Panoramic radiographic findings of the mandibular growth from deciduous dentition to early permanent dentition

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The outlines of mandibular rami, condyles, coronoid process, and corpus in panoramic radiographs of normal children from deciduous to early permanent dentition were traced and digitized. Nine linear and four angular measurements were measured. During the observation period, the lengths for all the linear measurements increased, however, the angles for all the angular measurements decreased. The shape of condyle and gonion significantly correlated with the growth of ramus and corpus.
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INTRODUCTION

Facial growth tends to proceed along a vector composed of variable amounts of horizontal and vertical growth, as a result of osseous development at facial sutures, alveolar processes, mandibular condyles, and tooth eruption.[1] Schudy[2] reported that growth of the mandible was a principle-determining factor of facial morphology. The mandible, a movable component in mastication, is suspended by the various muscles and ligaments. During the eruption of permanent teeth, the mandible receives a variety of functional forces, but continues to perform sophisticated movements required for mastication as well as speech. The mandible can be divided into four functional components: the condyle, the ramus, the corpus, and the alveolus. To understand how the mandible grows, each component needs to be studied.

Morphological studies of the dentofacial structures in human beings are usually made from radiographs. In particular, the first choice technique used in the imaging of the mandible is panoramic radiography. The panoramic radiography is a device widely used in clinical dentistry because of its simple procedures and low radiation dosage and is often a tool in the routine examination and dental diagnoses, especially for children before the dental treatment. The whole mandible including the two rami and condyles and associated structures are shown on a single panoramic radiograph. The film can provide qualitative and quantitative information and comparison between right and left homologous structures. Even though the use of panoramic radiographs is connected with large methodological pitfalls, some quantitative methods have been used for linear and angular measurements.[3-10]

The purpose of this study was to evaluate, using panoramic radiograph, morphology of mandible and its developmental changes of normal occlusion children through a group of linear and angular measurements.

MATERIALS AND METHODS

Panoramic radiographs of 30 Taiwanese children with deciduous dentition in Hellman's dental developmental stage IIA, 40 with early mixed dentition in Hellman's dental developmental stage IIIA, and 40 with early permanent dentition in Hellman's dental developmental stage IVA were obtained from the files of our department. All subjects had Angle Class I normal occlusion, no previous craniofacial trauma or surgery, and no temporomandibular joint or craniocervical disorders. All panoramic radiographs had good quality. The radiographic method enables imaging of the upper and lower jaws, including the maxillary sinuses and the condylar processes, on one single film. Radiographs that did not include interpretable images of both condyles were excluded.

The outlines of the mandible on each radiograph were traced on overlying matte acetate paper using an x-ray viewer and the reference points and planes (Figure 1) were identified. The selected landmarks were digitized by use of an image analyzer and converted to an X-Y coordinate system and input to the personal computer. Nine linear and four angular measurements (Figure 2) were calculated by using these points.

Reliability of measurement techniques, landmark identification, tracing method, and interrater reliability were statistically analyzed before commencing the

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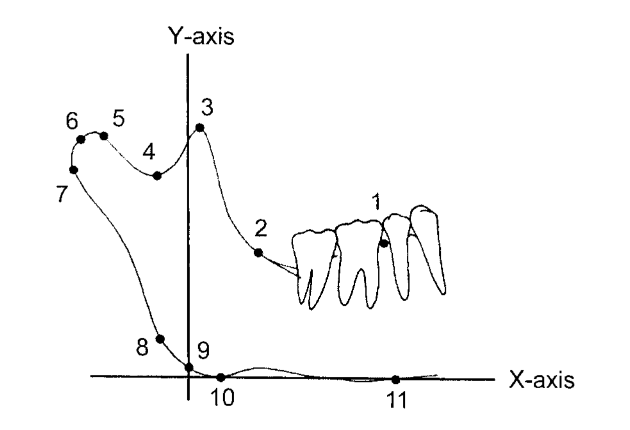

Figure 1. Reference points and planes.

1: distal alveolar crest of the second primary molar or second premolar
2: the deepest point on the bony curvature between the ramus and corpus
3: the most superior point on the coronoid process
4: the deepest point on the mandibular notch
5: the most anterior point on the condyle
6: Condylion (the most superior point on the condyle)
7: the most posterior point on the condyle
8: the most prominent posterior point at the angle of mandible
9: Goinon (the midpoint at the angle of the mandible)
10: the most prominent inferior point at the angle of mandible
11: the mandibular lower border at the reference point 1 region

X-axis: the line connecting the reference points 10 and 11
Y-axis: the vertical line drawn on X-axis through the reference points 9

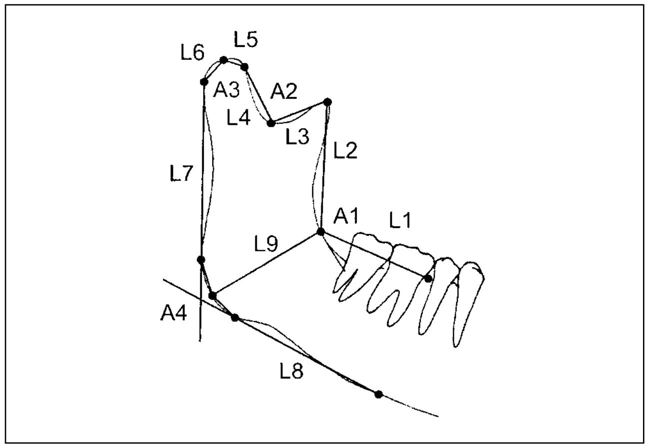

Figure 2. Linear and angular measurements.

L1: linear distance between the reference points 1 and 2
L2: linear distance between the reference points 2 and 3
L3: linear distance between the reference points 3 and 4
L4: linear distance between the reference points 4 and 5
L5: linear distance between the reference points 5 and 6
L6: linear distance between the reference points 6 and 7
L7: linear distance between the reference points 7 and 8
L8: linear distance between the reference points 10 and 11
L9: linear distance between the reference points 2 and 8
A1: angle between the lines L1 and L2
A2: angle between the lines L3 and L4
A3: angle between the lines L5 and L6
A4: angle between the lines L7 and L8

study. Ten randomly selected panoramic radiographs were randomly traced five times on separate days. Resultant measurements on interval variables were averaged and tested for significance by means of an analysis of variance (ANOVA) F-test. A one-factor repeated measure model was fitted to each variable separately and significance values were set at $p < 0.05$. All of the panoramic measurements displayed P values > 0.05. This indicated that no significant variability was noted between tracings.

Statistical analysis was done using SigmaStat software. Mean values and standard deviations of the X and Y coordinate values of the reference points and the linear and angular measurements in each stage were calculated. The Student's *t*-test was used to show whether or not statistically significant differences existed between right and left and between boys' and girls' mean values. However, where the data was significantly skewed or where the intra-group variances differed significantly then the Mann Whitney 'U' test was used instead. One-way analysis of variance (ANOVA) was used for comparison of mean values for each measurement among three stages. Pearson Product Moment correlation test between all the measurements in the three stages was then performed. Significant differences for all correlation coefficients were established at $P < 0.05$.

RESULTS

The means and standard deviations of linear and angular measurements in each stage and *t*-test comparison between boys and girls are shown in Table 1 and Table 2. Because no significant differences were noted between right and left mean values, the results of the comparison are not shown in the Table. Only one measurement (L9 in IIA stage) was found to be significantly different between boys and girls.

Because independent sample *t*-tests showed no significant sex differences for the measurements, data from boy and girl subjects were pooled. Then the mean values and standard deviations for the linear and angular measurements in each stage were plotted and the results of analysis of variance are presented in Figure 3 and Figure 4. There were significant differences in both linear and angular measurements among the three stages. The length for all the linear measurements increased form IIA stage to IVA stage, however, the angle decreased for all the angular measurements.

The results of the correlation analysis are shown in Table 3, Table 4, and Table 5. Significant correlations were found between some measurements (A3, L3, L6, L7, and L8) and the other measurements through the three stages.

The mean outlines of the mandible for the three developmental stages were constructed by connecting

Table 1. The mean values and standard deviations of linear measurements in each stage and t-test comparison between boys and girls.

	Stage														
	IIA					IIIA					IVA				
Linear measurements	Boys (N=14) mean	sd	Girls (N=16) mean	sd	*t*-test	Boys (N=20) mean	sd	Girls (N=20) mean	sd	*t*-test	Boys (N=20) mean	sd	Girls (N=20) mean	sd	*t*-test
L1	17.78	3.73	17.46	3.81	n.s.	23.06	2.80	23.16	3.24	n.s.	29.60	3.45	28.12	3.35	n.s.
L2	23.49	2.16	22.61	1.51	n.s.	23.54	3.36	23.91	2.84	n.s.	30.03	4.12	27.69	4.12	n.s.
L3	15.56	1.40	16.32	2.34	n.s.	17.29	2.57	15.70	2.43	n.s.	19.18	1.96	17.98	2.57	n.s.
L4	14.81	2.37	15.46	3.52	n.s.	16.28	3.19	17.60	4.08	n.s.	18.28	3.65	17.61	2.77	n.s.
L5	5.80	0.66	6.18	0.97	n.s.	6.97	0.88	6.49	1.04	n.s.	7.08	0.87	6.84	1.18	n.s.
L6	5.75	0.82	6.16	0.91	n.s.	6.97	0.74	6.44	1.08	n.s.	7.76	1.41	7.23	1.19	n.s.
L7	32.07	2.33	32.44	2.68	n.s.	35.25	3.98	33.80	3.62	n.s.	41.07	4.28	40.09	4.87	n.s.
L8	28.38	3.72	30.55	4.34	n.s.	34.25	3.76	32.88	4.76	n.s.	41.70	5.51	42.56	5.37	n.s.
L9	27.49	2.54	29.80	3.48	*	32.56	3.68	30.54	5.01	n.s.	34.10	4.53	32.56	4.32	n.s.

n.s. not significant
* $P<0.05$

Table 2. The mean values and standard deviations of angular measurements in each stage and t-test comparison between boys and girls.

	Stage														
	IIA					IIIA					IVA				
Angular measurements	Boys (N=14) mean	sd	Girls (N=16) mean	sd	*t*-test	Boys (N=20) mean	sd	Girls (N=20) mean	sd	*t*-test	Boys (N=20) mean	sd	Girls (N=20) mean	sd	*t*-test
A1	127.23	4.87	130.55	14.24	n.s.	126.27	5.44	128.98	5.35	n.s.	118.44	5.24	114.31	15.65	n.s.
A2	96.77	11.22	97.27	14.99	n.s.	93.04	8.62	91.03	12.92	n.s.	84.86	10.16	87.96	9.00	n.s.
A3	101.63	7.22	102.44	7.34	n.s.	97.60	7.77	96.53	7.62	n.s.	88.38	14.01	90.97	11.26	n.s.
A4	127.63	6.51	124.86	5.57	n.s.	122.53	8.10	123.81	11.14	n.s.	119.23	8.63	117.70	13.93	n.s.

n.s. not significant

the landmarks and the superimposition and their positions relative to Gonion (the reference point 9) and Y-axis are shown in Figure 6. These provide patterns that can be readily compared visually to illustrate relative overall differences between the three stages.

DISCUSSION

Panoramic radiographs have been found to be suitable for analyzing vertical dimensions of the mandible.[3,4] The usefulness of panoramic radiography in epidemiological studies of dental health has been demonstrated in previous study.[11] The method has also been used in studies of the TMJ.[12] This study measured the outline of mandible of children in Hellman's dental developmental stage IIA, IIIA, and IVA by using panoramic radiograph and obtained interesting results.

In linear measurements, there were most amounts of increase of L1 and L8 (both are measurements of mandibular corpus) in comparison with other measurements especially from IIIA stage to IVA stage. The growth of the mandibular corpus was probably due to eruption of the permanent first and second molars. The amounts of change of L2 and L7 (both are measurements of mandibular ramus) from IIIA stage to IVA stage were greater than those from IIA stage to IIIA stage. It is suggested that the growth of the mandibular ramus is remarkable during eruption of the permanent second molars.

For all angular measurements, the angles decreased from IIA stage to IVA stage and the amounts of change from IIIA stage to IVA stage were greater than those from IIA stage to IIIA stage with the four angular measurements as well. The gonial angle of the mandible has been observed to vary with the type of dentition and perhaps also with age.[13,14] It has been accepted that the shape of the mandibular base, and especially the gonial angle of the mandible, correlates with the function of the jaw closing muscles. The contractile power of the masseter and medial pterygoid muscles in particular influences the shape of the mandibular base, because they are inserted into this region.[15]

The condyle is constantly under physiological pressure and shows endochondral growth. Like all joints in the body, the temporomandibular joints are subject to continuous physiological remodelling caused by mechanical stress.[16] The decreases of the four angles in this study were probably due to growth of alveolar bone during molar eruption (A1), growth of coronoid process and function of temporal muscle (A2), growth

Table 3. Pearson Product Moment correlation test between all the measurements in IIA stage

	L1	L2	L3	L4	L5	L6	L7	L8	L9	A1	A2	A3	A4
L1		0.141	0.350	0.141	0.0374	0.260	0.392*	0.664	0.157	-0.192	-0.007	0.216	-0.164
L2			-0.041	-0.174	0.268	0.319	0.401*	0.139	0.171	-0.050	-0.145	0.157	-0.298
L3				0.606***	0.355	0.532**	0.386*	0.482**	-0.049	-0.246	-0.169	0.627***	0.128
L4					0.129	0.233	0.535**	0.342	-0.311	-0.146	-0.246	0.490**	0.554**
L5						0.700***	0.414*	0.299	-0.061	-0.017	-0.008	0.542**	-0.124
L6							0.436*	0.455*	0.179	0.013	0.003	0.580***	-0.133
L7								0.381*	-0.051	-0.093	-0.185	0.529**	0.126
L8									0.074	0.106	-0.265	0.655***	0.014
L9										0.148	-0.075	-0.024	-0.652***
A1											0.013	0.099	-0.022
A2												-0.542**	0.015
A3													0.154
A4													

* P<0.05
** P<0.01
*** P<0.001

Table 4. Pearson Product Moment correlation test between all the measurements in IIIA stage

	L1	L2	L3	L4	L5	L6	L7	L8	L9	A1	A2	A3	A4
L1		0.141	0.196	-0.031	0.188	0.084	0.213	0.463**	-0.184	0.202	0.204	0.279	-0.094
L2			0.346*	0.098	-0.100	0.193	0.558***	0.161	-0.327*	0.026	-0.015	0.176	-0.236
L3				0.390*	0.420**	0.730***	0.441**	0.537***	0.077	0.170	-0.441**	0.709***	-0.457**
L4					0.119	0.499**	0.426**	0.207	0.411**	0.269	-0.412**	0.445**	-0.063
L5						0.644***	0.145	0.491**	0.220	0.125	-0.243	0.559***	-0.142
L6							0.371*	0.547***	0.419**	0.212	-0.516***	0.692***	-0.336*
L7								0.195	-0.034	0.149	-0.139	0.424	-0.428**
L8									0.137	0.376*	-0.354*	0.789***	-0.146
L9										0.117	-0.437**	0.255	-0.118
A1											-0.192	0.404**	-0.079
A2												-0.682***	0.268
A3													-0.259
A4													

* P<0.05
** P<0.01
*** P<0.001

Table 5. Pearson Product Moment correlation test between all the measurements in IVA stage

	L1	L2	L3	L4	L5	L6	L7	L8	L9	A1	A2	A3	A4
L1		-0.146	-0.232	0.152	0.124	-0.020	0.124	0.534***	-0.096	0.135	-0.153	-0.043	-0.249
L2			0.574***	-0.230	0.262	0.391*	0.328*	-0.038	-0.321*	-0.158	0.039	0.094	0.060
L3				-0.121	0.296	0.343*	0.229	-0.112	-0.155	-0.040	0.048	0.373*	0.087
L4					-0.155	0.074	0.484**	0.357*	-0.092	-0.204	-0.201	0.171	-0.126
L5						0.345*	0.086	-0.042	0.018	0.089	0.165	0.188	0.085
L6							0.179	-0.131	-0.178	-0.602***	0.073	0.115	0.016
L7								0.284	-0.071	-0.073	-0.282	0.478	-0.160
L8									0.024	0.222	-0.317*	0.463**	-0.224
L9										0.371*	-0.060	0.281	-0.079
A1											0.219	0.218	0.241
A2												-0.182	0.907***
A3													0.100
A4													

* P<0.05
** P<0.01
*** P<0.001

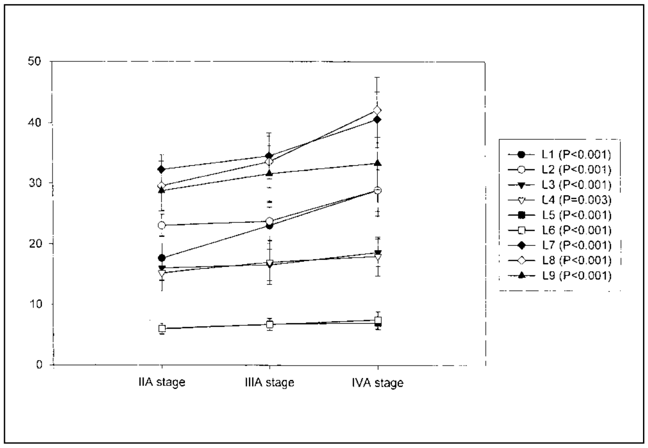

Figure 3. Changes of linear measurements and results of one way ANOVA analysis.

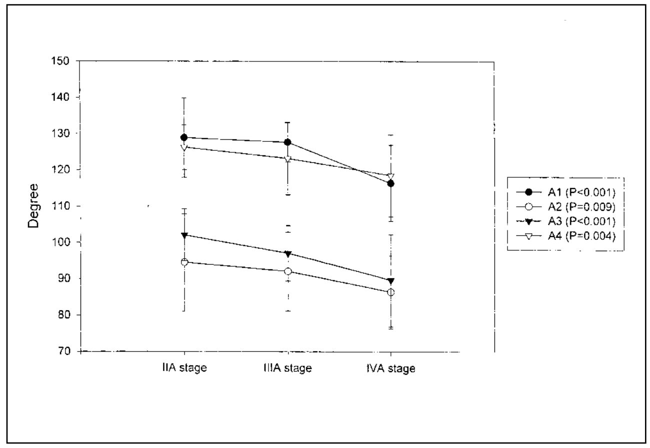

Figure 4. Changes of angular measurements and results of one way ANOVA analysis.

of condyle and function of lateral pterygoid muscle (A3), and bone resorption and deposition and function of masseter and medial pterygoid muscles (A4).

It has been confirmed by the implant technique that growth in the mandible occurs essentially at the condyle.[17,18] Growth at the condyle usually does not occur in the direction of the ramus, but curves slightly forward. On the other hand, Harvold and Vargervik[19] found that bone apposition required to obtain symmetry could be achieved by generating normal muscle balance even in the absence of the condyle. In this study it was found that measurements A3, L3, L6, L7, and L8 were correlate with the other measurements through the three stages. A3 and L6 represent the shape of the condyle, L3 represents the length of coronoid process, and L7 and L8 represent the lengths of ramus and corpus. This finding is full of interesting suggestions; these measurements may be the factors that affect the morphology of the mandible.

The classic theory of mandibular growth is based on the concept that mandibular growth is dependent on a condylar growth center.[20] Growth of this cartilage contributes to the increase of mandibular ramus height, the overall length of the mandible, and the intercondylar distance. Growth of the condyle is in a superior and posterior direction, displacing the mandible downward and forward. The condyle is an important organ in controlling the effective length of the mandible, as well as its spatial position. Previous investigation[21] of condylar shape demonstrated correlations between osseous changes and facial morphology and reported that children with irregular condylar contours had a typical cephalometric configuration with a steep mandibular plane, short mandibular corpus length, and consequently a retrognathic chin. The similar results can be found of this study. There were positive correlations between A3 and linear measurements and negative correlations between A3 and A2 and between A3 and A4. A2 represents the angle between condylar and coronoid processes and A4 represents the gonial angle. It is suggested that the shape of the mandibular condyle might influence growth of mandibular corpus and ramus and that mandible with better growth might have smaller A2 and A4.

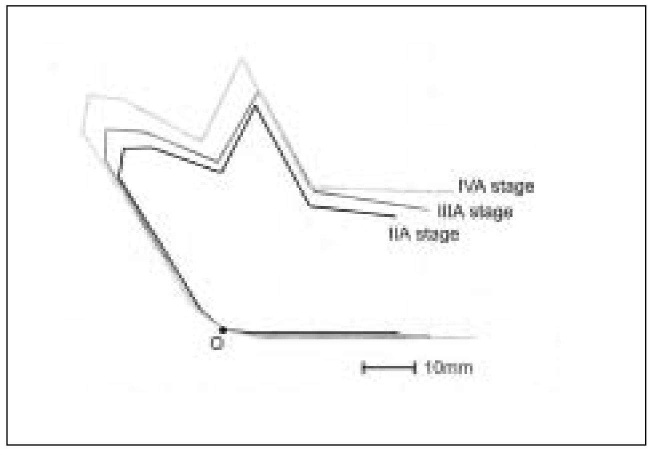

Figure 5. The mean outlines of the mandible for the three developmental stages.

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