comparison test were performed, [b]Paired t-test was performed. *$P<0.01$.

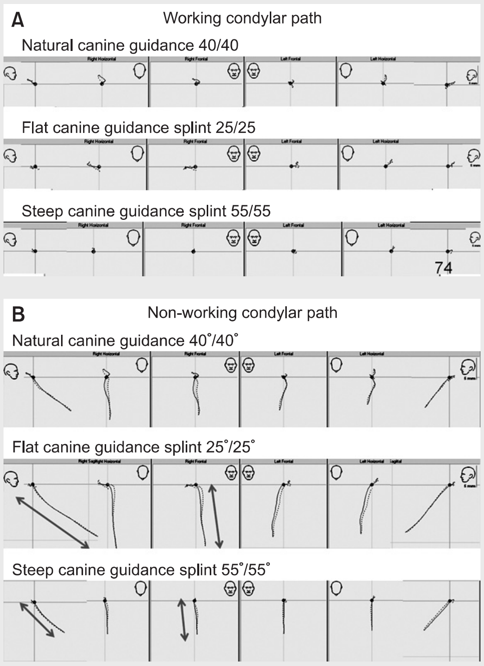


Figure 5. Example of Case 1. (A) Working condylar movement path, (B) Non-working condylar movement path. The arrows indicate the direction and amount of movement.

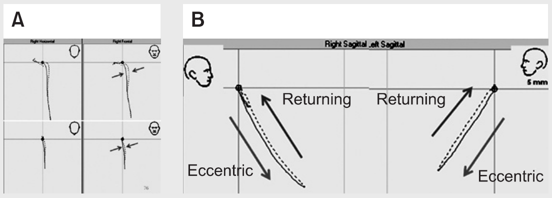


Figure 6. Comparison of the eccentric and returning paths in the non-working side. (A) The frontal view. The two arrows indicate the difference between the eccentric and returning paths. The upper row represents flat canine guidance and the lower row represents steep canine guidance. (B) The sagittal view. The solid line represents the eccentric path and the dotted line indicates the returning path in natural canine guidance.

kind of canine guidance that yields the least amount of immediate side shift and postero-superior movement in the working condylar paths and the solid, stable, and constant curve and small amount of difference between the eccentric and returning paths in the nonworking condylar paths. Out of the six subjects, five showed favorable working condyle paths with the steep canine guidance and one with the natural canine guidance. The flat canine guidance did not result in a favorable working condylar path. The average values of favorable canine guidance were approximately 58° to 59° within a given condition of ±15° of the natural canine guidance (Table 5).

Discussion

Baqaien et al.[15] reported that the condylar path inclination angle increases with the maturation of occlusion in a study of early mixed dentition without anterior guidance, early mixed dentition with anterior guidance, and late mixed dentition. In addition, there may be a difference in the condylar guidance according to gender. Therefore, this study used only young adult women as subjects.

A healthy condylar path has some common features. During lateral excursive movement, the working condyle shows mainly rotational movement and minimal laterotrusive movement (less than 1 mm)[11,16,17]. The non-working con-

Table 5. The value of canine guidance showing favorable working condylar paths

Patient	Canine guidance type	Values of canine guidance (°)		
		Right	Left	P-value
1	Steep	63	60	0.2850
2	Natural	45	45	
3	Steep	55	55	
4	Steep	65	61	
5	Steep	60	61	
6	Steep	65	65	
Mean±SD		58.83±7.76	57.83±7.05	-

The Mann-Whitney test was performed.

dyle shows a smooth gliding curved path and a small difference in inclination between the eccentric and returning paths. Compared to the normal healthy temporomandibular joint, some different features are observed in patients with internal derangements[18]: The working condyle often shows excessive and various laterotrusive movements in addition to rotational movement. The starting position often does not coincide with the ending position. The non-working condylar path may appear different at every measurement. In many cases, the velocity of the non-working condylar movement is uneven. Sometimes, a large difference is observed between the eccentric path and the returning path.

Although Broderson[19] insisted that the anterior guidance is a result of anterior tooth position and condylar border movements, the findings of this study that alterations of the anterior guidance can influence the working condylar path (Figs. 3 and 5) are in accordance with previous results[9,12,20].

The findings that the steep canine guidance produced minimal working condylar movement among the three types of canine guidance and the flat canine guidance tended to produce excessive and irregular movement of the working condyle in this study (Figs. 3 and 5) suggest that steep canine guidance might restrict the horizontal movement of the working condyle. This could be interpreted as a decrease in the lateral component of the condylar movement and an increase in the horizontal component of working condylar movement with the flat canine guidance.

The reason that the difference between the eccentric and returning paths in the nonworking condylar path appeared to be largest with the flat canine guidance (Figs. 4 and 6) seems to be positional instability of the meniscus between the eccentric and returning positions. Therefore, the flat canine guidance seems to allow the non-working condyle and meniscus to move laterally more easily.

Although there were obvious differences between the eccentric and returning paths at the condylar level, the lower incisal path did not show a significant difference between the eccentric and returning paths (Table 3). The reason for this seems to be that the condylar movement can be influenced more easily than the tooth position.

Within a 4 mm-range of lateral excursion, irrespective of the steepness of the canine guidance, the working condylar paths did not show significant differences in terms of direction and distance (Tables 2 and 4). The flat canine guidance tended to allow the mandible to move easily out of the functional range. On the contrary, the steep canine guidance restricted the excessive horizontal movement of the mandible to keep it within the functional range.

On the non-working side, the returning angle was smaller than the eccentric angle in most cases (Fig. 6). Powerful contraction of the strong closing muscles, which exert forces to push the condyle up into the glenoid fossa, seems to make the returning path flatter than the eccentric angle. The returning path is considered more important than the eccentric path in the field of restorative dentistry. Since prostheses made according to the eccentric path may cause posterior interferences in the patient's mouth, these results have important clinical implications.

The findings that five subjects and one subject showed favorable working condylar path using the splint with the steep canine guidance and the splint with the natural canine guidance, respectively (Table 5) imply that the flat canine guidance tends to have a negative influence on the working condylar path.

According to Hobo[12], the angle of hinge rotation created by the angular difference between the anterior guidance and condylar path could contribute to posterior disclusion, which is crucial in controlling harmful lateral forces. In addition, Hobo[21] suggested that if the dentist creates the occlusion properly, the condylar path may be corrected, thereby minimizing the micro-trauma that causes TMD.

According to numerous literature reviews, meta-analyses, and longitudinal studies[2,7,22-24], orthodontic treatment either with or without tooth extractions might not increase the risk for TMD. However, if proper anterior guidance cannot be established after orthodontic treatment, then the condylar path could be negatively affected.

This study has some limitations because of the small sample size and the absence of longitudinal data. Therefore, further studies employing large sample sizes and long-term follow-up will be needed to investigate the effects of anterior guidance on the condylar path and chewing pattern.

Conclusion

Since changes in the anterior guidance can affect the working and nonworking condylar paths and the lower incisal path, it is necessary to establish proper anterior guidance during orthodontic treatment.

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