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Type and Fusion Identification by Age and Sex in Human Hyoid Bone Using 3D CT Images in a Turkish Sample

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ABSTRACT

The morphometric measurement of the hyoid bone has been extensively studied in the literature, although morphological evaluations are covered in a limited number of studies. The aim of this study was to ascertain the fusion status and hyoid bone type and their relationships with age groups and sex.
An examination was made of computed tomography scans of 320 patients. The types and degrees of fusion of the hyoid bone were determined.
Hyoid type-U was most frequently observed in males (25.6%), type-D in females (31.9%) and the overall population (30.8%). There was no statistically significant difference in fusion formation on the right and left sides. The number of bones with fusion increased in both sexes with age (p=0.001). The earliest fusion observed was in a case aged 16 years, and 50% of the cases did not have fusion at age 61 years or older. Unlike previous studies, hyoid type and fusion status were evaluated using discriminant function analysis.
Hyoid type and fusion cannot be indicative criteria for sex and age determination, but it might be feasible to accurately identify a person younger than twenty years old. The data obtained in the current study can be considered to make an important contribution to future studies.

Keywords: Sex Estimation, Type of Hyoid Bone, Fusion, Discriminant Function Analysis, Age.

Introduction

The hyoid bone, which derives its name from the Greek “hyodeides” meaning “in the shape of the letter Upsilon”, plays a role in speech, breathing, eating, and swallowing as well as keeping the airway open between the oropharynx and tracheal rings (1,2). It is the only bone in the body without an articulated joint connecting it to other skeletal bones (3).

The hyoid bone plays a very important role definition of hanging and strangulation in forensic medicine, radiological imaging, surgical procedures, and anthropological studies due to its various functions, clinical consequences, and medico-legal meanings (4). The role of the hyoid bone is not limited to forensic medicine, especially in the identification of deaths as a result of neck trauma such as hanging, strangulation, and manual strangulation, however it also contributes greatly to forensic anthropological studies (5). Forensic anthropological examinations employ the remaining bone fragments to determine the identities of skeletonized, burned, or decomposed corpses, and advances in radiology have made it possible to build greater databases and obtain more trustworthy age and sex estimation results. One of the bones that can be used in identification is the hyoid bone (6).

From an analysis of 504 human hyoid bones, Koebke & Saternus suggested that age estimation could not be based on the connection between the corpus and cornu majus ossis hyoidei. They also performed hyoid bone typing, and observed that

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206 (153 males and 53 females) had parabolic shape, 66 (48 males and 18 females) had horseshoe shape, and 176 (103 males and 73 females) were hyperbolic (7).

Papadopoulos et al identified the hyoid bone into five categories as “U, H, B, D, V” and additionally classified them as symmetric, asymmetric, isometric, and anisometric (8).

Fisher et al defined four fusion categories as distant non-fusion, non-fusion, partial fusion and fusion, and examined bone densities, emphasizing that both fusion category and bone density are important determinants of the age group for adult females (9).

Many previous studies have revealed high rates of sexual dimorphism utilizing hyoid bone measurements and have reported that sex estimation accuracy rates increased with the use of discriminant function analysis (DFA) and machine learning approaches (6).

The morphometric measurement of the hyoid bone has been extensively studied in the literature, although morphological evaluations are covered in a comparatively limited number of studies. Particularly in light of the fact that variations in the hyoid bone occur based on population, research on this topic becomes more valuable (4).

As a pioneering investigation in the Eastern Anatolian population, the aim of this study was to ascertain the fusion status and hyoid bone type and their relationships with age groups and sex.

Material and Methods

Material: An examination was made of computed tomography (CT) scans of 320 patients displaying the hyoid bone from the radiology archives of the Dursun Odabaş Medical Center (Turkey) retrospectively from 31 December 2022. After 40 samples were gathered for each sex from each of four age groups ranging from 1 to 90 years old, the types and fusion degrees of hyoid bone images of 320 patients (160 males and 160 females) were classified. Following an examination of the medical center's Data management system (ENLIL® HBYS), patients with acquired or congenital hyoid bone illness, carcinoma, anomalies or trauma history were not included in the study. Neither were CT images that contained artifacts or that did not fully reveal the hyoid bone.

Radiological Technique: The CT images in the radiology archive were obtained using a 16-Section Multislice CT machine (Somatom Sensation 16; Siemens Medical Solutions, Erlangen, Germany) set up as follows: KV / Effective mAs / Rotation time (sec) values of 120/120 / 0.75; portal rotation time of 420 ms; physical detector collimation of 16 0.6 mm; section thickness of 0.75 mm; final section collimation of 32 0.63 mm; feed/rotate of 6 mm; Core of U90 u; 0.5 mm increment; resolution of 512 × 512 pixels. These previously acquired CT images were uploaded to a workstation (Leonardo, Siemens Medical Solutions, Erlangen, Germany) for DICOM processing in the study. On the workstation, multi-plane pictures and 3D reconstructions were created using the “Volume Rendering Plus InSpace MPR” component of the “SyngoVia” CT program. On sagittal and axial images, anatomical morphometric classification and fusion evaluations were performed utilizing free ROI selection processes.

Classification: Hyoid bones were divided into the following five types according to the classification of Papadopoulos et al (8) (Figure 1).

- Type U is a specific type of hyoid bone that has two straight edges and two semicircular anterior sections that resemble the letter “U”.
- Type H is the standard type hyoid bone, which looks like a horseshoe with a semicircle at the front and two converging edges at the back.
- Type B has the appearance of a boat in cross-section and resembles a semicircle with a diameter the same as the main transverse axis.
- Type D hyoid bones have a semicircular front or a part of it, and one or both of the greater cornua are deviated to one side or the other.
- Type V is a type of hyoid bone that resembles the letter “V” or an inverted triangle.

The fusion status of the right and left greater cornua and corpus of the hyoid bone were classified as “non-fusion”, “partial fusion”, or “complete fusion”, with reference to the work of Fisher et al (10).

After this classification, cases without bilateral fusion were evaluated as the “bilateral non-fusion” group, cases with bilateral partial or complete fusion as the “bilateral fusion” group, and cases with unilateral partial or complete fusion as the “unilateral fusion” group.

Statistical Analysis: Data obtained in the study were analyzed statistically using SPSS (ver: 21), Minitab (ver: 14), and Microsoft Excel 2013 software. Descriptive statistics were presented as mean and standard deviation values for continuous variables, and as number and percentage for categorical variables. The Z test or Fisher's exact probability tests were applied to compare the two group proportions. The statistical significance level in the calculations was set at 5%. Using univariate DFA, the accuracy of univariate sex estimation for all parameters was determined. Sex was determined using linear and stepwise DFA after testing for extra assumptions and normal distribution tests.

Ethics Approval: The study was approved by the Non-Interventional Clinical Research Ethics Committee of Van Yuzuncu Yil University Faculty of Medicine (decision number: 04, dated: 20.01.2023).

Results

The study included hyoid bone CT scans of 160 males with a mean age of 40.9 ± 24.2 years (median, 40.5; minimum, 1; maximum, 86 years), and 160 females with a mean age of 40.9 (median, 40.5; minimum, 1; maximum, 90 years) (p=0.996).

The most commonly seen hyoid type was type-U in males (25.6%; n=41) (p=0.001), type-D in females (31.9%; n=51) (p=0.002), and type-D in the whole population (27.5%; n=88) (p=0.001) (Table 1). Females were seen to be more likely to have type-V hyoid bone than males (p=0.016), and the distribution of other hyoid types according to sex was not statistically significant. The majority of cases in the 1-21 years' age group had type-B hyoid bone (48.8%; n=39) (p=0.001), and type-D hyoid bone was most prevalent in other age groups and the total population (p<0.05 for each).

Partial fusion was detected in 24.1% (n = 77) of the hyoid bones on the right side, 24.4% (n = 78) on the left side, and complete fusion was detected in 24.4% (n = 78) of the right and 21.9% (n = 70) of the left. Fusion did not develop on the right side in 54.7% (n=135) of the hyoid bones and on the left side in 56.6% (n=181). When the fusion degree of the hyoid bone was evaluated for both sides in each age group, for each sex, there was no statistically significant difference in fusion formation on the right and left sides.

When bilateral fusion was evaluated together, no bilateral fusion was detected in 50% of the cases (n=160). The rate of bilateral non-fusion in the hyoid bone was 45% in males and 55% in females (p=0.206). The distribution of both unilateral and bilateral fusion according to sex was not statistically significant (Table 2).

Unilateral and bilateral fusion was observed in just one (1.3%) of the cases in the 1-20 years' age group, and non-fusion was found in the others (97.5%) (p=0.001). Bilateral fusion was detected in a 16-year-old male patient and unilateral fusion was detected in another 18-year-old male patient. In the 21-40 years' age group, there was bilateral non-fusion in 52.5% of the hyoid bones, unilateral fusion in 15% and bilateral fusion in 32.5% (p=0.001). The rates of unilateral or bilateral fusion in males were 5% in the 1-20 years' age group, 47.5% in the 21-40 years' age group, 72.5% in the 41-60 years' age group, and 95% in the 61+ years age group. These rates in females were 0% in the 1-20 years' age group, 47.5% in the 21-40 years' age group, 62.5% in the 41-60 years' age group, and 70% in the 61 years and older age group. Thus, males had a higher rate of fusion formation than females after the age of 41 years (p=0.001). The mean age of non-fused hyoid bones was 23.7±17.1 years in males, 29.9±22.6 years in females and 27.2±20.4 years in the overall population. Unilateral fusion formation was determined at mean age of 53.5±20.9 years in males, 46.6±19.3 years in females, and 50.2±20.2 years in the overall population. The mean age of bilateral fusion formation was determined to be 55.3±19.4 years in males, 56.5±17.3 years in females, and 55.8±18.5 years in the overall population.

The maximum values of the results of univariate and multivariate DFAs were found to be 55.0% in males (with fusion), 66.9% in females (with type), and 56.9% in the overall population (with type). These values were not descriptive of sexual dimorphism (Table 3). When DFAs were applied to age groups, it was determined that 97.5% of the cases could be determined to be between the ages of 1-20 years (with fusion). The maximum accuracy rate in other age groups was 68.8% and it was not possible to make an identification.

Discussion

Despite the fact that the metric approach, which employs 3D reconstruction and has a rigorous, consistent, and repeatable methodology, provides more objective morphological descriptions of the hyoid bone than visual classification, the metric approach still has a morphological structure worth considering, particularly in the fields of forensic medicine and surgery (3).

In previous studies of hyoid typing, authors have defined rates ranging from 18.5% to 55.0% for type U, 10.0% to 25.0% for type H, 9.0% to 31.7% for type B, 5.0% to 63.3% for type V, and

Table 1: Sex and Age Group-Specific Distribution of Hyoid Bone Types

Hyoid Types			U	H	B	D	V	p
Sex	Males	n	41	34	40	37	8	0.001
		%	25.6	21.3	25.0	23.1	5.0	
	Females	n	26	27	35	51	21	0.002
		%	16.3	16.9	21.9	31.9	13.1	
Age Groups (years)	1-21	n	11	4	39	14	12	0.001
		%	13.8	5.0	48.8	17.5	15.0	
	21-40	n	21	15	9	27	8	0.003
		%	26.3	18.8	11.3	33.8	10.0	
	41-60	n	17	22	10	24	7	0.009
		%	21.3	27.5	12.5	30.0	8.8	
	61-61+	n	18	20	17	23	2	0.002
		%	22.5	25.0	21.3	28.8	2.5	
Total		n	67	61	75	88	29	0.001
		%	20.9	19.1	23.4	27.5	9.1	

Table 2: Sex and Age Group-Specific Distribution of Fusion

			Non-Fusion	Unilateral Fusion	Bilateral Fusion	p (fusion)
Sex	Males	n	72	19	69	0.001
		%	45.0	11.9	43.1	
	Females	n	88	17	55	0.001
		%	55.0	10.6	34.4	
p (sex)			.206	.739	.209	
Age Groups (years)	1-21	n	78	1	1	0.001
		%	97.5	1.3	1.3	
	21-40	n	42	12	26	0.001
		%	52.5	15.0	32.5	
	41-60	n	26	12	42	0.001
		%	32.5	15.0	52.5	
	61-61+	n	14	11	55	0.001
		%	17.5	13.8	68.8	
p (age group)			.000	.023	.000	
Total		n	160	36	124	0.001
		%	50.0	11.3	38.8	

9.1% to 29.0% for type D [4,7,8,10-20] (Table 4).

In addition, Kopuz & Ortug described the HK type hyoid bone in 4 of 60 cases (all males) in their series, in which “the right and left greater horns are not located in the same plane and the left horn is curved medially” (15). Of these different series, U type came to the fore in 6 hyoids, V type in 5 hyoids, D type in 2 hyoids, H type equivalent to U type in 1 hyoid, B type equivalent to U type in 1 hyoid, and B and V common type in 1 hyoid. In the current study, the most commonly seen hyoid type was D, while the least common was V, with incidence of 27.5% and 9.1%, respectively (p=0.001).

The majority of previous studies have reported the V-type hyoid bone to be more prevalent in males (36% to 71%) and the U-type hyoid bone to be more common in females (34% to 66%) (12-14,16-18,20). However, Papadopoulos et al found that type D was present more frequently in 47.1% of males while type H and B were equally present more frequently in 15.8% of females (8). Kopuz & Ortug reported that type B was most prevalent for both genders (32.6% in males, 28.6% in females)

Table 3: The Results of Sex and Age Group Estimation with Univariate and Multivariate Discriminant Function Analyses

The Univariate Discriminant Function Analysis			Correctly Matched	Incorrectly Matched	Accuracy Rate
Types of Hyoid	Sex	Males	75	85	46.9%
		Females	107	53	66.9%
		Total	182	138	56.9%
	Age Groups (years)	1-20	65	15	81.3%
		21-40	0	80	0%
		41-60	0	80	0%
		61-61+	38	42	47.5%
		Total	103	217	32.2%
Fusion of Hyoid	Sex	Males	88	72	55.0%
		Females	88	72	55.0%
		Total	176	144	55.0%
	Age Groups (years)	1-20	78	2	97.5%
		21-40	12	68	15.0%
		41-60	0	80	0%
		61-61+	55	25	68.8%
		Total	145	175	45.3%
Multivariate Discriminant Function Analysis			Correctly Matched	Incorrectly Matched	Accuracy Rate
Types + Fusion	Sex	Males	85	75	53.13%
		Females	96	64	60.0%
		Total	181	139	56.6%
	Age Groups (years)	1-20	78	2	97.5%
		21-40	5	80	6.3%
		41-60	7	63	8.8%
		61-61+	55	32	68.8%
		Total	145	175	45.3%

(15). Males had a higher percentage of U-type hyoid bones (33.3%) and females had had a higher percentage of D-type hyoid bones (30%), according to Savitha & Sunitha (19). In the current study, U-type hyoid bone was more common in males (25.6%) and D-type hyoid bone in females (31.9%). In contrast to above mentioned studies [12-14,16-18,20], it was found in the current series that females had a higher likelihood than males of having type-V hyoid bone (p=0.016). Only one study in the literature has examined the correlation between age and hyoid type, and all other studies have evaluated the relationship between age and morphometric measurements and fusion. According to Kopuz & Ortug (15), the majority of bones under the age of 30 years are U and B type (36.8%), the majority of bones between the ages of 31-50 years are type D (28.6%), the majority of bones between the ages of 51-70 years are U and B (35.7%), and the majority of bones above the age of 70 years are type B (66.7%). In the current study, the majority of cases in the 1-21 years age group had type B hyoid bone (48.8%) (p=0.001), while type D hyoid bone was most common in the other age groups and the overall population.

Consistent with previous studies by Fisher et al. (9), Parsons et al. (21), Gupta et al. (22), and D'Souza et al. (23), the current study showed no significant difference in the development of hyoid bone fusion between the left and right sides. According to Jadav et al (24), 79% of the cases with unilateral fusion were on the left side and 21% of them were on the right side in males; 68.7% were on the left side, and 31.3% were on the right side in females. According to Ito et al., in situations of unilateral ossification, left side

Table 4: Percentages of Hyoid Bone Types in Previous Studies (Listed by Publication Date)

Authors	Year	n	Type U	Type H	Type B	Type V	Type D	Type HK
Koebke & Saternus [7]	1979	504 (337M-167F)	34.9%	13.1%	40.9% (B+V)		11.1%	-
Papadopoulos et al. [8]	1989	76 (38M-38F)	18.5%	21.0%	26.5%	5.0%	29.0%	-
Harjeet & Jit [10]	1996	100	26.8%	11.1%	11.5%	25.8%	20.0%	-
Pollanen et al.[11]	1997	100	55.0%	-	45.0% (B+V)		-	-
Leksan et al. [12]	2005	70 (35M-35F)	51.6%	-	48.4% (B+V)		-	-
D'Souza et al. [13]	2013	130 (81M-49F)	48.5%	-	-	51.5%	-	-
Chandekar et al. [14]	2015	66 (42M-24F)	46.7%	-	-	63.3%	-	-
Kopuz & Ortug [15]	2016	60 (46M-14F)	31.7%	10.0%	31.7%	5.0%	15.0%	6.7%
Sameera et al. [16]	2016	100 (66M-34F)	21.0%	14.0%	10.0%	31.0%	24.0%	-
Priya & Kumari [17]	2016	100 (66M-34F)	21.0%	14.0%	10.0%	31.0%	24.0%	-
Srivastava &Jat [18]	2016	100 (50M-50F)	24.0%	15.0%	9.0%	28.0%	24.0%	-
Savitha & Sunitha [19]	2020	60 (30M-30F)	25.0.%	25.0%	15.0%	13.3%	21.7%	-
Shangase et al. [20]	2021	40 (20M-20F)	52.5%	-	-	47.5%	-	-
Chatzioglou [4]	2023	64	23.4% (U+H)		14.1%	10.9%	51.6%	-
Current Study	2024	320 (160M-160F)	20.9%	19.1%	23.4%	9.1%	27.5.%	

M: Male, F: Female; -: Undefined

Table 5: Comparisons of the Mean Ages of Hyoid Bone Fusion in Males and Females Within Several Studies

Authors	Year	Mean Age of Bilateral Non-Fusion		Mean Age of Unilateral Fusion		Mean Age of Bilateral Fusion	
		Males	Females	Males	Females	Males	Females
Gupta et al. [22]	2008	38.26	36.60	38.25	38.00	53.16	48.50
D'Souza et al.[23]	2010	27.04	23.21	39.39	37.50	41.77	45.00
Ito et al. [25]	2012	45.9	49.6	58.2	58.3	67.0	67.8
Jadav et al. [24]	2022	UD	UD	37.0	56.5	42.0	UD
Kose & Goller Bulut [30]	2022	35.96		33.7		39.75	
Current Study	2024	23.7	29.9	53.5	46.6	55.3	56.5

UD: Undefined

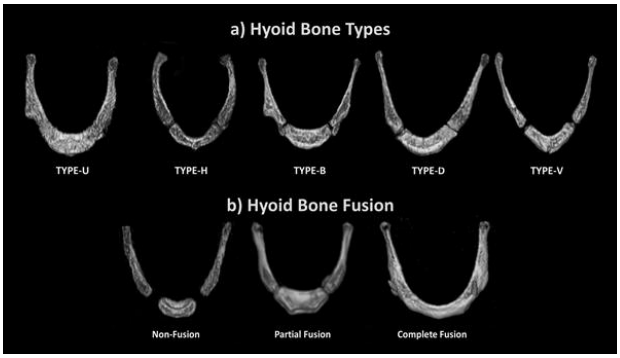

Fig. 1. Classification According to Hyoid Bone Types and Fusion Status (Figure Produced by the Authors of the Article)

ossification was prominent in both sexes (25).

Different opinions have been reported in different studies about the development of fusion formation by sex and age group. In one of the first articles into this topic, Parsson (1909) reported that the morphological appearance of male and female hyoid bones differed, the lesser cornua did not ossify until the age of 14 years, the hyoid bone body completely ossified at the age of 20 years, and that the greater cornua head had a cartilage cap until the age of 30 years (21). O'Halloran and Lundy discovered in 1987 that hyoid bone fusion increased with age, that it occurred more commonly in men than in women, and that it was more common in women to experience unilateral non-fusion (26). The majority of studies carried out in the following years reported that, as confirmed once again in the current study, there was no statistically significant difference in fusion rates between males and females (9,10,23,27,28), and that these rates increased with age for both sexes (22,23,25,27). The literature also has a few alternative definitions in addition to this widely held opinion. According to Shimizu et al (29), fusion of the hyoid joint space was more common in males than in females, possibly related to the earlier onset of cartilage mineralization in males than in females. Kose and Goller Bulut reported that the rate of non-fusion cases in females aged 20-30 years was statistically significantly higher than in males, and there was no significant difference in fusion rates between the sexes over the age of 30 years (30). Some of the articles did not evaluate cases aged 20 years (22,25,27), and the age at which fusion first occurred was defined as 20 years of age by D'Souza et al (23). and Fisher et al. (9), 23 years of age by Jadav et al (24), and 25 years of age by Jadav et al (10). In contrast, Kose and Goller Bulut described 6 hyoid bones showing partial fusion in the under 20 years' age group (30). In the current study, the youngest cases were a 16-year-old male patient with bilateral fusion and an 18-year-old male patient with unilateral fusion. It was thought that the causes of this early fusion could have been undiagnosed endocrine problems or population differences. Other possibilities considered were that the actual age was different as a result of a delay in registration or incorrect registration as is occasionally the case, particularly in the Eastern Anatolia region. Ito et al reported that ossification was seen in more than 50% of the hyoid bones over the age of 40 years in males and over the age of 50 years in females (25), while Jadav et al reported that, contrary to what was previously believed, fusion in the hyoid bone was not completed after the age of 50 years (24). The results of the current study were found to be compatible with the average ages of unilateral and bilateral fusion according to gender reported in the previous literature, which are shown in Table 5 for comparison. Males were shown to have a higher rate of fusion development than females after the age of 41 years in the current study. This can be considered to be associated with osteoporosis formation, which is more common in postmenopausal females.

In the current study, unlike previous studies, hyoid type and fusion status were evaluated with univariate and multivariate DFA according to gender and age groups. The results obtained revealed that hyoid type and fusion cannot be indicative criteria for sex and age determination, in accordance with the results previously described by Koebke and Saternus (7). As a result of DFA, the rate of absence of bilateral fusion was found to be 97.5% in the group under 20 years of age. Additionally, Fisher et al. defined that the non-fusion of the hyoid bone may provide a reliable means of identifying a person under the age of 20 (9).

The data previously obtained based on a relatively small number of observations made on dry bones or cadavers has begun to change in the field of forensic anthropology and anthropology with the use of 3D CT scans.

In the current study, the detection of the proportional excess of type D hyoid bone, the data showing that fusion begins at age 16 years, and that 50% of the cases do not have fusion at age 61 years and over in the Eastern Anatolian population, are some of the important data obtained which differ from the outcomes of earlier studies.

The data obtained in the current study, which reveal the shape and fusion of the hyoid bones as well as the anatomic characteristics of the easthern Anatolian population, can be considered to make an important contribution to future studies in forensic medicine, anthropology, and anatomy.

List of Abbreviations: CT: computed tomography, DICOM: digital imaging and communications in medicine, DFA: discriminant function analysis, and ROI: region of interest

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