Original Article

Variations in the Inclination of the Condylar Path in Children and Adults

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ABSTRACT

Objective: To test the null hypothesis that there are no differences between children and adults in the condylar path inclination angle on the right and left sides.

Materials and Methods: A group of 80 children aged 6 to 10 years (subgroups I through V, according to chronologic age) was compared with an adult group with regard to the condylar path inclination angle (CPIA) on the right and left sides. The CPIA was measured using the ultrasonic JMA-System for registration.

Results: During development of the temporomandibular joint the condylar path inclination angle increased with age in the subgroups of children. A significant difference was found in the CPIA between the groups of adults and children. In the group with the oldest children (mean age: 10.3 years) the condylar path inclination angle had reached 81.87% on the right side and 78.85% on the left side compared with the adult group at a 5 mm protrusive path. In the pooled group of children the CPIA amounted to 73.08% on the right side and 72.13% on the left side compared with the values for the adults. No significant difference was found between the right and left CPIA in any group.

Conclusion: The hypothesis is rejected. The CPIA on the right and left sides increased with age in the group of children and was significantly smaller in the group of children compared with the group of adults. (*Angle Orthod.* 2009;79:958–963.)

KEY WORDS: Condylar path inclination angle; Articular eminence; Temporomandibular joint; JMA-System; Growth-related changes; Children compared to adults

INTRODUCTION

The temporomandibular joint (TMJ) with its anatomic structure is considered to be one of the compensatory mechanisms of the stomatognathic system.[1] It allows neuromuscular dimeric link chain guided mandibular movements[2] that are dictated by the shape of the mandibular fossa, the disk, the degree of tension on the associated ligaments, the neuromuscular system, the guiding planes of the teeth, and the articular eminence.[3]

The articular eminence is that part of the temporal fossa over which the condyle disk complex slides during the various mandibular movements. Its inclination is defined as the angle formed by the articular eminence and the Frankfort horizontal (FH) plane or any other horizontal plane, such as the occlusal or palatal plane.

The flatness or steepness of the articular eminences dictates the path of condylar movement as well as the degree of rotation of the disk over the condyle.[4,5] If the articular eminence is steep, the condyle features a large vertical movement upon opening and is forced to move inferiorly as it shifts anteriorly. Some authors have showed that the posterior disk rotation is more prominent in joints with a steep articular eminence compared with joints with a less steep articular eminence.[6]

Widman[7] showed that there is a strong correlation between the axiographically recorded angle of the condylar protrusive path and the anatomic angle of the

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Table 1. Distribution of Patient Age

Age subgroup	Age (years)	N	Age (years) Mean	SD[a]	Median	Minimum	Maximum
I–V	Children	80	8.54	1.32	8.50	6.30	10.60
I	6.0–6.9	15	6.73	0.21	6.80	6.30	6.90
II	7.0–7.9	15	7.47	0.33	7.60	7.00	7.90
III	8.0–8.9	20	8.52	0.28	8.50	8.10	8.90
IV	9.0–9.9	15	9.63	0.25	9.70	9.10	9.90
V	10.0–10.9	15	10.34	0.18	10.30	10.00	10.60
	Adults	40	27.43	6.42	26.50	18.00	44.60

[a] SD indicates standard deviation.

articular eminence. Axiographic studies measuring kinematic variables in the TMJ have thus far been conducted mainly in adults.[8–10]

The articular eminence and the condylar path inclination angle (CPIA) have been studied mostly in relation to facial morphology,[11] its height and relationship to teeth.[12–14] Only a few studies have involved the kinematic variables of the TMJ in children during the growth period.[15,16]

The purpose of the present study was to test the null hypothesis that there is no difference between children and adults with regard to the CPIA on the right and the left sides. The aim was to quantify and compare the mean CPIA in children between the ages of 6 and 10 years and in adults and to reveal possible growth-related differences.

MATERIALS AND METHODS

Patients

In this population-based study the test group was composed of two major groups: the first group comprised 80 children ranging between 6.0 and 10.9 years of age. The child group was further divided according to their chronologic age into five subgroups (Table 1) according to Baqaien.[16] Each subgroup covered a 12-month interval. The mean ages of the five subgroups were 6.7 years, 7.5 years, 8.5 years, 9.6 years, and 10.3 years, respectively. The examination was conducted in an elementary school in Bavaria, Germany. The second group was composed of 40 randomly selected adults ranging in age from 18 to 44 years (mean age: 27.4 years). All adults had complete permanent dentitions. The gender distributions of the child and adult groups were equal. All patients in both groups had a neutral class I occlusion and no history of orthodontic treatment.

Before starting the instrumental functional analysis test, the TMJ of each patient was checked using the Modified Hamburg CMD-Screening Test.[17] None of the children or adults showed any subjective or objective symptoms of functional disorders. All experiments were undertaken with the understanding and written consent of each subject.

Instrumental Functional Analysis

For measuring the condylar and mandibular movements the JMA-System, Jaw Motion Analyzer (Zebris Medical GmbH, Isny, Germany) was used. This ultrasonic registration system is based on the measurement of real-time latency period of sequentially transmitted ultrasound pulses between a sending device mounted on the lower jaw and a receiver mounted on the forehead.[18] The accuracy of this method has been shown in previous publications.[8,16,19,20] In the functional analysis test all subjects performed three maximum protrusion-retrusion movements not manipulated and tooth guided. Each movement was repeated more than one time to allow for more accurate readings.

The software program WinJaw (version 10.05.03, Zebris Medical GmbH, Isny, Germany) was used to calculate the actual CPIA stepwise for each successive millimeter in the sagittal plane. In the present study, the CPIA for the 3 mm and 5 mm protrusive path was noted.

Error Study

An error study was carried out to assess the reproducibility of the CPIA measured with the JMA-System. The measurement of the CPIA was repeated twice for 20 randomly selected children (four children in each age subgroup) and 12 randomly selected adults. The standard error of repeated measurement was calculated for the children and the adult group according to the formula $SE = \sqrt{\Sigma\ d^2/2n}$, where SE is standard error and is the sum of the squared differences between the different CPIA measurements and n is the number of subjects ($\Sigma\ d^2$).

Statistics

The statistical analyses of the recorded data were carried out using the Statistical Package for Social Sciences, (version 15.0 for Windows, SPSS, Chicago, Ill). The data were visualized using box-and-whisker plots (SigmaPlot 10.0, Systat Software GmbH, Erkrath, Germany). The normal distribution of data was examined with the Kolmogorov-Smirnov test, and Levene's test was used to test for homogeneity of variances. Because data showed a normal distribution but no variance homogeneity, testing was done using Mann-Whitney U test.

RESULTS

Results of the Error Study

Results of the error studies are summarized in Table 2. There was a strong correlation between the different

Table 2. Repeatability of CPIA Measurement in the Children Group and the Adult Group at a 3 and 5 mm Protrusive Path on the Right and Left Sides[a]

	Child Group		Adult Group	
	SE[b]	Range	SE	Range
CPIA left 3 mm	0.92	26.0–44.5	0.77	35.4–56.4
CPIA left 5 mm	0.90	25.5–39.9	0.84	34.1–53.8
CPIA right 3 mm	0.84	27.0–42.2	0.75	44.7–51.7
CPIA right 5 mm	0.89	29.0–41.8	0.76	39.5–51.4

[a] All values are in degrees (°).
[b] SE indicates standard error of the mean.

measurements of the CPIA in the child group as well as in the adult group. The standard error of repeated measurement was below 0.92° in the children group and below 0.84° in the adult group for all parameters.

Condylar Path Inclination Angle at a 3 mm Protrusive Path

Among the five subgroups of children there was a consistent pattern for the mean CPIA to increase with increasing age on the right and left sides at a protrusive path of 3 mm (Table 3, Figure 1). On the right and left sides the mean CPIA ranged between 32.11° and 32.74° (subgroup I) and 40.88° and 40.12° (subgroup V). The consistent increase in the mean CPIA showed an average value of about 2° (Table 2).

Compared with the adult group, the mean CPIA in the youngest child group (subgroup I) was equivalent to 64.80% on the right and 66.13% on the left side. In the oldest child group, the CPIA (subgroup V) corresponded to 82.50% on the right and 81.03% on the left side in comparison to the adult values.

The mean CPIA of the pooled children group (subgroups I through V) amounted to 36.71° on the right and 36.27° on the left side. This is equivalent to 74.09% on the right and 73.26% on the left side of the CPIA in the adult group.

The results of the adult group showed a mean CPIA of 49.55° on the right side and 49.51° on the left side at a protrusive path of 3 mm. This is a much higher value than in any of the child subgroups.

A significant difference was found between the CPIA of subgroup I and subgroup IV ($P = .023$) and sub-

Table 3. Descriptive Statistics for the Right and Left Mean Condylar Path Inclination Angle at a Protrusive Path of 3 and 5 mm. The Child Group was Divided into Five Subgroups (subgroup I to V) According to Chronologic Age and Compared to the Adult Group[a]

Variable (protrusion, mm)	Age Group	N	Condylar Path Inclination Angle (°)					Percent (%) of CPIA of Adult Group
			Mean	SD[b]	Median	Minimum	Maximum	
right_3	I	15	32.11	7.47	31.50	17.90	44.10	64.80
	II	15	34.83	10.16	34.80	19.50	51.90	70.29
	III	20	36.80	10.02	34.35	24.50	54.20	74.27
	IV	15	38.87	6.31	38.80	29.30	50.40	78.45
	V	15	40.88	6.86	40.80	24.20	52.20	82.50
	I–V	80	36.71	8.75	36.50	17.90	54.20	74.09
	Adults	40	49.55	4.24	49.60	39.80	58.50	100.00
right_5	I	15	30.10	7.30	29.60	15.90	42.30	63.54
	II	15	32.90	8.48	32.90	20.30	47.00	69.45
	III	20	34.69	8.39	32.35	22.50	47.10	73.23
	IV	15	36.60	5.87	35.80	27.20	48.20	77.26
	V	15	38.78	5.70	38.40	25.30	45.90	81.87
	I–V	80	34.62	7.71	34.55	15.90	48.20	73.08
	Adults	40	47.37	4.43	48.10	35.80	53.80	100.00
left_3	I	15	32.74	7.67	32.60	14.50	45.80	66.13
	II	15	34.44	11.21	35.90	14.50	50.20	69.56
	III	20	36.08	8.98	34.00	25.30	58.50	72.87
	IV	15	38.04	8.62	37.70	25.30	55.70	76.83
	V	15	40.12	4.81	41.10	29.20	46.40	81.03
	I–V	80	36.27	8.70	35.85	14.50	58.50	73.26
	Adults	40	49.51	5.86	49.45	31.60	64.60	100.00
left_5	I	15	30.77	8.04	30.30	8.90	43.10	64.62
	II	15	32.88	7.99	32.80	18.10	45.90	69.05
	III	20	34.36	7.55	32.90	23.40	51.80	72.15
	IV	15	36.18	7.04	36.20	26.80	49.80	75.98
	V	15	37.55	4.79	38.50	28.20	45.10	78.85
	I–V	80	34.35	7.40	33.35	8.90	51.80	72.13
	Adults	40	47.62	5.56	47.70	31.60	63.20	100.00

[a] Modified table from SPSS.
[b] SD indicates standard deviation.

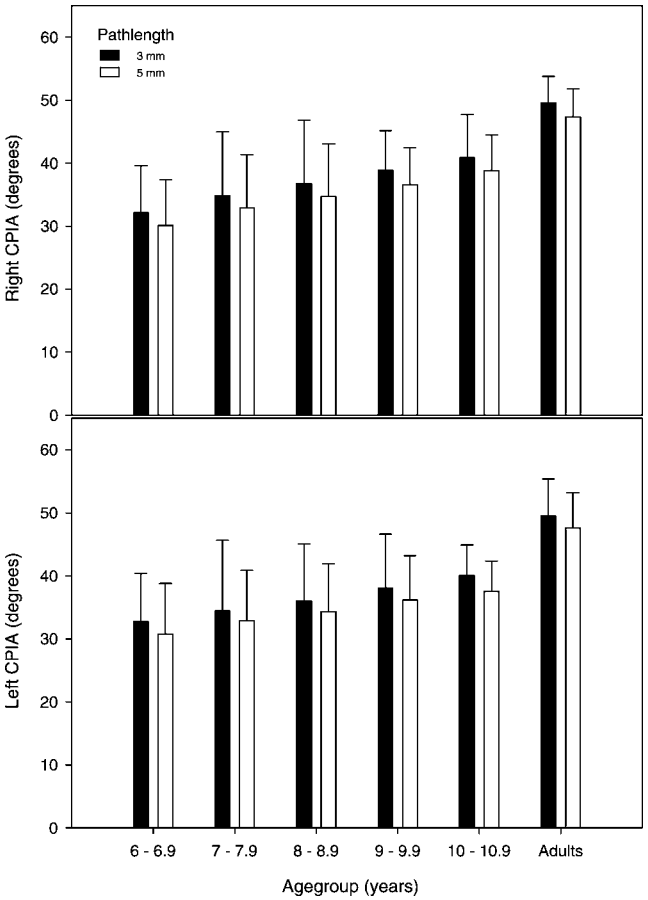

Figure 1. Box-and-whisker plots showing the mean CPIA of the child group (different age subgroups) and the adult group on the right and left sides at a 3 and 5 mm protrusive path.

group V (p =.004) in the child group on the right side and between subgroup I and subgroup V (*P* =.004) as well as between subgroup III and subgroup V (*P* =.023) on the left side (Table 3) at a 3 mm protrusive path. There was a significant difference in the CPIA of all child subgroups compared with the adult group on the right and left sides.

Condylar Path Inclination Angle at a 5 mm Protrusive Path

On the right and left sides the mean CPIAs at a protrusive path of 5 mm were smaller in comparison to the 3 mm protrusive path in all groups (Figure 1). The mean values ranged between 30.10° (subgroup I) and 38.78° (subgroup V) on the right side and between 30.77° (subgroup I) and 37.55° (subgroup V) on the left side in the child group (Table 3). Similar to the CPIA measured at a 3 mm protrusive path, the CPIA at a 5 mm protrusion increased throughout the subgroups with increasing age of the children by about 2° on average.

The mean CPIA in the youngest child group (subgroup I) corresponded to 63.54% on the right and 64.62% on the left side in comparison to the adult values. The CPIA in the oldest child group (subgroup V) was equivalent to 81.87% on the right and 78.85% on the left side of the CPIA in the adult group. The mean CPIA of the adult group amounted to 47.37° on the right side and to 47.62° on the left side and, therefore, was much higher than in any of the children subgroups.

The mean CPIA on the right and left side in the pooled child group (subgroups I through V) amounted to 34.62° (right side) and 34.35° (left side). This is equivalent to 73.08% on the right and 72.13% on the left side in comparison to the mean CPIA of the adult group.

A significant difference was found in the children between the CPIA of subgroup I and subgroup IV (*P* =.010) and V (*P* =.001) and subgroup II and subgroup V (*P* =.026) on the right side and between subgroup I and subgroup V (*P* =.007) on the left side (Table 4) at a 5 mm protrusive path. There was a significant difference in the CPIA of all child subgroups compared with the adult group on the right and left sides.

Table 4. Significant Differences Between the Condylar Path Inclination Angle of the Child Group (subgroups I–V) and the Adult Group at a 3 and 5 mm Protrusive Path on the Right and Left Sides According to the Mann-Whitney U Test

	right_5					
right_3	I	II	III	IV	V	Adults
I		0.325	0.191	0.010*	0.001*	0.000*
II	0.436	0.657	0.174	0.026*	0.000*	
III	0.227	0.564		0.400	0.191	0.000*
IV	0.023*	0.250	0.347		0.305	0.000*
V	0.004*	0.061	0.139	0.345		0.000*
Adults	0.000*	0.000*	0.000*	0.000*	0.000*	
	left_5					
left_3	I	II	III	IV	V	Adults
I		0.461	0.330	0.106	0.007*	0.000*
II	0.389		0.730	0.412	0.106	0.000*
III	0.438	0.856		0.382	0.099	0.000*
IV	0.148	0.595	0.458		0.345	0.000*
V	0.004*	0.148	0.023*	0.305		0.000*
Adults	0.000*	0.000*	0.000*	0.000*	0.000*	

* Significant at $P \leq .05$.

Comparison of Right and Left Sides and Gender Specifities

The U-test showed that there were no significant differences in the condylar path inclination angle at a 3 mm and 5 mm protrusive path between the right and the left sides for all groups (subgroups I through V) of child and the adult groups. Testing for gender effects

revealed no significant differences of the CPIA in the child and the adult groups either.

DISCUSSION

The present study showed a constant increase of the CPIA according to age in the child group during development of the mixed dentition at the age between 6.0 and 10.9 years. In the oldest children group (mean age: 10.3 years) the CPIA amounted to 40.88° on the right and to 40.12° on the left side at a protrusive path of 3 mm, thus reaching 82.50% on the right side and 81.03% on the left compared with the average adult value. At a protrusive path of 5 mm the CPIA of the 10-year-old children amounted to 38.78° on the right and to 37.55° on the left side corresponding to 81.87% on the right side and 78.85% on the left side compared with the adult value.

These results agree well with the findings of Ingervall,[15] who studied the movements of the mandibular condyles in the sagittal plane and the inclination of the condylar path at 5 mm protrusion with the help of cephalometric radiographs in children aged 7 and 10 years and in an adult group. The inclination of the condyle path appeared to increase with age. In 10-year-old boys he found an inclination of the condyle path of 37.09°, corresponding to about 79.69% of the adult value, and in 10-year old girls he found a CPIA of 40.74° relative to the nasal line. In adult men he measured an average inclination of condyle path of 46.54° and in adult women of 42.63° at a 5 mm protrusion. These values correspond pretty well to the average CPIA found in the present study (adults: 47.37° right side, 47.62° left side).

Katsavrias[4] investigated 90 dry skulls from Asian Indian individuals and found that the inclination of the articular eminence changes rapidly until completion of the deciduous dentition, with more or less than 50% of the adult value being attained at the age of 2 years, 72.5% at the age of 10 years, and 90% at the age of 20 years. Full inclination is reached by the age of 30 years. He investigated three groups, one with deciduous, one with mixed, and one with permanent teeth. Mean values of the mixed dentition group were 29.33° on the right side and 28.11° on the left side, and mean values of the permanent-teeth group were 36.10° on the right side and 36.19° on the left side. Values of CPIA in the present study are slightly higher than the corresponding ones in the Katsavrias[4] study, although the percentage of maturation is almost equal in both studies. The difference could be due to the different measuring technique, which is described later.

Baqaien[16] measured the CPIA of children at the ages of 6.5 to 12.9 years and compared them to an adult group. In the group of children at an average age of 10.0 years, he found the CPIA to be 47.90° on the right side and 46.82° on the left side. He measured the CPIA of the adult groups and found a mean of 59.27° on the right side and 58.20° on the left side. In his study, the values of the children at an average age of 10 years correspond to the adult values at 80.82% on the right side and 80.45% on the left side, which agrees well with the findings of the present study (right side: 81.87%, left side: 78.85%) at a 5 mm protrusion.

Ricketts[21] studied the angle of the articular eminence in 50 persons by means of cephalometric laminography and concluded that the inclination of articular eminence was 46° (77.9% of its mature form) at the age of 7.5 years and 52° (88% of its mature form) at 12.5 years. In the present study, 40 adults with a neutral class I occlusion were examined. The average CPIA in the adult group was 47.37° on the right side and 47.62° on the left side at a protrusive path of 5 mm. The normal value of this angle in adults has been reported to be 30° to 60°.[22] Nevertheless, these values should not be regarded as fixed, but they may still undergo a morphologic alteration process. The mean age of the adult group was 27.4 years, which was, according to the data of Katsavrias' study,[23] more or less representative of the fully grown articular eminence.

Results of the mean CPIA failed to show any significant differences between the right and left sides either in the child group or the adult group. There was mainly a symmetric growth pattern between the right and the left side of the TMJ in all different age groups. This agrees well with Moffett[24] and Baqaien et al[16] who also found no significant difference in eminence height between the right and left sides.

Different Methods Exist to Measure the Articular Eminence Inclination and Condylar Path Inclination

Measurement of the mean value of the articular eminence inclination was performed using three consecutive sections taken 2.5 mm apart,[4] regenerating one mean value measured at a 10 mm protrusive path each single mm,[16] and using a tangent to the longest curvature of the posterior slope of the eminence.[21] In accordance with Ingervall,[11] we compared the CPIA of the different groups at a protrusive path of 5 mm. In addition we also measured the CPIA at a 3 mm protrusion as a control measurement. We found these values to provide the best information because this area belongs to the central part of the eminence and therefore enables an exact measurement.

CONCLUSIONS

- The null hypothesis that there is no difference between children and adults in the condylar path incli-

nation angle on the right and left sides is rejected. There is a significant difference in the CPIA of the children group and the adult group.

- The mean CPIA increases with age in children. In the oldest chil subgroup (average age: 10.3 years) the CPIA had reached 81.87% on the right side and 78.85% on the left side of the size of the adult group at a 5 mm protrusive path. There is still a remaining increase of about 20%.
- The biggest CPIA is found in the adult group. However, even the final CPIA still undergoes a morphologic alteration process.

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