Comparison of mandibular growth with other variables during puberty

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Mandibular growth plays a major role in the development of the anteroposterior relationship between the mandible and the maxilla. Remarkable growth occurs in the mandible during puberty, and occlusion of the permanent dentition is largely determined during this period. Mandibular growth, however, shows wide ranges of variability in amount, direction, velocity, sequence and timing. Among these variables, timing is the most critical for orthodontic treatment planning. .

Nanda,[1] Bambha,[2] Hunter,[3] Björk et al.,[4] Fukuhara et al.,[5] Matsumoto,[6] Brown et al.,[7] Tofani,[8] and Bishara et al.[9] used body height as a measure of general skeletal maturation when discussing the timing of mandibular growth. Seide,[10] Johnston et al.,[11] Bergersen,[12] Grave,[13] Pileski et al.,[14] and Fishman[15] related facial growth to hand-wrist growth. Hägg et al.,[16] Lewis et al.,[17] and Demirjian et al.[18] all used sexual maturity as their scale to evaluate craniofacial growth. Lamparski[19] used the cervical vertebrae to assess skeletal age and O'Reilly et al.[20] studied growth of the cervical vertebrae as it relates to mandibular growth.

In each of these previous studies, mandibular growth was compared with one other parameter. The present study was undertaken to examine the timing of mandibular growth during puberty and relate it to the growth of several other components.

Materials and methods

The sample consisted of 33 Japanese girls. Data were compiled from serial lateral cephalometric roentgenograms, hand-wrist roentgenograms and records of body height. Records were collected annually, at nearly the same time of day, from 9 to 14 years of age. The sample consisted of a random selection of skeletal patterns; the choice of material was based solely on the serial completeness of the records and the quality of the roentgeno-

Abstract

The purpose of this investigation was to compare growth characteristics of the mandible during puberty with growth characteristics of the hyoid bone, cervical vertebrae, hand bones and standing height. Data were compiled from serial lateral cephalometric roentgenograms, hand-wrist roentgenograms and body height records of 33 Japanese girls between 9 and 14 years old. Records were updated annually. The mandibular growth rate differed from the other growth rates. The timing of maximum growth velocity of the mandible varied more widely than the timing of maximum growth velocity of the other parameters measured, and the total amount of mandibular growth did not correlate to any other measurement. The timing and magnitude of circumpubertal growth acceleration of various components of the body vary within a certain range of difference. However, the amount and timing of mandibular growth seems to be more variable than the other areas studied.

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Key Words

Growth • Mandible • Cervical vertebrae • Hyoid bone • Standing height • Time lag

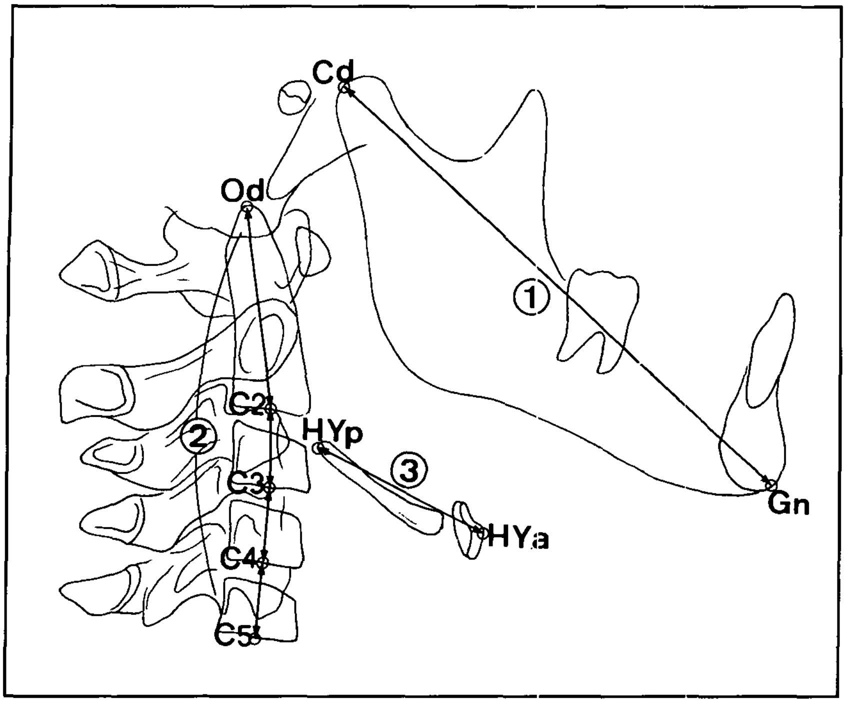

Figure 1

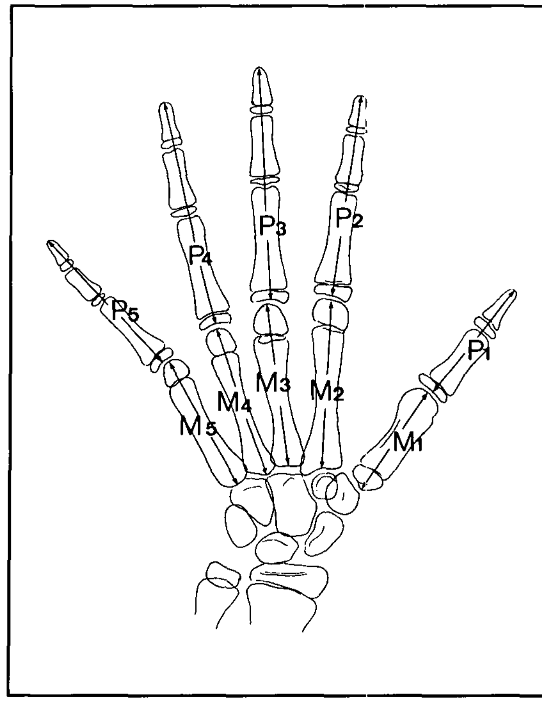

Figure 2

Figure 1
Points and diagram for linear measurements of (1) mandible, (2) cervical vertebrae and (3) hyoid bone.
Cd:condylion - most superior and posterior point of the mandibular condyle
Gn:gnathion - most anterior and inferior point of the mandibular symphysis
Od: - apex of the odontoid process of the axis
C2-C5: - midpoint of the basal width of the axis (C2), the third (C3), fourth (C4) and fifth (C5) cervical vertebrae.
Hya: - most anterior point of the hyoid body
Hyp: - most posterior point of the greater cornue of the hyoid bone.

Figure 2
Points and diagram for linear measurement of hand bones. Length was determined by sum of P + M.

grams. However, since certain types of facial growth may be associated with a tendency toward certain types of malocclusion, only subjects with normal occlusion or minor Class I malocclusion were included in the study. None of the subjects were treated with any type of growth-controlling appliance. Orthodontic mechanotherapy was instituted in some cases late in the study period. Cases were carefully selected to avoid the effects of mechanotherapy on the maxillo-mandibular growth to prevent bias in the growth data.

All records were obtained from the files of the Department of Orthodontics, Tohoku University Dental School, Sendai, Japan.

To compare mandibular growth rates with other growth rates, cervical vertebrae, hyoid bone, hand bones and body height were included in the present study as measurement parameters.

The outline of the mandible, the odontoid process of the axis, the bodies of the second, third, fourth and fifth cervical vertebrae, and the body and greater cornue of the hyoid bone were all traced onto properly registered roentgenograms. The points and diagram for the linear measurements are shown in Figure 1. To measure the cervical vertebrae, the length of each vertebra was taken; because they were not always properly aligned in the x-ray, the sum of four vertebra (second through fifth) was recorded.

To measure the growth of hand bones, outlines of the metacarpus and phalanges (proximal, middle and distal) were traced on hand roentgenograms. These were standardized and the enlargement ratio was negligible. The points and diagram for linear measurement of the hand roentgenograms are shown in Figure 2. The hand bone was measured from the tip of the distal phalange to the bottom of the metacarpus of five fingers. Incremental changes in growth were studied on the data of a total of five fingers.

To determine the rate or velocity of growth during the period studied, the increments of growth of each variable were measured each year. Mean values were determined for each parameter, for each year from 9 to 14 years of age. The size ratios relative to that of 9 years were determined when the subjects were 14 years old and the correlation coefficients between pairs of parameters were determined. The correlation coefficients of the total growth increments were also determined between pairs. The timing of maximum growth velocity for each parameter was examined and similarities were sought.

Results

Means and standard deviations of body height, hand bone, cervical vertebrae, hyoid bone and mandibular length at each age are shown in Table 1. The size ratios between the measurements made at 9 years 6 months and those made at 14 years 6 months are also shown in Table 1.

Correlation coefficients of the length between parameters at each age are shown in Table 2.

The size of the mandible, body height, hand bone and cervical vertebrae all correlated strongly with one other. However, the correlation between

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Table 1
Means and standard deviations of mandibular length, hyoid bone length, cervical vertebral length, hand bone length and body height at each age (n=33)

	9y6m		10y6m		11y6m		12y6m		13y6m		14y6m		size ratio (%)	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Mandible(mm)	100.4	3.7	103.2	4.2	106.2	4.8	109.1	4.7	111.4	4.6	113.0	4.5	12.6	2.2**
Hyoid bone	30.0	2.0	31.0	1.8	32.0	2.1	32.9	2.0	33.5	2.2	33.9	2.2	13.5	5.2**
Cervical v.	70.3	4.3	73.2	4.8	76.7	5.3	80.2	5.5	82.9	5.2	84.2	5.0	19.9	4.1**
Hand bone (cm)	51.3	2.4	54.3	2.9	57.4	2.9	59.9	2.5	61.3	2.2	62.1	2.0	21.3	4.9**
Body Height	131.5	5.9	138.0	6.6	144.2	6.8	150.3	6.6	153.8	5.3	156.1	4.6	18.9	3.8**

**p<0.01

Table 2
Correlation coefficients of the length between each pair of parameters at each age

		9y	10y	11y	12y	13y	14y
Mandible:	Body height	.749**	.763**	.734**	.698**	.679**	.554**
	Hand bone	.674**	.700**	.714**	.639**	.469**	.269
	Cervical v.	.589**	.584**	.586**	.575**	.504**	.352*
	Hyoid bone	.282	.294	.301	.287	.296	.217
Body height:	Hand bone	.844**	.867**	.875**	.788**	.647**	.577**
	Cervical v.	.777**	.804**	.853**	.851**	.813**	.761**
	Hyoid bone	.024	.079	.142	.134	.235	.178
Hand:	Cervical v.	.712**	.749**	.764**	.682**	.605**	.449**
	Hyoid bone	-.069	.006	.048	.126	.179	.194
Cervical v.:	Hyoid bone	.182	.137	.170	.162	.256	.151

**p<0.01, *p<0.05

any two parameters generally became weak with age after the age of 11 years. At 14 years, the strong correlation between the mandible and both the hand bone and cervical vertebrae began to weaken, although other correlations remained strong. The size of the hyoid bone did not correlate to any other parameter at any age. Thus both the mandible and the hyoid bone seem to have different incremental ratios than other parameters.

Body height showed a strong correlation with the hand bone and cervical vertebrae. The correlation was relatively consistent between body height and cervical vertebrae.

The size ratio between 9 and 14 years of age showed that relative size increased for hand bone, cervical vertebrae and body height when compared to hyoid bone and mandible. Paired t-tests showed that the incremental size ratios of the hyoid bone and mandible were significantly smaller than those of the hand bone, cervical

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Table 3
Correlation coefficients of the total growth increment between two parameters

	Mandible	Body height	Hand bone	Cervical vertebrae
Body height	.190			
Hand bone	.160	.874**		
Cervical v.	.260	.597**	.462**	
Hyoid bone	-.089	.149	.241	.112

**p<0.01

Table 4
Sample numbers with percentages in ages at occurrence of maximum growth velocity

	9-10y	10-11y	11-12y	12-13y	13-14y
Mandible	10 30.3%	10 30.3%	6 18.2%	4 12.1%	3 9.1%
Body height	10 30.3%	10 30.3%	10 30.3%	3 9.1%	0
Hand bone	7 21.2%	14 42.4%	9 27.3%	2 6.1%	1 3.0%
Cervical v.	8 24.2%	10 30.3%	9 27.3%	5 15.2%	1 3.0%
Hyoid bone	10 30.3%	8 24.2%	11 33.3%	3 9.1%	1 3.0%

vertebrae and body height at the 1% level of probability. Correlation coefficients of total growth from 9 to 14 years of age are shown in Table 3. Significant correlations were found among body height, hand bone and cervical vertebral length. The correlation was particularly strong between body height and hand bone length, but neither total mandibular growth nor hyoid bone growth showed a significant correlation to any other parameter.

The distribution of age at the time of maximum growth velocity is summarized in Table 4. Maximum growth velocity of body height, hand bone, cervical vertebrae and hyoid bone occurred mostly at the ages of 9, 10 and 11 years, although each showed some variety of distribution in these three ages. The mandible, however, seemed to show a tendency for more variety in distribution of peak growth. Individuals may experience more variation in mandibular growth with regard to the timing of maximum peak occurrence in the pubertal growth period.

In order to study individual variation of the timing of growth, the time lag ratio of coincidence of maximum growth peak was examined. Time lag correlation in this study is the method of analyzing correlations of occurrence of the maximum growth peak between two parameters by a unit of annual lag. Time lag ratio of the timing of the maximum growth peak occurrence between two parameters is shown in Table 5. Without time lag, the maximum growth velocity of the mandible showed simultaneity of timing with any one of the parameters in approximately 50% of the sample. This means that one-half the sample showed a coincidence in timing of the maximum peak occurrence between the mandible and any one of the parameters. However, within a limit of ±1 year lag, the mandible showed a coincidence in maximum peak occurrence with body height in approximately 73% of the sample, with hand bone or cervical vertebrae in 82% and with hyoid bone in 67%.

The timing of maximum peak occurrence of the mandible is not highly correlated to any parameter without time lag.

Discussion

Parameters employed for measurements in this study are structurally, functionally and environmentally different.

The mandible, a movable component in mastication, is suspended by the various muscles and ligaments. It fully accommodates tooth germs which show a unique development in the bone. 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 condyle, the main site of mandibular growth, is constantly under physiologic pressure and shows endochondral growth. Its structure is unique, unlike any observed in other articular cartilage of the body. Thus, the structure and function of the mandible have specific characteristics.

The hyoid bone, suspended from cranial base by the stylohyoid ligaments, also gives attachment to several muscles. Its function relates mainly to jaw movements and deglutition with the interconnection of supra and infra hyoid muscles acting as a connecting point. The body is connected to the greater cornue by a synchondrosis and, after mid-life, usually by bony union as well. Therefore, any increase in size of the hyoid bone

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is assumed to be accomplished by growth of the cartilage.

The cervical vertebrae are articulated by means of fibrocartilaginous inter-vertebral disks and connected with strong ligaments. This system supports the weight of the head with various muscle functions. It represents the vertebral foramina, forming vertebral canals which enclose the spinal cord. The mechanisms of growth in this part of the central nervous system and in bones are different. Therefore, growth of the vertebral column should be related closely to growth of the nervous tissue.

The hand bones are divided into three segments: carpus, metacarpus and phalanges. The present study measured the length of the metacarpus and phalanges which ossify from two centers: one for the body and one for the distal extremity. The hand bones, located at the end of the upper limb, are in a relatively low thermometric condition and far from the craniofacial region.

Body height consists of various components, namely the head, vertebral column, hip bones and lower limb. Body height increases were recorded as the sum of growth of these different components.

The structure, function, environment and location in the body of the parameters measured in this study all have wide ranges of variety. Although the function of each parameter does not necessarily require simultaneity of growth timing, each somehow exhibited remarkable growth in the pubertal period within some ranges of time difference. This means that the pubertal period is basically a growing period for most structures of the body. The differences in timing of peak growth found in this study indicate that the influence of pubertal growth factors may not work simultaneously on each part of the body.

Size ratios showed that the mandible and hyoid bone do not grow as much between the ages of 9 and 14 as the hand bone, cervical vertebrae or body height. This may indicate that the mandible and hyoid bone develop relatively early, before 9 years, perhaps because they are required earlier for functional reasons.

Correlation coefficients show that the size of the mandible is determined independently of the other parameters. This could contribute to the mandible's wider range of variability in relative size among individuals. Body height, hand bone and cervical vertebrae, on the other hand, exhibited a significant correlation in total growth. This may indicate that they are under the stronger influence of an intrinsic genetic factor.

The timing of maximum growth velocity for each parameter shows wide ranges of variability.

Table 5
Sample numbers and percentages showing coincident timing of occurrence of the maximum growth peak between two parameters

Without time lag

	Mandible	Body height	Hand bone	Cervical
Body height	16 48.5%			
Hand bone	17 51.5%	20 60.6%		
Cervical v	15 45.5%	15 45.5%	16 48.5%	
Hyoid bone	16 48.5%	11 33.3%	16 48.5%	13 39.3%
average	48.5%			

With ±1 year time lag

	Mandible	Body height	Hand bone	Cervical
Body height	24 72.7%			
Hand bone	27 81.8%	32 97.0%		
Cervical v	27 81.8%	28 84.8%	30 90.9%	
Hyoid bone	22 66.7%	25 75.8%	27 81.8%	28 84.8%
average	75.8%			

In this study, the total growth of the hyoid bone was smaller than the total growth of any other parameter. Its annual increment may hardly determine a "peak" during growth change.

Regarding the timing of the mandible's maximum growth velocity, only about 50% of the individuals in this study exhibited year-unit coincidence with other parameters. However, bone growth at each portion of the body generally demonstrated a coincidence of occurrence of the maximum growth velocity within a time lag range of a few years. Relative maturity indicators can only show growth trends; the information such indicators provide on mandibular growth is not accurate enough to be useful for precise treatment planning.

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Conclusions

The present study explored some characteristics of mandibular growth during puberty. The results showed that various components of the body undergo a circumpubertal growth acceleration within a range of difference in timing and magnitude. Although the body enters into a process of unique physiological change during puberty, each part of the body acts in a variety of ways due to differences in structure, function and location. Mandibular growth has some unique characteristics of size and timing of peak growth velocity. Although the mandible and hyoid bone resemble each other morphologically, have endochondral growth sites, are correlated functionally, and are very close in location, their growth characteristics did not exhibit a higher degree of similarity than the other parameters.

Thus, growth of each part of a human body may not be well correlated; instead, it may differ randomly within a range of variability according to conditions particular to each part. Orthodontists should understand that mandibular growth may show unpredictable, random variation in timing and amount. When planning treatment, orthodontists should always be careful to recognize such inscrutable biologic phenomenon during active treatment as well as during retention.

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