Morphological study of the human hyoid bone with three-dimensional CT images – Gender difference and age-related changes –

By

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Abstract: The human hyoid bone supports the base of the tongue and is involved in breathing, chewing, and swallowing as well as in the muscle movements associated with articulation. Accordingly it plays an important bone for a human to live. It is a very interesting organ also in multiple special area, including anatomy, mastication, swallowing, articulation, and also forensic medicine. In the morphological study of the human hyoid bone, there is a comparative anthropological research early in 1900, whereas the metrological research has been little reported later. We first used MDCT, and recorded each organic hyoid locus with a three-dimensional image for three-dimensional morphometry of gender differences, age-related changes, and the morphologic characters of the hyoid bone, and compared them with the results of our predecessors. By measuring the volume of the human hyoid bone, we identified gender difference at high rates, and estimated a certain level of ages based on the ossification at the junction area of the hyoid body and greater horns observed. Our results can be applied in the forensic medicine. By examining 600 cases, atypical horseshoes-shapes were found and the existence of the hyoid bone protrusion was demonstrated at high rates.

Introduction

In human anatomy, the hyoid bone is located immediately above the larynx at the height of the third cervical vertebra, and is consisted of the hyoid body, a pair of greater horns and a pair of lesser horns. The hyoid bone shows U-shaped in appearance, and is a small bone that is independent of the skull. To this small bone, ten different muscles that are classified in middle constrictor muscle of pharynx, glossus muscles and hyoid muscles are attached intricately. Stylohyoid ligament is attached to the lesser horn, the hyoid bone is suspended with long stylohyoid ligaments from the styloid process of the temporal bone of the outer skull base and maintains the position of the hyoid bone^{1,2)}. The hyoid bone is phylogenetically equivalent to the structure of a branchial arch. The upper part of the

body, lesser horns, and stylohyoid ligament are derived from the 2nd branchial cartilages, and the lower part of the body and greater horns are derived from the third branchial cartilages³⁾.

In the human hyoid bone, a mutation is often observed that is considered to be the result of ossification and atavisms^{4–6)}. Takada *et al.* compared it with the basic shape of a mammalian hyoid apparatus based on comparative anatomy with other mammalian mutations and reported that the styloid process and stylohyoid ligament is contained in the element of the anterior horn among the basal hyoid bone, anterior horn, and a dorsal horn which compose the mammalian hyoid apparatus. Furthermore, they discussed the changes to the intermediate ligament of the human hyoid anterior horn in relation to human evolution to human bipedal walking. Moreover, the human hyoid bone

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supports the root of the tongue and stabilizes breathing, mastication, swallowing, and the muscle movement of articulation. Therefore, the human hyoid bone is an important bone for a human to live phylogenetically and functionally, and is a very interesting organ also across multiple special areas including anatomy, mastication, swallowing, articulation, and forensic medicine.

The morphological study of the human hyoid bone has been reported by Kamijo⁷⁾, Haga⁸⁾, and Parson⁹⁾. However, they are comparative anthropological researches conducted early in 1900, whereas the metrological research has been little reported thereafter. Moreover, there is no report which examined 600 cases like our study. Gender difference is observed in the size of the hyoid bone, and the hyoid bone of the human male is larger than that of the female^{10,11)}. They were studied in dried skull or cadaver, and their morphological information is limited because it was difficult to do three-dimensional measurement of the hyoid bone with soft tissue or the human radiography with a ruler or slide calipers.

In the 21st century, diagnostic imaging equipment such as CT and MRI has remarkably developed and multi-detector row computed tomography (MDCT) became widespread recently. As a result, collection of the volume data in thin slice became available, and measurement accuracy on three-dimensional CT picture has been improved. Moreover, in Autopsy Imaging (Ai), diagnostic imaging equipment was proved to be effective, and it is widely introducing through the whole country. With this diagnostic equipment, it is easy to measure the volume, length, and angle of the hyoid bone. Moreover, in the hyoid bone, a stable image is obtained without influence of an artifact of a denture. In measurement of the hyoid bone, CT is more effective than MR because the hyoid bone is a bone. After the Great East Japan Earthquake, identification of the victims is relatively easy if they are found immediately after incidence of an earthquake disaster. However, the bodies found 1 or more years later are often difficult to identify with fingerprint matching and gender is often unknown because of severely decomposed bodies. When household and private goods were carried out to sea by at tsunami, the material to identify the body such as hairs necessary for a DNA test is fewer, and the body identification becomes difficult significantly. In the process of changes after death, the denture mold and bones remain to the last. It was covered in the media that the forensic odontology technique was useful in the present earthquake disaster. If a denture mold is matched, it is effective in identification of the body. If a denture mold is absent and gender is identified by the hyoid bone, the family may accept the body. We first observed and measured each part of the hyoid bone *in vivo* using MDCT to investigate gender difference, age-related changes, and three-dimensional morphological features, and compared with the results of predecessors for application of our results to forensic medicine.

Table 1. Age and sex distribution of study subjects

Age Group (Years)	Total	%	Number of Cases			
			Males	%	Females	%
20–29	39	6.5	20	51.3	19	48.7
30–39	54	9.0	26	48.1	28	51.9
40–49	73	12.2	38	52.1	35	47.9
50–59	102	17.0	52	51.0	50	49.0
60–69	129	21.5	73	56.6	56	43.4
70–79	135	22.5	66	48.9	69	51.1
80–89	64	10.7	35	54.7	29	45.3
90–99	4	0.7	0	0.0	4	100.0
Total	600		310		290	

Materials and Methods

We used the data of 600 cases (310 males aged 20–87 years, mean 59.7 years; 290 females aged 20–94 years, mean age 59.6 years) which performed head and neck CT in the International Goodwill Hospital for this study (Table 1). This study was approval by the Ethics Committees of the International Goodwill Hospital and the Komazawa University. Patient information was analyzed after strict anonymity. Image information was anonymized with the code linked to the original data, and was strictly kept in the hospital, and inhibited its carrying out. The numerical data was accumulated in the database after anonymity with the code linked to the original data.

The CT equipment which we used is 64 rows of Light Speed VCT (GE Healthcare Japan), and image parameters are tube voltage of 120 kV, tube current of auto mA, and reconstruction interval of 0.625 mm. Advantage Workstation ver4.4 (GE Healthcare Japan) was used for the three-dimensional image-processing equipment. The three-dimensional image of the hyoid bone was prepared first, and the distance, angle, and volume of each part of the hyoid bone were measured with the measurement tool software of Advantage Workstation at the field of view (FOV) of 13 cm. As shown in Fig. 1, measurement included volume and 10 parameters of hyoid body major axis (A-A'), hyoid body minor axis (B-B'), hyoid body thickness (C-C'), right greater horn length (D-D'), left greater horn length (E-E'), the distance between right and left lesser horns (F-F'), the distance between right and left greater horn centers (G-G'), posterior distal distance between right and left greater horn (D-E), the angle made by the right greater horn and the hyoid body (GHI), and the angle made by the left greater horn and the hyoid body (G'HI). In order to test statistical significance of gender differences, the measurement values of each parameter were tested by the F-test for equality of variance in the mean values of males and females. Student's t-test was selected when the variance was equal, and Welch's t-test was selected for unequal variance under statistical signifi-

Fig. 1. Three views of the measurement points A-A', The major axis of the hyoid body. B-B', The minor axis of the hyoid body. C-C', The thickness of the hyoid body. D-D', The length of the right greater horn. E-E', The length of the left greater horn. F-F', The distance between right and left lesser horns. G-G', The distance between the centers of right and left greater horns. D-E, The Posterior distal distance between right and left greater horns. GHI, The angle made by the right greater horn and the hyoid body. G'H'I, The angle made by the left greater horn and the hyoid body.

Fig. 2. The classification of changes in ossification at the connection between hyoid body and greater horns. The degree of ossification by aging and development of ossification of right and left bones were investigated after ossification was classified into the no fusion observed at the connection area (no fusion: Fig. 2. A, arrow), ossification commenced at the connection area but observed linear junction fusion alone (incomplete fusion: Fig. 2. B, arrow), and the complete ossification without trace of fusion line (complete fusion: Fig. 2. C, arrow)

cance level of $p < 0.05$. Fig. 2 shows the classification of changes in ossification at the connection between hyoid body and greater horns. The degree of ossification by aging and development of ossification of right and left

bones were investigated after ossification was classified into the no fusion observed at the connection area (no fusion), ossification commenced at the connection area but observed linear junction fusion alone (incomplete fusion), and the complete ossification without trace of fusion line (complete fusion). Moreover, the lingual-related morphological features of the hyoid bone are classified into the lingula developed at the center of upper peripheral hyoid body (development), the lingula that its scar was identified (scar), the lingula that was not identified (nothing) (Fig. 3), and their frequencies were examined.

As mentioned above, we investigated gender differences in the hyoid bone, the degrees of age-related changes and bone fusion of hyoid body and greater horn, and the lingula as the morphological characteristics of the hyoid bone.

Results

Measurement values and gender differences in the hyoid bone

The measurement values of the hyoid bone and the results of their significance test (t-test) for gender differences are shown in Table 2. In male and female mean values other than the angle made by the right and left hyoid bodies and greater horns, the statistically significant differences were detected. Their male mean values were higher than female values, and male maximum values did not exceed to female maximum values. On the contrary, female minimum values did not fall below the male minimum values.

In the parameters measured this time, the volume of the hyoid bone showed gender differences significantly. The number of the females who exceeded the male maximum values and the number of the males who are below the female minimum values are shown in Table 3. The 229 females (79.0%) were below the minimum value

Fig. 3. The lingual-related morphological features of the hyoid bone are classified into the lingula developed at the center of upper peripheral hyoid body (development: Fig. 3. A, allow), the lingula that its scar was identified (scar: Fig. 3. B, allow), the lingula that was not identified (nothing: Fig. 3. C, allow)

of 3.270 cm³ of the male hyoid volume, and 172 males (55.5%) exceeded female maximum volume of 4.151 cm³. The means of the hyoid bone volume by ages are listed in Table 4. Changes in the volume by aging were not observed.

The only angle which was made by the right and left hyoid bodies and the greater horns did not show statistically significant differences. The mean values of the angle which was made by the right and left hyoid bodies and the greater horns are listed by ages in Table 5. The significant differences by ages were not observed. Female right and left angles were 10 higher than the male angles.

Age-related changes in the hyoid bone and bone fusion

The connection between the hyoid body and greater horn develops ossification by aging. In our patients, the mean ages of ossification were male 45.9 ± 15.8 years and female 49.6 ± 17.1 years for bilateral non-fusion, male 58.2 ± 14.9 years and female 58.3 ± 14.5 years for unilateral fusion, and male 67.0 ± 12.7 years and female 67.8 ± 14.3 years for bilateral fusion. Moreover, in the unilateral ossification, left side ossification was significant in both sexes (Table 6). Although ossification generally commences in adults, the people who commenced ossification in the ages of 20 years were so fewer as 15% in males and 5.3% in females. The people of 50% and more observed ossification at the ages of 40 years and more in males and at the ages of 50 years and more in females. Development of ossification by aging was observed in approximate 80% of people after the age of 70 years in males and 80 years in females (Table 7). The changes in ossification at the connection between the hyoid bodies and the greater horns classified on the right and left bones separately and were shown in Table 8. The degree of ossification development was classified on the right and left bones separately. The results showed the same age distribution with the results shown in Table 7. Table 9 shows the age distribution of the people who observed unilateral ossification. Only the left side ossification was significantly much more, but there was no significant deviation in age distribution.

Table 2. Measurements of hyoid bone

		A-A'	B-B'	C-C'	D-D'	E-E'	F-F'	D-E	G-G'	DHI	D'H'I	Volume
		[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[°]	[°]	[cm ³]
Males	Mean	27.6	9.4	7.2	34.1	33.5	28.2	48.5	38.7	135.7	135.0	4.308
	SD	2.4	1.4	1.1	2.8	2.8	2.3	7.0	3.7	7.2	7.7	0.664
	Max	36.6	16.0	10.5	44.9	43.1	37.8	69.2	48.6	155.3	156.3	7.159
	Min	20.6	6.3	4.6	27.6	26.9	20.1	32.5	30.5	114.6	113.9	3.270
Females	Mean	22.0	7.8	5.9	30.0	29.6	24.0	42.2	33.0	136.4	136.0	2.949
	SD	2.2	1.2	1.1	2.5	2.5	1.9	5.3	2.8	6.8	7.2	0.449
	Max	27.9	11.9	8.8	36.9	36.7	28.9	57.8	40.9	157.6	159.9	4.151
	Min	16.0	4.8	3.0	20.0	23.6	18.3	27.9	24.9	119.7	116.8	1.893

p > 0.05 * p < 0.05 **

Table 3. Relationship between the maximum and minimum values of each measurement point

	Minimum Value of Male	The Number of Females are Smaller than the Minimum Value of Male	%	Maximum Value of Female	The Number of Males are Greater than the Maximum Value of Male	%
A-A' [mm]	20.6	89	30.7	27.9	128	41.3
B-B' [mm]	6.3	35	12.1	11.9	15	4.8
C-C' [mm]	4.6	38	13.1	8.8	29	9.4
D-D' [mm]	27.6	44	15.2	36.9	52	16.8
E-E' [mm]	26.9	43	14.8	36.7	44	14.2
F-F' [mm]	20.1	11	3.8	28.9	112	36.1
D-E [mm]	32.5	10	3.4	57.8	31	10.0
G-G' [mm]	30.5	61	21.0	40.9	92	29.7
GHI [°]	114.6	0	0.0	157.6	0	0.0
G'H'I [°]	113.9	0	0.0	159.9	0	0.0
Volume [cm ³]	3.27	229	79.0	4.151	172	55.5

Table 4. The average Volume of hyoid bone by age in males and females

Age Group (Years)	Males		Females	
	Average	SD	Average	SD
20–29	4.450	0.701	2.903	0.486
30–39	4.555	0.565	2.933	0.373
40–49	4.376	0.530	2.923	0.496
50–59	4.410	0.677	2.932	0.461
60–69	4.220	0.629	2.893	0.461
70–79	4.199	0.616	2.980	0.460
80–89	4.211	0.901	3.094	0.387
90–99	–	–	2.946	0.336
Total	4.308	0.664	2.949	0.449

Morphological characteristics of the hyoid bone

The appearance of majority of the hyoid bone shows U-shape. In the present study, there were patients who showed the horseshoe-shape, not U-shape (Fig. 4). The hyoid bone of which posterior distal distance (D-E) of right and left greater horns was longer than the distance

(G-G') between measurement site and the center of right and left greater horns was defined as a U-shape, and the hyoid bone of which distance was shorter was defined as a horseshoe-shape. This horseshoe-shape is the shape we first observed and has never been described in the published papers. The horseshoe-shaped hyoid bone was very few, and approximate 90% or more of the hyoid bones showed a U-shape regardless of gender differences and ages (Table 10).

The frequency of the lingula in the center of upper peripheral hyoid bodies is shown in Table 11. Lingula at the hyoid body was clearly observed in 174 males (56.1%) and 161 females (55.5%). If the scar of lingula is included, the lingula was observed in 283 males (91.3%) and 261 females (90.0%). Existence of lingula was identified regardless of gender differences.

Discussion

Previously, we thought that the artifact may exert a serious influence on the analysis of three-dimensional data of the hyoid body obtained by MDCT.

Table 5. Unilateral Angle of hyoid bone in males and females

Age Group (Years)	Males				Females			
	Right Side Angle	SD	Left Side Angle	SD	Right Side Angle	SD	Left Side Angle	SD
20–29	133.4	6.1	131.9	7.0	137.2	6.5	136.3	8.3
30–39	134.8	7.0	133.2	9.3	135.5	7.4	135.1	8.6
40–49	133.9	6.4	133.6	7.9	136.4	5.5	136.3	6.6
50–59	137.4	7.7	135.4	7.7	135.7	6.9	134.8	6.6
60–69	135.9	7.2	136.3	7.6	136.1	6.9	136.0	7.2
70–79	135.3	7.6	134.6	6.9	136.7	7.5	135.8	7.2
80–89	137.8	7.1	136.9	7.7	137.6	6.4	138.4	6.9
90–99	–	–	–	–	136.5	7.7	140.3	2.6
Total	135.7	7.2	135.0	7.7	136.4	6.8	136.0	7.2

However, it was found that stable three-dimensional MDCT data can be obtained without influence of the artifact such as oral denture and implant and also without lack of X-ray doses which determine quality of imaging because of the anatomical spatial location of the hyoid bone. MDCT visualizes CT values alone of the bone and the peripheral soft tissues can be erased, so that the bone tissue of the hyoid bone alone is accurately displayed.

In our method of the three-dimensional measurement with MDCT, the hyoid bone with soft tissue collected from cadaver can be measured using a slide calipers, and accurate measurement by two-dimensional radiography is available.

Gender differences of the hyoid bone

Among the parameters of the hyoid bone measured, the volume of the hyoid bone showed most significant gender differences (Table 2). The people whose volumes were less than the minimal value of 3.270 cm³ of male hyoid

bone were 229 females (79.0%), and 172 males (55.5%) exceeded the maximum volume of 4.151 cm³ of female hyoid bone. It can be estimated that the human whose volume of the hyoid bone is less than 3.270 cm³ is a female with a probability of approximate 79.0%, and the human whose volume is more than 4.151 cm³ is a male with a probability of approximate 55.5% (Table 3). In the mean volume of the hyoid bone by aging, the changes in the volume by aging was not observed, which suggests that formation of the hyoid bone was completed in adults, and the morphology is little changed by aging thereafter (Table 4).

As far as we investigated, there were no reports which measured the volume of the hyoid bone. The measurement using a three-dimensional CT imaging is simple and has high precision, and it can be applied effectively to the forensic medicine. Among the parameters measured, it was only the angle made by the right and left hyoid bodies and greater horns that did not detect statistically significant differences. Kamijo made same conclusion with us that the angle in females was higher than the angle in males without statistical differences⁷⁾. In our study, significant differences in the angle were not observed in gender differences and ages (Table 5).

The unknown dead bodies that deserted and soft tissues were decomposed are difficult to identify their gender. In such case, bone, tooth, and hair are often used for forensics examination. Bone retains the original form for a long period of time. The authors thought that measurement of the hyoid bone might be an effective tool for gender estimation. However, it might have a high risk to estimate gender based on the measurement data of the hyoid bone. In our present study, statistically significant differences were observed in a majority of parameters, but we could not find the standard values for reliable classification of gender differences. Size and thickness of the greater horn might be related. The hyoid bone was not changed by aging. Therefore, measurement of the volume will be most

Table 6. Mean age of hyoid bone fusion in males and females

	Case No	Mean Age (Years)	SD
Males			
Bilateral non-fusion	89	45.9	15.8
Unilateral fusion	43	58.2	14.9
Right side fusion	9	66.2	14.0
Left side fusion	34	56.1	14.6
Bilateral fusion	178	67.0	12.7
Total	310	59.7	16.7
Females			
Bilateral non-fusion	114	49.6	17.1
Unilateral fusion	32	58.3	14.5
Right side fusion	10	54.4	16.9
Left side fusion	22	60.0	13.3
Bilateral fusion	144	67.8	14.3
Total	290	59.6	17.6

Table 7. Fusion of hyoid bone in males and females

Age Group (Years)	Males						Females					
	Bilateral Non-Fusion		Unilateral Fusion		Bilateral Fusion		Bilateral Non-Fusion		Unilateral Fusion		Bilateral Fusion	
	No	%	No	%	No	%	No	%	No	%	No	%
20–29	17	85.0	1	5.0	2	10.0	18	94.7	0	0.0	1	5.3
30–39	19	73.1	4	15.4	3	11.5	17	60.7	4	14.3	7	25.0
40–49	15	39.5	9	23.7	14	36.8	22	62.9	6	17.1	7	20.0
50–59	19	36.5	6	11.5	27	51.9	19	38.0	7	14.0	24	48.0
60–69	13	17.8	14	19.2	46	63.0	19	33.9	6	10.7	31	55.4
70–79	5	7.6	7	10.6	54	81.8	17	24.6	6	8.7	46	66.7
80–89	1	2.9	2	5.7	32	91.4	2	6.9	3	10.3	24	82.8
90–99	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	100.0
Total	89	28.7	43	13.9	178	57.4	114	39.3	32	11	144	49.7

Table 8. Classify degree of bone fusion

Age Group (Years)	Right Side											
	Males						Females					
	No Fusion		Incomplete Fusion		Complete Fusion		No Fusion		Incomplete Fusion		Complete Fusion	
	No	%	No	%	No	%	No	%	No	%	No	%
20–29	18	90.0	1	5.0	1	5.0	18	94.7	0	0.0	1	5.3
30–39	23	88.5	1	3.8	2	7.7	18	64.3	2	7.1	8	28.6
40–49	22	57.9	4	10.5	12	31.6	27	77.1	2	5.7	6	17.1
50–59	25	48.1	9	17.3	18	34.6	24	48.0	11	22.0	15	30.0
60–69	24	32.9	11	15.1	38	52.1	23	41.1	7	12.5	26	46.4
70–79	8	12.1	15	22.7	43	65.2	22	31.9	7	10.1	40	58.0
80–89	3	8.6	5	14.3	27	77.1	4	13.8	0	0.0	25	86.2
90–99	0	–	0	–	0	–	0	0.0	1	25.0	3	75.0
Total	123	39.7	46	14.8	141	45.5	136	46.9	30	10.3	124	42.8

Age Group (Years)	Left Side											
	Males						Females					
	No Fusion		Incomplete Fusion		Complete Fusion		No Fusion		Incomplete Fusion		Complete Fusion	
	No	%	No	%	No	%	No	%	No	%	No	%
20–29	17	85.0	1	5.0	2	10.0	18	94.7	1	5.3	0	0.0
30–39	19	73.1	4	15.4	3	11.5	20	71.4	2	7.1	6	21.4
40–49	17	44.7	9	23.7	12	31.6	23	65.7	4	11.4	8	22.9
50–59	19	36.5	7	13.5	26	50.0	21	42.0	6	12.0	23	46.0
60–69	16	21.9	15	20.5	42	57.5	21	37.5	11	19.6	24	42.9
70–79	9	13.6	13	19.7	44	66.7	18	26.1	9	13.0	42	60.9
80–89	1	2.9	4	11.4	30	85.7	3	10.3	1	3.4	25	86.2
90–99	0	–	0	–	0	–	0	0.0	1	25.0	3	75.0
Total	98	31.6	53	17.1	159	51.3	124	42.8	35	12.1	131	45.2

Table 9. Unilateral fusion of hyoid bone in males and females

Age Group (Years)	Males		Females	
	Right Side Fusion	Left Side Fusion	Right Side Fusion	Left Side Fusion
20–29	0	1	0	0
30–39	0	4	3	1
40–49	2	7	1	5
50–59	0	6	2	5
60–69	3	11	2	4
70–79	4	3	1	5
80–89	0	2	1	2
90–99	0	0	0	0
Total	9	34	10	22

sensitive for estimation of gender differences in the hyoid bone having complicated form. We will clarify the morphological characteristics related to the size of the hyoid bone in the future.

Changes by aging and ossification of the hyoid bone

Ossification of the hyoid bone occurs at the connection between hyoid body and greater horns. Ossification commences in adults, and develops by aging^{12,13}. In our subjects, bilateral complete fusion was observed in the males aged 50 years and the females aged 60 years with a probability of 50% and more, showing that complete fusion in females was delayed for 10 years compared with males. In the population over 80 years of age, a probability is 80% or more in both sexes. Age can be estimated to a certain degree based on the observation of ossified condition.

In our study, there were significantly many people whose left hyoid bone alone was ossified regardless of gender differences and ages. The muscles adhered to the

Fig. 4. The hyoid bone of which posterior distal distance (D-E) of right and left greater horns was longer than the distance (G-G') between measurement site and the center of right and left greater horns was defined as a U-shape (A, B), and the hyoid bone of which distance was shorter was defined as a horseshoe-shape (C).

hyoid bone have origin stops in upper and lower large area, and most of them are concentrated in the hyoid body and the connection between hyoid body and greater horns. These lines are classified into suprahyoid muscle and infrahyoid muscle groups. The suprahyoid muscle is known as opening line and the infrahyoid muscle as swallowing source. Moreover, the line adhered to the hyoid bone has origin stops in the cranium, the lower jaw, sternum, and shoulder blade, and the hyoid bone plays an important role in maintaining the commutative spatial relationship of the bones of the upper body³⁾. In this study, it is difficult

to explain the reason why the ossification of left hyoid bone alone was significant. The authors presume that there are many right-handed individuals among Japanese people, the left jaw is used predominantly for the peculiarity at the time of mastication, or the balance and motor action of the upper body might be involved in the causes, but further research is required in the future. It would be a really challenging question. In the future, ages will be estimated using CT image together with the histological findings of the soft tissues at the connection between greater horns and hyoid body and the results of age-related changes compared with CT image.

The hyoid bone has U-shape formed with the forefinger and thumb, and located under lower jawbone, immediately above the pharynx, at the front third cervical vertebrae and at the position of the third molar tooth. Appearance of all hyoid bones does not always show U-shape, and a tightly angled V-shape is included in them¹⁴⁾. In our study, there were the people having horseshoe-shape neither belonged to U-shape nor V-shape in 4.2% of the males and 2.1% of the females. The connection between hyoid body and greater horns will be ossified by aging, and the angle will be changed. However, the greater horns tended to curve strongly towards the rear inner side in the people having a horseshoe-shape. There were few people who showed horseshoe-shape, and no deviation was observed in their age distribution. It is presumed that asymmetric or the horseshoe-shaped hyoid bone may show any abnormal findings. The population of the hyoid bones examined in this study was so many 600 examples, which contributed to the detection of very rare the horseshoe-shaped hyoid bone.

Hyoid projection

A small process is observed in the hyoid bone at the center of upper peripheral hyoid body. Some process grows well. Large process of the major axis of 5.5 mm was found in this study. Kamijo gave a name of lingula to this process¹⁵⁾. Parson described that such rudimentary lingula belongs to the normal process, the site of incidence is same with the point where thyrolingual duct reaches the hyoid bone, and that this process is the residue of the thyrolingual duct⁹⁾. These processes were found in 65% and 55.9% of Japanese hyoid bones including a rudimentary process, and in 62.0% of South Chinese reported by Kamijo, Haga, and Kinbara, respectively. In our study, clear lingula was observed in 174 males (56.1%) and 161 females (55.5%). If rudimentary lingula was included together, lingula was observed in 283 males (91.3%) and 261 females (90.0%), and existence of lingula was identified regardless of gender differences (Table 11). They were found to be slightly different with the results of Kamijo and others. Since we analyzed the hyoid bone in three dimensions, our detection rate of lingula might have been higher than the results obtained by the method to observe the hyoid bone collected from body donation.

Table 10. Shape of the hyoid bone (Horseshoe-shaped or trapezoidal)

Age Group (Years)	Males				Females			
	D-E > G-G'	%	D-E < G-G'	%	D-E > G-G'	%	D-E < G-G'	%
20–29	19	95.0	1	5.0	19	100.0	0	0.0
30–39	24	92.3	2	7.7	27	96.4	1	3.6
40–49	38	100.0	0	0.0	35	100.0	0	0.0
50–59	51	98.1	1	1.9	50	100.0	0	0.0
60–69	69	94.5	4	5.5	55	98.2	1	1.8
70–79	64	97.0	2	3.0	66	95.7	3	4.3
80–89	32	91.4	3	8.6	28	96.6	1	3.4
90–99	0	0.0	0		4	100.0	0	0.0
Total	297	95.8	13	4.2	284	97.9	6	2.1

D-E > G-G': Trapezoidal

D-E < G-G': Horseshoe-shaped

Table 11. Presence or absence of hyoid bone protrusion

Age Group (Years)	Males						Females					
	Development		Scar		Nothing		Development		Scar		Nothing	
	No	%	No	%	No	%	No	%	No	%	No	%
20–29	10	50.0	8	40.0	2	10.0	14	73.7	5	26.3	0	0.0
30–39	18	69.2	7	26.9	1	3.8	17	60.7	7	25.0	4	14.3
40–49	23	60.5	10	26.3	5	13.2	20	57.1	12	34.3	3	8.6
50–59	30	57.7	20	38.5	2	3.8	29	58.0	13	26.0	8	16.0
60–69	42	57.5	23	31.5	8	11.0	30	53.6	24	42.9	2	3.6
70–79	30	45.5	30	45.5	6	9.1	35	50.7	26	37.7	8	11.6
80–89	21	60.0	11	31.4	3	8.6	15	51.7	10	34.5	4	13.8
90–99	0	–	0	–	0	–	1	25.0	3	75.0	0	0.0
Total	174	56.1	109	35.2	27	8.7	161	55.5	100	34.5	29	10.0

Description of lingula has not been found in any morphological papers and anatomy guidebook after Parson *et al* reported in 1909. In our study, lingula was identified in the people of 90.0% and more. The authors suggest that such existence of lingula is surely the morphological characteristics of the hyoid bone, not the pathologic phenomenon of the hyoid bone, and should be described in the anatomy guidebook in the future.

The forensic odontology technique to use dental records is known to be effective for identification of dead body, which was already proved at the work of victim's body identification in the Great East Japan Earthquake. However, the death toll exceeded 15,000 people, and 3000 or more people are still missing. The body identification for returning the dead body to the family has become extremely difficult. The in-vivo body information used for body identification includes dentistry information, finger palm print, and a DNA type. However, damage of dead bodies increases with lapse of time from disaster. Now it has passed 1 year and more, and individual identification with finger palm-print and DNA type has been in much

more difficult situation. Significance of dentistry for individual identification has been reaffirmed^{16,17)}. Our results suggest that three-dimensional CT of the hyoid bone is effective for estimation of gender and age in addition to conventional techniques when such a great earthquake occurs in any country of the world.

Conclusion

Up to now, there is no measurement science research of the hyoid bone which uses a three-dimensional CT imaging. By using MDCT, we can measure and observe the hyoid bone very easily with high accuracy. Existence of lingula should be described in anatomy guidebooks in the future.

The volume of hyoid bone is effective for identification of gender differences at high rates, and ages are able to estimate to some degree from the level of ossification at the connection between hyoid body and greater horns. These results are applied in the forensic medicine.

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