

A Cone-Beam Computed Tomography Assessment of the Relationship between Incisal and Condylar Guidance

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ABSTRACT

The success of complex prosthodontic treatment is believed to be conditioned by condylar path replication in the articulator, as there is a continuing debate in the scientific community regarding the anatomical relationship between joint and dental morphology. The purpose of this study was to investigate the potential correlation between incisal and condylar guidance. The study population consisted of 20-30-year-old full dentate individuals with Angle class 1 occlusion, whose cone-beam computed tomography (CBCT) scans were analyzed by two investigators. The anterior slope of the right and left glenoid fossa angle and the palatal slope of all maxillary frontal teeth were measured by software tools at three defined landmarks, and the mean values were calculated. Statistical analysis was performed using IBM SPSS Statistics software (version 19.0), and the Pearson *r* coefficient test was used to assess correlations. The results reveal a highly statistically significant correlation between median condylar slopes and between median incisal slopes of the anterior teeth, on the left and right side, in the three standard areas ($p < 0.01$). However, no significant correlation was found between the condylar slopes and the incisal slopes of the anterior teeth ($p > 0.01$) in class 1 Angle subjects. In conclusion, this study did not provide evidence to support the existence of a significant correlation between incisal and condylar guidance in the population under investigation.

Keywords: incisal guidance, condylar guidance, CBCT.

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INTRODUCTION

The replication of condylar path in the articulator is considered to be influential factor in determining the success of prosthodontic treatment (1, 2). This inclination is measured in degrees with normal values between 30° and 60° (3). It is classified as a steep slope below the lower limit and as a flat slope above the upper limit (4). The inclination of the articular slope varies individually and dictates the direction but also the degree of rotation of the disc above the condyle (5) during functional movements. The steep inclination of the articular tubercle facilitates the presence of longer cusps and deeper fossae in the posterior teeth, along with less concavity on the palatal surfaces of the anterior teeth. This is due to a rapid separation occurring in the molar region during mandibular movements. Conversely, a flat articular tubercle necessitates shorter cusps and shallower grooves in the posterior teeth. Research also indicates that the influence of the incisal slope on dynamic interocclusal relationships during propulsion and lateral movements is twice as significant as that of the condyle. Increased overbite and decreased overjet correspond to longer cusps and deeper fissures (6).

The inclination of the anterior wall of the glenoid fossa can be measured radiographically, using a jaw movement recording device, or with a protrusive interocclusal bite registration method (7). Several techniques have been employed to assess the angle of the articular eminence, including skull measurements (8-10), conventional X-rays (11), traditional tomography (3, 12), and magnetic resonance imaging (MRI) (13, 14), computed tomography (CT) (15, 16). Cone-beam CT (CBCT) was recently introduced in the diagnosis of dental and bone lesions, having the advantage of a reduced scanning time and a low radiation dose compared to the conventional one (17, 18).

Historically it has been stated that the incisive guidance is related to the anterior wall of the glenoid fossa (19), and some studies' results (20, 21) have highlighted that there was a relationship between anterior controlling factor (incisal guidance) and posterior controlling factor (temporo-mandibular joint structure) (22). According to Dawson *et al* (23), the anterior guidance is associated with the motion of the early condylar movement and may be linked to the size and path of the condyle

and fossa. In the Hanau quint, the incisal guidance has an inverse correlation with the condylar inclination (24). Other studies established a relationship between the sagittal condylar guidance (SCG) and the disclusive angle of the IG led to the formula (25): $SCG + 5 = IG$. However, there are authors who claim that there is no correlation between the path of the condyle and the anterior incisal slope (26-28). Their therapeutic recommendation is reconstruction of anterior maxillary teeth in line with aesthetics, anatomical, and phonetic criteria (26).

Because the existence of an anatomical correlation between joint and dental morphology is still a subject of debate in the scientific world and there is limited literature on the subject (27, 29), the aim of this study was to investigate whether there is a statistically significant correlation between the degree of inclination of the articular tubercle slope and that of the upper front teeth when compared to a horizontal reference. □

MATERIALS AND METHODS

Study participants

The measurements were performed retrospectively on closed-mouth CBCT records of 64 class 1 Angle full dentate subjects in the maxillary frontal area, with an equal number of women and men, aged between 20 and 30 years. This interval was chosen because previous studies by Sulün *et al* confirmed that the articular eminence reaches its full size between 21 and 30 years of age in healthy patients and decreases after the age of 31 (30). The radiological exams were selected from a private dental clinic database, where written consent for use in scientific purposes was obtained from every subject. The CBCTs were obtained for various clinical purposes, including impacted tooth, extraction of third molar, dental implantation, and other clinical examinations. The exclusion criteria for our study comprised subjects with joint, periodontal or systemic pathology, orthodontic treatments, history of facial trauma, dental anomalies such as crowding in the frontal area, facial or dental asymmetries.

Study protocol

The midfacial region of each participant was imaged using a CBCT scan performed by the same operator using a consistent unit (Carestream Kodak 9300C; Kodak). The patient was placed in

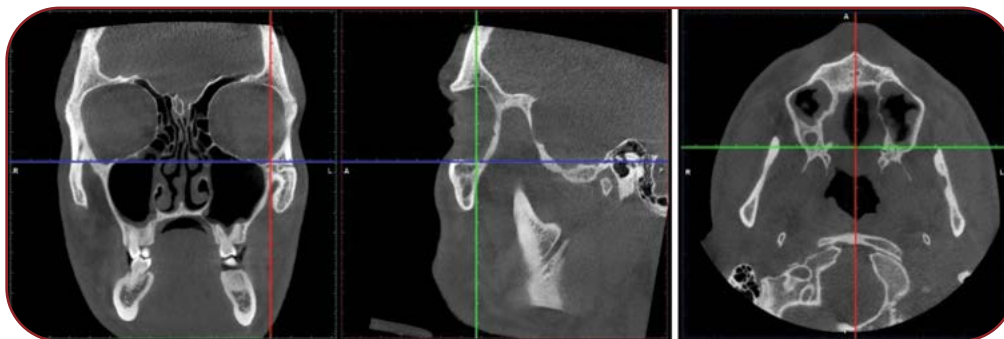


FIGURE 1. Adjusting the image in the three planes, respecting the parallelism between the axial plane and the Frankfort plane

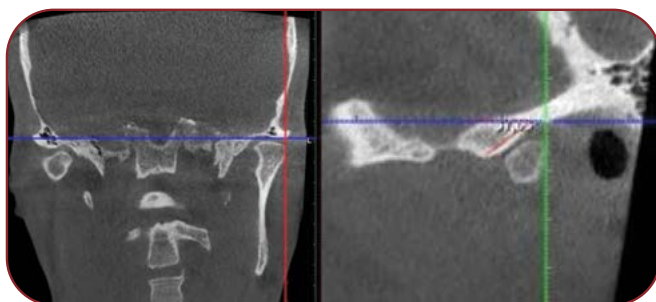


FIGURE 2. Example of the measurement of the inclination of articular slope angle at the level of the external pole on the left side on a sagittal section using the angle measurement tool in the Romexis Software

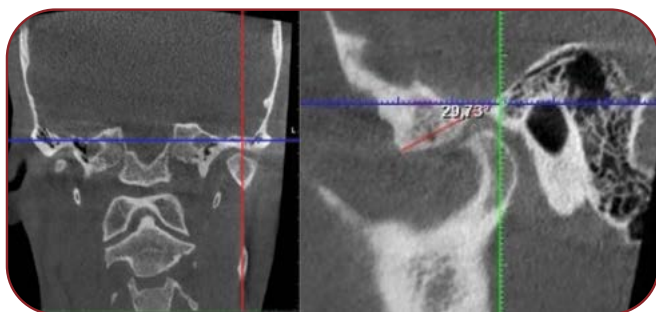


FIGURE 3. Example of the measurement of the inclination of articular slope angle at the level of the central part of the left condyle on a sagittal section using the angle measurement tool in the Romexis Software

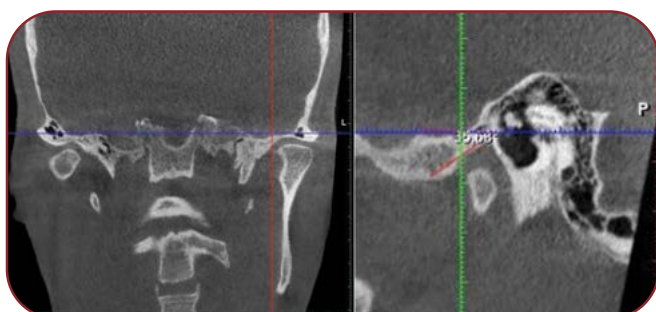


FIGURE 4. Example of the measurement of the inclination of articular slope angle at the level of the internal pole of the left condyle on a sagittal section using the angle measurement tool in the Romexis Software

a horizontal position so that the Frankfort horizontal plane was perpendicular to the table, with their head within the circular gantry housing of the X-ray tube to obtain a consistent orientation of sagittal images.

Using appropriate software (Planmeca Romexis) and a 21.3" monitor at a resolution of 1280x1024 pixels, the patient's head scan was verified and corrected, in some cases, to be positioned based on the Frankfort plane (Po-Or) perpendicular to the sagittal midline previously located in the axial viewpoint opisthion (Op) and crista galli (Cg) (Figure 1). Sections were obtained at the level of the condylar head, perpendicular to its long axis, with axial orientation. These sections had a width of 200 mm, and a thickness of 1 mm, and were spaced at intervals of 2 mm. The porion and orbitale were identified, and the Frankfort horizontal plane was constructed. In the next step, a second line was drawn, following the posterior inclination of the articular eminence (AE), connecting the most concave (highest, deepest) point on the glenoid fossa to the most convex (lowest) point on the apical section of the articular eminence (AE). Condylar inclination angles for both sides were obtained by measuring the angle between the Frankfort horizontal plane and the second constructed line for each participant, using a method previously used in other studies (2, 31, 32).

The measurements at the joint level were quantified in three areas represented by the external condylar pole (Figure 2), the middle portion of the condyle (Figure 3), and the internal condylar pole for each subject (Figure 4).

The angle of inclination of the palatal slope was measured using the implants module of the software. The axis aligned with the Frankfort plane was lowered to the cingulum portion of the tooth

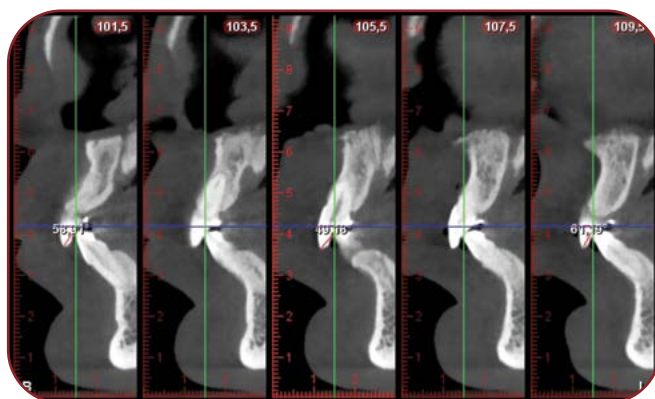


FIGURE 5. Example of the measurement of the inclination angle of the palatal slope of tooth 11 in the sagittal plane at the mesial, central and distal point using the implant module of the Romexis Software. The axis aligned with the Frankfort plane is lowered to the cingulum, and the angle is measured between this line and the one joining the incisal edge to the cingulum.

being measured, and the angle was measured between this line and the line connecting the incisal edge to the cingulum (Figure 5). The teeth included in the study are 13, 12, 11, 21, 22, and 23, and the measurements were taken in the sagittal plane at three points (mesial, central, and distal) for each tooth in the segment of interest.

Statistical analysis

The measurements were performed twice by a single investigator at both the condylar and dental levels on the left and right sides. The collected data were recorded in a spreadsheet (Microsoft Office Excel 2007; Microsoft Corp) and analyzed using statistical software (IBM SPSS Statistics, v19.0; IBM Corp). Data with normal distribution (determined by the Shapiro-Wilk test) underwent parametric tests. The Pearson r coefficient test was used to test for correlations as appropriate. □

RESULTS

Descriptive analysis of data

In the first step of the study, we performed a descriptive analysis of data by calculating the mean value of the condylar slope angle at the three established landmarks on the right and left sides. The mean value was obtained from the two datasets for each measured condylar region (Table 1).

The mean value of condylar inclination measured to the external pole was different by three degrees from the left side to the right side and similarly for the medial and internal poles.

For the means of the palatal slopes of the upper frontals, we calculated the arithmetic mean of the three determinations for each tooth and then the mean on both sets of data (Table 2). The mean palatal slope obtained varies at the incisive landmark by two degrees left to right, but is similar at the canine.

Correlation test between condylar slope angle and frontal teeth formed slope angle of the in relation to the reference plane (Frankfort), on the mean of the two sets of data (Table 3).

When applying the Pearson correlation test, statistically significant correlations were found between measurements. In 58% of cases, the condylar slope near the external pole correlated with that of the median condylar portion on the right side, with a highly significant correlation of $p < 0.01$. In 45% of cases, the condylar slope next to the external pole correlated with that of the median condylar pole on the right side, with an intensely significant correlation of $p < 0.01$. The slope of the median condylar portion on the right side correlated with the slope of the internal pole on the

Statistics							
Mean angle (grades)		EP_right	MP_right	IP_right	EP_left	MP_left	IP_left
N	Valid	64	64	64	64	64	64
	Missing	0	0	0	0	0	0
Mean		47,342	44,64	45,133	44,416	45,092	45,637
Std. deviation		9,7120	12,825	10,365	8,696	8,7069	11,500
Minimum		66,61	69,79	64,52	58,93	59,3	73,61
Maximum		30,84	21,2	26,44	27,82	26,74	20,6
Percentiles	25	55,28	57,7825	53,19	52,39	52,82	54,087
	50	47,29	42,61	45,265	44,33	44,025	44,32
	75	39,647	34,937	35,897	37,105	38,247	41

TABLE 1. Mean of both data sets for external pole (EP), medium pole (MP), and internal pole (IP) on the left and right sides

Statistics							
Mean angle (grades)		t11_mean	t12_mean	t13_mean	t21_mean	t22_mean	t23_mean
N	Valid	64	64	64	64	64	64
	Missing	0	0	0	0	0	0
Mean		42,630	41,503	42,644	40,608	39,659	42,267
Std. Deviation		10,192	12,256	9,0801	10,244	8,341	8,101
Minimum		67,97	65,836	53,293	55,4	53,29	67,646
Maximum		24,71	18,743	16,313	22,403	22,263	27,853
Percentiles	25	49,8242	49,456	49,736	51,785	46,329	46,573
	50	42,9367	41,783	44,511	40,273	42,063	41,593
	75	35,5842	33,382	39,354	33,189	31,534	36,700

TABLE 2. Mean angle values were measured for the palatal slope of the teeth on both data sets. For each tooth, the mean of the angle measurement was calculated and then the mean was obtained for both sets of data (t11mean = mean angle value for tooth 11, t12mean = mean angle value for tooth 12, t13mean = mean angle value for tooth 13, t21mean = mean angle value for tooth 21, t22mean = mean angle value for tooth 22, and t23mean = mean angle value for tooth 23)

TABLE 3. Pearson correlation between the condylar angles and palatal dental angle values on the right side (EP=external pole, MP= medium pole, IP= internal pole)

Correlations							
Mean angle (grades)		EP_right	MP_right	IP_right	t11_mean	t12_mean	t13_mean
EP_right	Pearson correlation	1	.581**	.455**	.093	.196	.079
	Sig. (2-tailed)		.000	.009	.612	.281	.666
	N	64	64	64	64	64	64
MP_right	Pearson correlation	.581**	1	.501**	.189	.026	.202
	Sig. (2-tailed)	.000		.003	.299	.889	.268
	N	64	64	64	64	64	64
IP_right	Pearson correlation	.455**	.501**	1	-.113	-.017	.218
	Sig. (2-tailed)	.009	.003		.538	.925	.231
	N	64	64	64	64	64	64
t11_mean	Pearson correlation	.093	.189	-.113	1	.437*	.461**
	Sig. (2-tailed)	.612	.299	.538		.012	.008
	N	64	64	64	64	64	64
t12_medie	Pearson correlation	.196	.026	-.017	.437*	1	.653**
	Sig. (2-tailed)	.281	.889	.925	.012		.000
	N	64	64	64	64	64	64
t13_medie	Pearson correlation	.079	.202	.218	.461**	.653**	1
	Sig. (2-tailed)	.666	.268	.231	.008	.000	
	N	64	64	64	64	64	64
**.Correlation is significant at the 0.01 level (2-tailed).							
*.Correlation is significant at the 0.05 level (2-tailed).							

right side in 50% of cases. The mean slope of the 11th tooth correlated with the mean slope of the 12th tooth in 43% of cases, and with the mean

slope of the 13th tooth in 46% of cases. The mean slope of the 12th tooth correlated with the mean slope of the 13th tooth, in addition to the 11th tooth, in 65% of cases with a highly significant correlation of $p < 0.01$.

No significant correlation was found between the condylar slopes and the incisal slopes of the front teeth on the right side.

The Pearson correlation analysis continued with the benchmarks from the left side, based on the mean of the two data sets (Table 4).

According to the analysis, the following measurements showed a correlation at the level of the left condyle: in 52.2% of cases, there was a strongly statistically significant correlation of $p < 0.01$ between the slope of the external pole and the median condylar slope. Also, in 37.7% of cases there was a strongly statistically significant correlation ($p < 0.01$) between the slope of the external pole and the slope of the median pole. There was a strongly statistically significant correlation ($p < 0.01$) in 71.8% of cases between the slope of the median pole and the slope of the internal pole, and in 42.3% of cases with the mean slope of 23; in 74.1% of cases between the mean slope 21 and the mean slope 22; in 55.2% of cases between the mean slope of the 22nd tooth and the mean slope of the 23rd tooth.

No significant correlation was found between the condylar slopes and the incisal slopes of the front teeth on the left side.

Correlation test of the measurements at the left and right homologous landmarks (Table 5)

When considering the mean of the two determinations, highly significant correlations were found

TABLE 4. Pearson correlation between the condylar and palatal dental angle values on the left side (EP=external pole, MP= medium pole, IP= internal pole)

Correlations							
		EP_left	MP_left	IP_left	t21_mean	t22_mean	t23_mean
EP_left	Pearson correlation	1	0.522**	0.377*	-0.044	-0.140	-0.157
	Sig. (2-tailed)		.002	.034	.810	.444	.391
	N	64	64	64	64	64	64
MP_left	Pearson correlation	.522**	1	0.718**	0.138	0.006	0.181
	Sig. (2-tailed)	.002		.000	.450	.976	.322
	N	64	64	64	64	64	64
IP_left	Pearson correlation	.377*	.718**	1	0.007	-0.222	-0.119
	Sig. (2-tailed)	.034	.000		.972	.222	.517
	N	64	64	64	64	64	64
t21_mean	Pearson correlation	-0.044	.138	.007	1	0.741**	0.423*
	Sig. (2-tailed)	.810	.450	.972		.000	.016
	N	64	64	64	64	64	64
t22_mean	Pearson correlation	-.140	.006	-.222	.741**	1	0.552**
	Sig. (2-tailed)	.444	.976	.222	.000		.001
	N	64	64	64	64	64	64
t23_mean	Pearson correlation	-0.157	.181	-.119	.423*	.552**	1
	Sig. (2-tailed)	.391	.322	.517	.016	.001	
	N	64	64	64	64	64	64
** Correlation is significant at the 0.01 level (2-tailed).							
* Correlation is significant at the 0.05 level (2-tailed).							

TABLE 5. Paired test for the correlation between the values of the condylar and dental palatal angles on the right and left side (EP=external pole, MP= medium pole, IP= internal pole)

Paired samples orrelations				
		N	Correlation	Sig.
Pair 1	EP_right & EP_left	64	0.307	0.087
Pair 2	MP_right & MP_left	64	0.574	0.001
Pair 3	IP_right & IP_left	64	0.766	0.000
Pair 4	t11_mean t21_mean	64	0.655	0.000
Pair 5	t12_mean t21_mean	64	0.733	0.000
Pair 6	t13_mean t23_mean	64	0.541	0.001

between the analyzed angles, both on the left and on the right. Specifically, there was a correlation with $R > 0.7$ between the angle determined at the level of the internal condylar pole and the in-

cisal slope of the lateral incisor. However, the only exception was the angle measured at the level of the external pole, where asymmetries were highlighted in the measured sagittal plane. Regarding the possibility of correlating the condylar slopes with the incisal slopes on the mean of the datasets, no statistically significant correlations could be established on either the right or the left.

Correlation test between mean values of the left-right measurements at the condylar and dental level (Table 6)

Upon analysis, results show that there is an intensely statistically significant correlation between the mean angle of the external pole of the articular eminence and the mean angle of the median pole in 62% of cases, and in 44% of cases with the internal pole, between the mean angle of the median portion of the articular eminence and that of the internal portion in 65% of cases, between the mean palatal slope of the central incisor in 65% of cases with that of the lateral incisor, and in 60% of cases with that of the canine and between the

Correlations							
		EP Left Right	MP Left Right	IP Left Right	t11_t21	t12_t22	t13_t23
EP_Left_Right	Pearson correlation	1	.627**	.440*	-.123	0.068	-0.042
	Sig. (2-tailed)		.000	.012	.504	.714	.820
	N	64	64	64	64	64	64
MP_Left_Right	Pearson correlation	.627**	1	.659**	0.114	0.061	0.297
	Sig. (2-tailed)	.000		.000	.534	.740	.098
	N	64	64	64	64	64	64
IP_Left_Right	Pearson correlation	.440*	.659**	1	-.134	-0.186	0.058
	Sig. (2-tailed)	.012	.000		.464	.307	.754
	N	64	64	64	64	64	64
t11_t21	Pearson correlation	-.123	.114	-.134	1	.653**	.605**
	Sig. (2-tailed)	.504	.534	.464		.000	.000
	N	64	64	64	64	64	64
d12_d22	Pearson correlation	.068	.061	-.186	.653**	1	.773**
	Sig. (2-tailed)	.714	.740	.307	.000		.000
	N	64	64	64	64	64	64
t13_t23	Pearson correlation	-.042	.297	.058	.605**	.773**	1
	Sig. (2-tailed)	.820	.098	.754	.000	.000	
	N	64	64	64	64	64	64
** Correlation is significant at the 0.01 level (2-tailed).							
* Correlation is significant at the 0.05 level (2-tailed).							

TABLE 6. The Pearson correlation between the mean values of the left-right condylar angles and the left-right dental palatal angles

mean palatal slope of the lateral incisor and that of the canine in 77% of cases.

In addition, the comparison between the right and left sides in females and males also showed no statistical differences between the means of the angles, as corroborated by Wu *et al* (33). □

DISCUSSIONS

Data from the literature related to the possibility of an association between the value of the articular parameters and the morphology of the palatal face of the upper front teeth are limited. Additionally, there is heterogeneity in the measurement method of the temporomandibular joint in CBCT radiological analysis.

In our study, the difference between the mean angle of the condylar slope at the three landmarks was between 1-2 degrees, values that according to Cimic's study (34) fall within the normal range. The mean angle of the condylar slope on the right side is 45.71° , and on the left side, it is 45.06° , results that are close to those obtained in the studies of Gysi (1910), Kohno (1987), and Pelletier (1990) (35).

The differences between the inclination of the condylar slope on the right and left sides were not statistically significant, results that correlate with the reports of previous studies (31, 36). El Gheriani and Winstanley reported significant differences between bilateral condylar slope values, but their result can be attributed to the heterogeneity of the group in which they had partially edentulous or completely edentulous cases (37).

The left-right differences are very small – approximately 1-2 degrees in homologous teeth – and clinically insignificant. However, the values obtained are lower than those obtained in previous studies and difference between the angle of the condylar slope and the angle of the central incisor slope is 3.07° on the right side and 4.45° on the left side, values much lower than those reported in previous experiments (35).

In our study, there are highly significant correlations between the slopes measured at the three levels - external, middle, and internal pole of the condyles on the same side, and there are highly significant correlations between the right and left side of the condyles, except for the external pole

where no correlation can be established. Furthermore, the results show correlations between the incisal slopes of the front teeth on the same side, incisal slopes of the front teeth on the two sides, showing the morphological harmony of anterior guidance.

Our analysis could not establish correlations between the incisal guidance angle and TMJ anatomy. This conclusion contradicts the gnathological approach, which suggests that an anterior guidance steeper than the condylar guidance is a mandatory rule as it eliminates all horizontal forces from the posterior teeth. (35, 38, 6). Nonetheless, some reports suggest that a steep incisal guidance may cause temporomandibular joint malfunction (39) and that the palatal inclination slope of frontal teeth influences the movements of the condyles, which in turn modifies the growth and morphology of TMJ (40). Han *et al.* demonstrated weak but statistically significant correlations between the incisal angle, the size of the condyle and glenoid fossa. On the other hand, other studies concluded that the shape variation of the fossa and condyle was not related to the occlusal plane angle and incisal guidance angle (40) and consequently teeth morphology does not affect the TMJ formation in young adults (41).

Our conclusion is in accordance with Soto's study, which stated that there is no direct proportional correlation between the angle of the incisal guidance and the angulation of the anterior wall of glenoid fossa when it is analyzed by 3D Cone Beam CT (42). Luca and Manfredini also concluded that there were no differences between the

features of the glenoid fossa and the upper incisor inclination in subjects with different facial types, and that there was an absence of clinically relevant relationships between the articular shape and incisor inclination (43). However, the age range of the population in this study was 18 to 40, which is an important factor as the TMJ develops between 21 and 23 years old. Following the peak of growth and development, which typically occurs around the age of 17, the temporomandibular joint (TMJ) undergoes gradual adaptations that may be influenced by the incisal slope (44).

The limitation of our research is that the measurements of the incisor and condylar guidance angle were made in a static state. Further research is needed to consider the dynamic aspects and other skeletal classes. ▣

CONCLUSION

Even though the study found several statistically significant correlations between the slopes of different condylar regions and between the mean slopes of different teeth, no significant correlation was found between the condylar slopes and the incisal slopes of the front teeth. These findings provide important information for understanding the relationships between different aspects of dental anatomy, which can be useful in various clinical applications. ▣

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