CORRECTED LATERAL TOMOGRAPHIC ANALYSIS OF GROWTH AND DEVELOPMENT OF THE TEMPOROMANDIBULAR JOINT

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تم إعـداد هذا البحث لدراسـة النمو الأفقي والرأسي لمفصل الفك الصدغي عن طريق فحص الصور الشعاعية المقطعية المصححة للمفصل في واحد وتسعين شخصا تتراوح أعمارهم بين خمسة أعوام إلى عشرين عامًا.
أظهر التحليل الإحصائي للقياسات المأخوذة من هذه الصور الشعاعية أن القياس الأمامي ـ الخلفي للقمة المفصل وكذلك الفراغ الأمامي للمفصل يتزايد مع زيادة السن، في حين يتناقص الفراغ الخلفي للمفصل، مبينًا أن لقمة المفصل تنمو إلى الخلف وليس للأمام.
كذلك أظهرت النتائج أن ارتفاع لقمة المفصل مع رقبة الفك السفلى يتزايد مع زيادة السن في حين يتناقص الفراغ العلوي للمفصل مبينًا أن النمو الرأسي للمفصل يحدث من أسفل إلى أعلى. تبين أيضًا أن الحد الأقصى لنمو المفصل يحدث عند سن ١٧ إلى ١٨ عامًا.
تكمن أهمية هذه النتائج في أنها قد تساعد على فهم أوضح لعملية نمو مفصل الفك الصدغي مما قد يساعد على إعداد خطط العلاج الجراحي أو التقويمي الذي قد يكون له أثر على نمو المفصل.
ونعتقد أيضًا أنه يكون من الأفضل تأجيل أي تدخل جراحي تصحيحي للمفصل لما بعد سن الثامنة عشر عامًا لإعطاء فرصة لاكتمال نمو المفصل.

The antero-posterior, as well as the vertical growth of the temporomandibular joint (TMJ) were studied on corrected lateral cephalometric tomographs of ninety-one male and female subjects, age five to twenty years. Statistical analysis of measurements obtained from these tomograms showed that the antero-posterior width (APW) of the condyle, as well as the anterior joint space (ANTS), increased by age while the posterior joint space (POS) decreased, indicating that the condyle growth is in a posterior rather than anterior direction. The results also showed that the condyle-neck height (HGHT) increased by age while the superior joint space (SUPS) decreased, suggesting an upward vertical growth of the condyle. The maximum anterior posterior, as well as vertical growth, was found to occur at age 17 to 18 years. These findings would be helpful in further understanding the growth and development of the TMJ which might also have significant clinical implications in planning surgical and orthodontic interventions. We believe that any corrective surgical intervention in the TMJ would be better delayed till the age of 18 years, if possible, to allow for complete growth of the joint.

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Introduction

The temporomandibular joint (TMJ) is a true synovial diarthroidal articulation between the mandible and the squamous portion of the temporal bone which develops from the Mekel's cartilage late in embryonic life (at 12 weeks).[1] While both the mandible and squamous and tympanic parts of the temporal bone are considered as membrane bone with no primary

cartilage, the developing condyle contains a secondary cartilage which is replaced by bone during development. At birth, only a thin layer of the cartilage remains over the bony condyle with no secondary center of ossification. This cartilage was reported to disappear at age 16 to 1 7 years.[2] It is reported that TMJ dysfunction in various forms affects between 4 to 28% of the adult population.[3,4] This finding had led to the special interest on TMJ in various levels of research and investigation. The possible effect of maxillofacial surgical and orthodontic interventions on the TMJ necessitates a better understanding of the process of growth and development of this joint. The absence of a typical bony epiphysis or a cartilogenous epiphyseal plate in the developing condyle makes clinical radiographs virtually useless in assessing the growth potential of the TMJ.[1,2] The aim of this study was to evaluate the antero-posterior, as well as the vertical, growth of the TMJ based on corrected lateral cephalometric tomographic measurements in a group of individuals and its different growth stages.

Materials and Methods

Submento vertex radiographs (SMV), as well as corrected lateral cephalometric tomographs, made for the right and left TMJ's of 91 subjects aged 5 to 20 years between 1986 to 1992 at the College of Dentistry, University of Illinois at Chicago were included in this study. These radiographs were made according to referral from orthodontists, with no history of TMJ problems, accidents or obvious developmental abnormalities.

The corrected lateral cephalometric radiographs were made according to the technique developed by Yale and Rosenberg in 1961, and further refined by Yale and Graczyk in 1986.[5,6] Simply, SMV radiographs were made and the horizontal condylar angle was measured, then an antero-posterior tomograph (AP) was made for the TMJ and the vertical condylar angle was measured. Corrected lateral cephalometric radiographs were then made for each joint by placing the patient's head in a specially designed cephalostat and by correcting the individually measured horizontal and vertical condylar angles. On the SMV radiograph, the center of the right and left condyles was identified and the line connecting them was measured indicating the intercondylar space (ICSP) [Figure 1]. The anterior, posterior and superior joint spaces (ANTS, POS and SUPS, respectively) were measured on the corrected tomograms according to the technique designed by Dumas and associates in 1984.[7] The tomographic images were traced on an acetate paper. A reference line was drawn tangential to the most superior aspect of the glenoid fossa. Another line was drawn tangential to the crest of the condyle and parallel to the reference line. A third line (Y axis) was drawn intersecting the height of the fossa and perpendicular to the reference line. A line was drawn from the intersection of the reference line and the Y axis, tangential to the anterior aspect of the condyle, and another line from the same point of intersection tangential to the posterior aspect of the condyle. A perpendicular line was then drawn from the anterior tangential line to the anterior wall of the fossa representing the anterior joint space (ANTS), and another perpendicular line was drawn from the posterior tangential line to the posterior aspect of the fossa representing the posterior joint space (POS). The line from the intersection of the reference line, with the Y axis to the crest of the condyle, represented the superior joint space (SUPS). The antero-posterior width of the condyle was measured as a line joining the anterior pole of the condyle with the posterior pole parallel to the reference line. Finally, a line was drawn tangential to the crest of the sigmoid notch and parallel to the reference line. The distance on the Y axis from the crest of the condyle to this tangential line represents the condyle-neck height (HGHT) [Figure 2]. Four

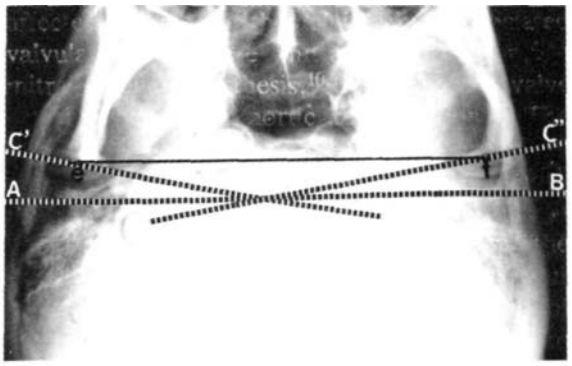

Figure 1. An SMV radiograph showing ICSP measurement; CC' - right condylar axis; CC' - left condylar axis; AB - intermeatal line; e - center of right condyle; f - center of left condyle; ef - intercondylar space "ICSP".

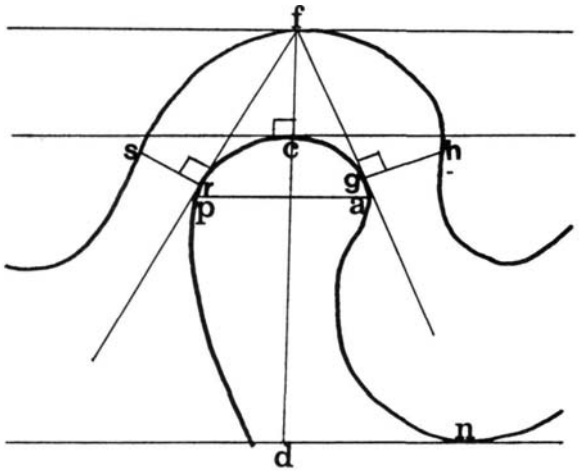

Figure 2. Diagrammatic representation of TMJ measurements: ap - antero-posterior width (APW); cf - superior joint space (SUPS); gh - anterior joint space (ANTS); rs - posterior joint space (POS); cd -condyle-neck height (HGHT); and n - sigmoid notch.

consequent tomographic images in closed mouth made for each joint were traced and previous measurements were done on all of them. Average of measurements obtained from these images was calculated. All tracing? and measurements were done by the same investigator (AEZ). Actual measurements were calculated by correcting the standard 30% magnification factor.

Results

Age and sex distribution of the 91 subjects included in this study are summarized in Table 1. Majority of the subjects were females, with a female to male ratio of 10:3. The overall age range was found to be between 5 to 20 years with a mean age of 13.3 years (SD ± 3.0). For the female subjects, the age range was 5 to 20 years with a mean age of 13.7 years (SD ± 2.8). On the other hand, age range for the male subjects was 6 to 17 years with a mean age of 11.9 years (SD ± 3.3).

The means and standard deviation of the average joint measurements (right and left side) are shown in Table 2. The trend of APW, ANTS, HGHT and ICSP was found to increase by age, however, both POS and SUPS were found to decrease by age. Correlation of right, left and average TMJ measurements with regard to age are shown in Tables 3, 4 and 5, respectively. These tables show

Table 1. Age and sex distribution of subjects evaluated.

Age Group	Gender		
	Female	Male	Total
5-9	5	5	10
	(5.49)	(5.49)	(10.99)
10-11	10	5	15
	(10.99)	(5.49)	(16.48)
12-13	19	3	22
	(20.88)	(3.30)	(24.18)
14-15	22	5	27
	(24.18)	(5.49)	(29.67)
16-17	5	3	8
	(5.49)	(3.30)	(8.79)
18-20	9	0	9
	(9.89)	(0.00)	(9.89)
Total	70	21	91
	(76.92)	(23.08)	(100.00)

that APW (antero-posterior width of the condyle) correlated with the ANTS (anterior joint space) ($P < 0.001$ for the right side, $P < 0.0001$ for the left side and for the average of right and left side measurements). Also, APW showed a significant positive correlation with the height (HGHT) ($P < 0.0001$ for the right side and $P < 0.01$ for the left side and for the average of the right and left side measurements). The posterior joint space POS showed a significant negative correlation with regard to age ($P < 0.01$ for both the right and left sides and $P < 0.001$ for the average of right and left POS). The condylar-neck height (HGHT) showed a positive correlation with age ($P < 0.001$ for the left side, $P < 0.0001$ for both the right side and the average right and left sides). A significant negative correlation was shown between the superior joint space (SUPS) and age ($P < 0.05$ for the right side, $P < 0.0001$ for both the left side and the average right and left sides). The anterior joint space (ANTS) showed a significant negative correlation with the posterior joint space (POS) ($P < 0.05$ for all the three right, left and average right and left sides). Finally, the intercondylar space (ICSP) showed a highly significant positive correlation with age ($P < 0.0001$).

The linear regression of the variables that showed significant correlation was examined by applying the linear regression equation, Ya + bX,

Table 2. Mean and standard deviation of average* TMJ measurements by age groups.

Age Group	APW	ANTS	POS	SUPS	HGHT	1CSP
5-9	11.436 ±1.233	8.315 ± 1.853	5.149 ± 1.730	3.21 3 ± 1.161	18.985 ±3.661	11.440 ±0.602
10-11	11.142 ±1.646	8.627 ±1.221	5.173 ± 1.558	3.328 ±1.070	20.405 ±3.190	11.607 ±0.732
12-13	11.465 ±0.922	8.570 ±1.661	4.742 ±1.567	2.974 ±0.788	21.528 ±2.999	12.186±0.759
14-15	11.500 ±1.345	8.726 ±1.703	3.934 ± 1.169	2.440 ±0.664	22.800 ±2.014	12.575±0.639
16-17	11.171 ± 1.669	7.864 ± 1.209	4.322 ± 1.220	2.589 ±0.522	22.698 ± 3.151	12.850±0.551
18-20	12.066 ±1.664	8.712±1.449	3.668 ±1.030	2.148±0.539	22.316 ± 1.823	12.350±0.472

TM) Measurement:
APW = anterior-posterior width; ANTS = anterior joint space; POS = posterior joint space; SUPS = superior joint space;
HGHT = condylar-neck height; ICSP = intercondylar space; * Average = Average of right and left

Table 3. Correlation matrix of age and right TMJ measurements.

	AGE	APW	ANTS	POS	SUPS
APW	0.0675				
ANTS	0.0247	0.3763***			
POS	-0.3416**	-0.1143	-0.2187*		
SUPS	-0.2534*	0.0009	-0.0472	0.7459****	
HGHT	0.4119****	0.3953****	0.1719	-0.3573***	-0.1103

TMJ measurements: * P < .05; ** P < .01; *** P < .001; **** P < .0001

Table 4. Correlation matrix of age and left TMJ measurements.

	AGE	APW	ANTS	POS	SUPS
APW	0.1488				
ANTS	0.0686	0.4236****			
POS	-0.3134**	-0.0649	-0.2133*		
SUPS	-0.4110****	-0.0077	0.0297	0.7279****	
HGHT	0.3787***	0.3208**	0.2000	-0.2568	-0.1706

* P < .05; ** P < .01; *** P <.001; **** P < .0001

Table 5. Correlation matrix of age and average TMJ measurements.

	AGE	APW	ANTS	POS	HGHT	SUPS
APW	0.1046					
ANTS	0.0385	0.4805****				
POS	-0.3632***	-0.0845	-0.2340*			
HGHT	0.4097****	0.3154**	0.2264*	-0.3906***		
SUPS	-0.4081****	0.0281	-0.0034	0.7331****	-0.1967	
ICSP	0.5166****	0.0564	0.0657	-0.2506*	0.4135****	0.1596

* P < .05; ** P < .01; *** P <.001; **** P < .0001

where V is the predicted dependent variable, a is the point of intercept (where the regression line intercepts the Y axis), b is the regression coefficient and X is the independent variable. The regression coefficient defines the increment of increase or decrease of the dependent variable (according to sign) relative to 1 unit increment increase in the independent variable. The linear regression of height versus age is shown in Figure 3, which shows a positive coefficient (0.504) with $P < 0.0001$. A significant negative linear regression was found between the average POS in relation to age with a regression coefficient (-0.19) and $P < 0.0005$ as shown in Figure 4. Figure 5 shows the negative linear regression of the average SUPS versus age with regression coefficient (-0.123) and $P < 0.0001$. The positive linear regression of the ICSP, relative to age, is shown in Figure 6, where the regression coefficient is 0.126 and $P < 0.0001$. The regression of the average APW versus average ANTS is represented in Figure 7, where a positive linear regression was detected with a regression coefficient of 0.405 and $P < 0.0001$. Finally, the regression line of the average APW versus the average ANTS and POS is shown in Figure 8 where the regression coefficients are 0.42 and $P < 0.005$,

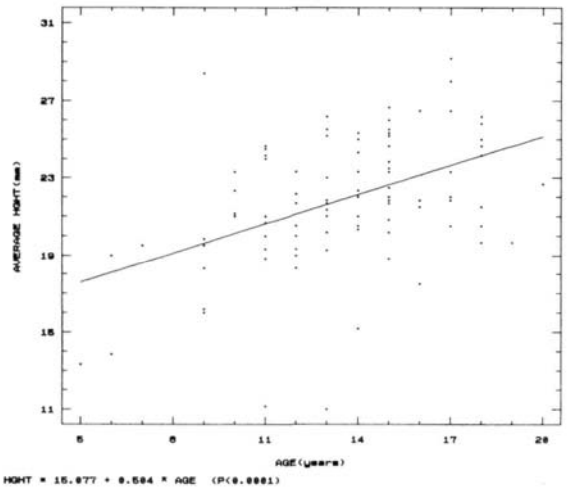

Figure 3. Regression of average height (HGHT) on age.

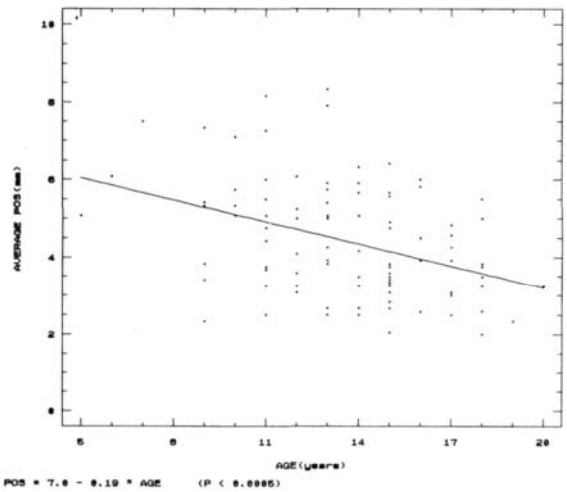

Figure 4. Regression of average posterior joint space (POS) on age.

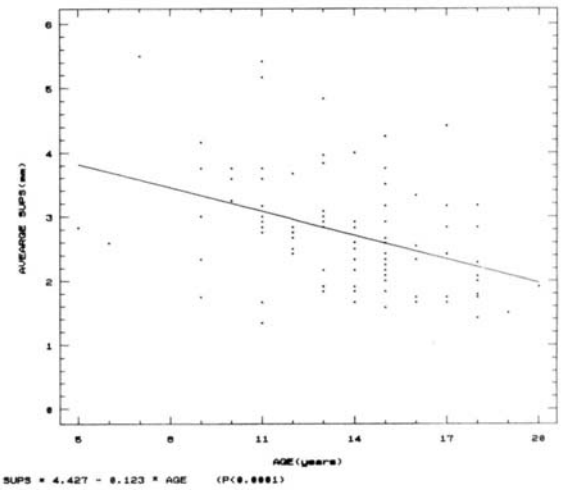

Figure 5. Regression of average superior joint space (SUPS) on age.

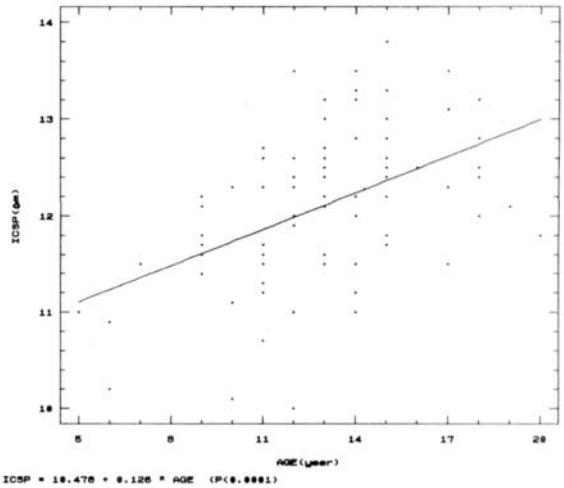

Figure 6. Regression of inter-condylar space (CSP) on age.

respectively. The scattered graphs, as shown in Figures 3 - 6, show that the maximum peak of vertical growth occurs at age 17-18 years as illustrated by the maximum height and minimal POS. The maximum ICSP was reached at age 15 and the minimum POS was reached at the age of 18 years.

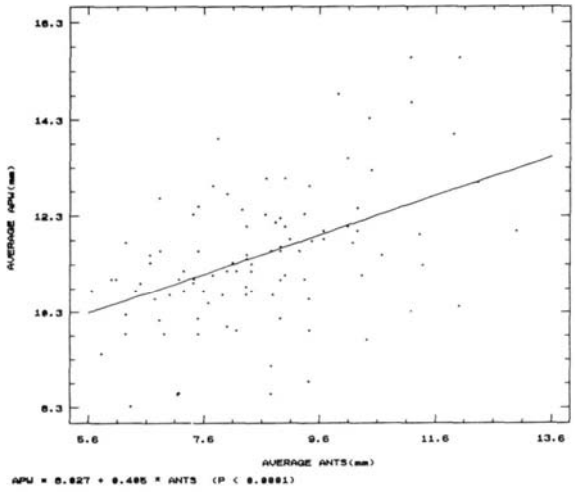

Figure 7. Regression of average antero-posterior width (APW) on age.

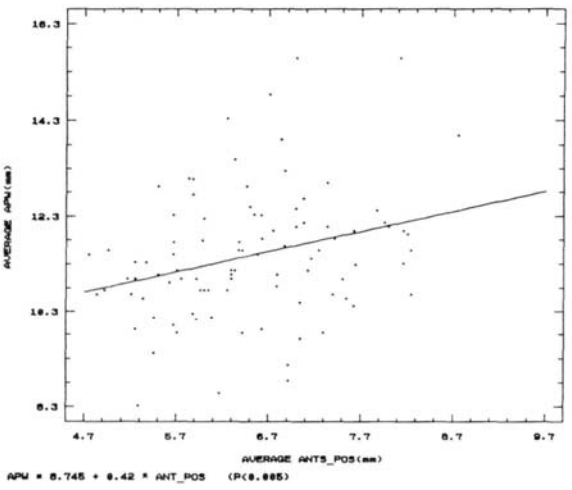

Figure 8. Regression of average antero-posterior width (APW) on average anterior joint space (ANTS) and average posterior joint space (POS).

Discussion

The current study is, to our knowledge, the first attempt to evaluate the directional growth of the TMJ components (condyle, joint spaces and fossa) on radiographic images during the growth phase of the joint. The problem of having no bony epiphysis on the condyle makes evaluating the growth potential of the condyle a difficult task on routine clinical radiographs. Measuring the joint spaces (ANTS, POS and SUPS), as well as the HGHT, ICSP and APW, might aid in understanding the growth status of this joint. The advent of obtaining true images of the TMJ by correcting for the horizontal and vertical condylar angulation when producing tomographic images for the TMJ was previously reported.[5,6,8,9] The accuracy of measuring joint spaces, as well as joint relationships, using the corrected lateral cephalometric tomographs was also reported by Haffez and associates in 1987.[10] Applying the technique of measuring the various joint spaces, as described by Dumas and associates in 1984, has shown the validity and reproducibility of this technique.[7] Measuring the joint spaces was done according to the same technique in a study used by Gianely and his co-workers in 1988.[11] These investigators used the joint space measurements as an indicator for the condylar position in patients who have undergone premolar extraction for orthodontic treatment and patient's without extraction. No difference was found between the two groups as far as the condylar position in the fossa is concerned. The noticeable decrease in the superior joint space (SUPS) accompanied by increase of the condyle-neck height (HGHT) in our subjects indicate an upward vertical growth of the condyle on the expense of the superior joint space. Also, the increase of the antero-posterior width of the condyle (APW) accompanied by decrease of the posterior joint space (POS) in respect to age increase, further indicates the backward growth of the condyle, in the antero-posterior plain. The finding of increase of the anterior joint space (ANTS) by age might be explained by the possibility that such increase might facilitate the position of the growing meniscus. These observations are in agreement with the hypothesis by Mohl in 1979 who suggested that the condyle, with its secondary cartilage grows adaptively, posteriorly and

superiorly to maintain an optimal relationship to the developing temeral squama as the mandible is carried inferiorly and anteriorly within the developing craniofacial complex.[1] The extent of the role of the cartilage on the condyle in the overall growth of the mandible is a controversial one. Many authors believe that the condyle is a primary growth center that governs the overall growth of the mandible, not only under the influence of intrinsic factors, but also displaces the mandible downward and forward.[1216] However, other researches adopted the view that the growth of the mandible occurs secondary to or as an adaptive response to the functional behavior of the oral cavity and associated musculature.[1719] Through his study of the effect of condylectomy on the overall growth of the mandible, Meikle in 1973 has shown that the cartilage on the mandibular condyle does produce periosteal bone.[20] He further suggested that while the condyle does not control the overall growth of the mandible, still, it is essential for the enlargement of the ramus. Our findings of increased condyle-neck vertical height (HGHT) by age, accompanied by decrease of the superior joint space is in agreement with these observations. The results also clearly showed that the peak of vertical as well as the antero-posterior growth of the TMJ is attained at age 1 7 to 18 years. These results are in agreement with the findings of Wright and Moffett in 1974.[2] Our findings might prove to be important for better understanding of the directional growth of the TMJ (antero- posterior and vertical). We also believe that by evaluating the measurements of the joint space pre and post orthodontic or surgical treatment, we might be able to better determine the extent of this treatment on the condylar-fossa relationship. We also suggest that any surgical intervention in the TMJ should be planned at or after the age of 18 years to assure complete growth of the joint and to avoid any interruption in the process of growth.

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