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Araştırma/ Research Article

ASSESSMENT OF FORAMEN MAGNUM AND CLIVUS FOR ESTIMATION OF AGE AND GENDER USING CONE-BEAM CT

YAŞ VE CİNSİYET TAYİNİNDE FORAMEN MAGNUM VE KLİVUSUN KONİK IŞINLI BT KULLANIMI İLE DEĞERLENDİRİLMESİ

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ABSTRACAT

Aim: The aim of this study is to perform morphometric analysis of the foramen magnum (FM) and clivus using cone-beam computed tomography (CBCT) and to evaluate their applicability in age and gender estimation.

Materials and Methods: CBCT images of 412 individuals (248 females and 164 males) were included in the study. The sagittal dimension (SD) and transverse dimension (TD) and area of the FM were measured. The width and length of clivus were calculated. The data were statistically analyzed with ANOVA, Kruskal-Wallis and t-tests to assess the level of significance for sex and age.

Result: The mean values of SD, TD, area of FM and width and length of clivus were higher in males than in females. Statistically significant differences were found between sexes for all variables ($p<0.05$). There was no statistically difference between age and FM dimensions ($p>0.05$). There was a significant relationship and positive correlation between length of clivus and age groups ($p=0.009$, $r=0.351$).

Concusion: CBCT provides valuable information about the dimensions of the FM and clivus, and can be used reliably for anthropometric analysis and forensic medicine in the field of sexual dimorphism. The length of clivus can also help in determining age groups.

Keywords: Age estimation, CBCT, clivus, foramen magnum, sex estimation

ÖZ

Amaç: Bu çalışmanın amacı foramen magnum (FM) ve klivusun morfometrik özelliklerini konik ışınlı bilgisayarlı tomografi (KIBT) ile belirleyip ve yaş ve cinsiyet belirlemede kullanılabilirliğini değerlendirmektir.

Materyal ve Metod: 412 bireye (248 bayan ve 164 erkek) ait KIBT görüntüsü çalışmaya dahil edildi. FM'un sagittal boyutu (SB), transversal boyutu (TB) ve alanı ölçüldü. klivusun genişlik ve uzunluğu ölçüldü. Veriler, cinsiyet ve yaş için önem düzeyini değerlendirmek amacıyla ANOVA, Kruskal-Wallis ve t-testleri ile istatistiksel olarak analiz edildi.

Bulgular: SB, TB, FM alanı ile klivus genişliği ve uzunluğuna ait ortalama değerler erkeklerde kadınlara nazaran yüksek bulundu. Tüm değişkenler için cinsiyetler arasında istatistiksel olarak anlamlı fark görüldü ($p<0.05$). Yaş ve FM boyutları arasında istatistiksel olarak farklılık yoktu ($p>0.05$). Klivusun uzunluğu ile yaş grupları arasında anlamlı bir ilişki ve pozitif korelasyon görüldü ($p=0.009$, $r=0.351$).

Sonuç: KIBT, FM ve klivus boyutları hakkında değerli bilgiler sağlar ve cinsiyet ayrımında antropometrik ve adli tıp alanında güvenilir bir şekilde kullanılabilir. Ayrıca klivusun uzunluğu da yaş gruplarının belirlenmesinde yardımcı olabilir.

Anahtar Sözcükler: Yaş tayini, KIBT, klivus, foramen magnum, cinsiyet ayrımı

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INTRODUCTION

In physical anthropology, skull is most studied skeletal remain for sex estimation. [1] It is difficult to define anatomical structures prior to many surgical procedures, so morphometric analysis of the skull is routinely performed by clinical anatomists. In addition, anthropologists can distinguish the age, sex, and race of individuals by physical morphology of face and head. [2] However, gender discrimination poses a major problem in the unknown human skeleton, especially for legal anthropology. It is almost always impossible and complicated to find a perfectly sound skeleton in explosions or battles, because of the fragmentation of the bones and the presence of parts of the victims' bodies, so it is necessary to apply them correctly and carefully. [2, 3] The pelvis is the best and skull is the second best area for gender estimation because the craniofacial structures are less affected by environmental factors and comparatively undamaged. [3] Previous studies have shown that the length of the skull, the circumference and height of the head, the mastoid process, the occipital condyle, measurements were made. [2-6] Forensic age estimation is also needed to identify unidentified bodies and skeletons. Age estimation is important for the legal responsibilities and definitions of living individuals. In current years, migration movements have increased and this increased the demand for estimating the age of living individuals. [7]

Foramen magnum (FM) is a 3-dimensional opening in the basal central region of the occipital bone, and at the same time a transition region between the spine and the skull.[2] FM is an important anatomical landmark due to its position between the brain and spinal cord [6] and is an area of interest for anatomy, anthropology, forensic medicine and other medical fields.[4] Radiographic methods can be used to determine gender by giving the actual dimensions of FM to which certain formulas can be used. [8]

The clivus is a part of the skull base located between the dorsum sellae and magnum. Clivus has a more dense bone structure than the other parts of the skull. It can be saved without being damaged by a burned or damaged skull. Even after burning, clivus can alternatively be used for medical gender estimation with anthropometric measurements.[9] The clivus formation is caused by the fusion of the synchondrosis between the exoccipital and basioccipital bones. After the fusion, it starts to grow. The process of ossification of the clivus starts from the third year and continues until the age of 25 to create basophanoid and basiocciput.[1, 10]

Cone beam computed tomography (CBCT) is a relatively new technology that is used primarily for many applications in the dentomaxillofacial region. [11] CBCT is used in both pre and post-mortem forensic practices and has previously been used for identification [8], age prediction [12], sex estimation [13], restructuring [14] and bite analysis. [15]

In the present study, clivus and FM were assessed quantitatively by CBCT by measuring the width and length of clivus in axial and sagittal section respectively and measuring the sagittal diameter, transvers diameter and the area of the FM in the axial section to determine their medicolegal and forensic significance in morhphometric analysis.

MATERIALS AND METHODS

The study protocol was conducted according to the principles set out in the Declaration of Helsinki, and ethical approval was granted by the Local Ethics Committee of the Medical Faculty of the University.

A total of 412 CBCT images of the skull were analysed from the database of the Dentomaxillofacial Radiology Department of the Bolu Abant Izzet Baysal University by I-Cat System (Imaging Sciences International, Hatfield, PA, USA) Invivo 5. The voxels were isotropic and in 0.3 mm size. Only high quality reconstructed full Field of View (FOV) CBCT images without artefacts were selected. Images with trauma or any surgery history in the skull were excluded. Scans that included full of FM and clivus were assessed.

i. Sagittal Dimension (SD) of FM: The maximum length was measured in the anteroposterior direction along the main axis of the foramen magnum (Fig. 1A).
ii. Transverse Dimension (TD) of FM: The largest transverse diameter of the foramen magnum was measured to be approximately perpendicular to SD (Fig. 1B).
iii. Area of FM; calculated automatically by using Invivo 5 (Anatomage, Inc, San Jose, USA) (Fig.

1C).

iv. The length of clivus (LC) was defined as the longest distance superio-inferiorly from the upper point of dorsum sella to the lowest point on anterior margin of foramen magnum and it was measured on sagittal section in CBCT (Fig 2A).

v. The width of clivus (WC) was defined as the longest distance from left to right side near the anterior peripheral margin of foramen magnum inferiorly and it was measured on axial sections in CBCT (Fig 2B).

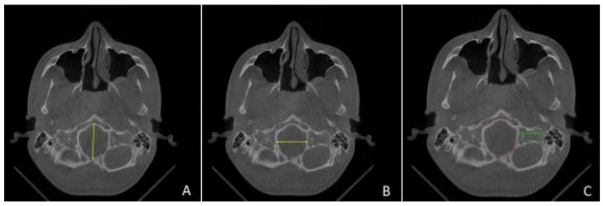

Figure 1.Sagittal diameter (A), transverse diameter (B), area of foramen magnum (c).

Figure 2.Length (A) and width (B) of clivus.

Statistical Analysis

Statistical analyses were conducted with SPSS for Windows SPSS® v. 16.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). Variables between groups were compared using independent t-test between two groups and one-way analysis of variance (ANOVA) test and post-hoc (Gabriel) test for multiple groups comparisons if the data were normally distributed. The Kruskal-Wallis test with post-hoc (Mann-Whitney U with the Bonferroni correction) was performed to analysis differences between data that not normally distributed. Values of $p<0.05$ were considered to indicate statistical significance.

RESULTS

All measurements were performed independently by an oral radiologist with 8 years of experience. Randomly selected 20% CBCT images were evaluated again after 2 weeks to assess the intra-observer's calibration (Pearson correlation coefficients for SD of FM: 0.92, TD of FM: 0.94, area FM: 0.97, LC: 0.92, WC: 0.93).

In total 412 individuals (248 females, %60.2 and 164 males, 39.8%, mean age ± standard deviation: 17.05 ± 10.8) were observed. Majority of the study subjects were between 14 to 15 years of age (27.7%) followed by subjects 12 to 13 years (25.2%), subjects 16 to 17 years (16%), upper than 18 years (17.5%) and lower than 11 years (13.6%) (Table 1). SD, TD, and the area of the FM and length and width of the clivus were calculated in both genders. Table 2 showed the descriptive values of parameters according to genders. There were significant differences between sexes for all variables. Mean values of all measurements were lower in females than in males ($p< 0.05$).

Table 3 shows the descriptive values of all measurements according to age groups. When the measurements were evaluated according to age groups regardless of gender difference, no statistically significant difference was found between all measurements and age groups except the length of clivus ($p=0.009$, $r=0.351$). In Table 4, LC and WC were evaluated separately for women and men according to age groups. For LC, there were significant differences between the age groups in both males and females ($p=0.006$, $p=0.02$ respectively).

Table 1. The distribution of age groups.

Age Group	Number of individuals	Percent
≤ 11	56	13.6
12-13	104	25.2
14-15	114	27.7
16-17	66	16.0
18≤	72	17.5
Total	412	100.0

Table 2. Descriptive values and statistical analyses for all parameters-sex comparative results.

Variables	Sex	Minimum (mm)	Maximum (mm)	Mean	Std. Deviation	P value
SDFM (mm)	Male	16.31	44.14	33.5994	4.74742	0.044*
	Female	15.44	40	32.2592	4.16894	
TDFM (mm)	Male	24.18	44.55	37.0687	4.36493	0.003*
	Female	24.54	42.89	36.2502	3.48333	
Area FM (mm^2)	Male	354.73	1239.04	906.0517	174.04215	0.002*
	Female	265.43	1157.32	850.0767	156.0461	
LC (mm)	Male	35.84	52.01	45.8538	3.51437	0.000*
	Female	34.54	52.56	44.0984	3.66837	
WC (mm)	Male	3215	54.43	44.8741	3.84217	0.003*
	Female	34.36	50.64	42.9065	4.8792	

SDFM; Sagittal dimension of foramen magnum, TDFM; transverse dimension of foramen magnum, area FM; area of foramen magnum, LC; length of clivus, WC; width of clivus.
* Difference is statistically significant P < 0.05 levels.

Table 3. The difference between age groups for all subjects in parameters.

Variables	Age Groups	N	Mean	Std. Deviation	Minimum	Maximum	P value
SDFM (mm)	≤ 11	56	37.4650	2.2006	33.48	42.89	0.053
	12-13	104	37.5354	3.2125	26.27	43.47	
	14-15	114	36.2895	3.7365	24.54	44.55	
	16-17	66	36.2133	3.8061	25.12	41.31	
	18≤	72	35.2850	5.4176	24.18	43.9	
	Total	412	36.5760	3.8691	24.18	44.55	
TDFM (mm)	≤ 11	56	34.0071	2.8483	29.05	40	0.110
	12-13	104	33.3671	3.8257	16.09	40.15	
	14-15	114	32.8495	3.7573	15.71	40.1	
	16-17	66	32.4415	4.4628	15.44	39.16	
	18≤	72	31.2503	6.5689	16.31	44.14	
	Total	412	32.7927	4.4459	15.44	44.14	
Area FM (mm^2)	≤ 11	56	897.0268	112.2139	737.39	1113.94	0.078
	12-13	104	903.5444	141.2314	333.73	1239.04	
	14-15	114	882.8551	140.9252	265.43	1216.16	
	16-17	66	852.5515	197.9177	279.68	1165.34	
	18≤	72	809.6597	217.2589	354.73	1179.34	
	Total	412	872.3580	165.3274	265.43	1239.04	
WC (mm)	≤ 11	56	43.9589	3.8511	36.88	51.09	0.344
	12-13	104	43.9423	2.9846	38.31	52.91	
	14-15	114	44.0512	6.3578	4.36	54.43	
	16-17	66	43.1888	4.3998	31.71	49.67	
	18≤	72	43.0025	3.9248	36.14	50.85	
	Total	412	43.6898	4.5879	4.36	54.43	
LC (mm)	≤ 11	56	43.3064	3.2600	36.18	49.45	p= 0.009* r= 0.351
	12-13	104	44.4035	3.6709	37.47	52.56	
	14-15	114	45.4404	3.2073	39.08	52.01	
	16-17	66	45.1812	4.1179	35.34	51.04	
	18≤	72	45.3656	4.1840	34.54	51.27	
	Total	412	44.4163	3.7572	34.54	52.56	

Table 4. The difference between age groups for man and woman individuals in length and width of clivus

	Variables	Age groups	N	Mean	Std. Deviation	Minimum	Maximum	p value
MALE	LC (mm)	≤ 11	18	43.21	3.00062	38.77	47.97	0.006*
		12-13	42	45.255	3.23859	38.91	51.72	
		14-15	46	46.959	3.17381	41.33	52.01	
		16-17	20	48.086	2.2559	44.27	51.04	
		18≤	38	45.759	3.95217	35.84	51.27	
		Total	164	45.739	3.51437	35.84	52.01	
	WC (mm)	≤ 11	18	45.699	3.90402	39.25	51.09	0.594
		12-13	42	44.971	3.09149	40.2	52.91	
		14-15	46	45.842	3.60964	41.62	54.43	
		16-17	20	43.911	4.96451	32.15	49.22	
		18≤	38	43.712	4.15942	36.85	50.85	
		Total	164	44.874	3.84217	32.15	54.43	
FEMALE	LC (mm)	≤ 11	38	43.352	3.45433	36.18	49.45	0.02*
		12-13	62	43.827	3.88129	37.47	52.56	
		14-15	68	44.413	2.83654	39.08	50.16	
		16-17	46	43.918	4.13273	35.34	50.45	
		18≤	34	44.982	3.56719	34.54	46.57	
		Total	248	44.098	3.66837	34.54	52.56	
	WC (mm)	≤ 11	38	43.135	3.63898	36.88	50.64	0.615
		12-13	62	43.246	2.74399	38.31	49.67	
		14-15	68	42.84	7.49415	4.36	50.52	
		16-17	46	42.875	4.21117	31.71	49.67	
		18≤	34	42.209	3.60097	36.14	49.5	
		Total	248	42.907	4.8792	4.36	50.64	

LC; length of clivus, WC; width of clivus. * Difference is statistically significant p < 0.05 levels.

DISCUSSION

The estimation of the skeleton and the separating human remnants is one of the most difficult issues in forensic medicine. By using metric or morphological methodologies, gender identification can be successful. If almost all of the bones that make up the skeleton are present, gender estimation is easier. Craniofacial structures have the advantage of being formed from a largely rigid tissue, which is relatively harmless. [4, 16] FM is an important and vital structure of the skull base. It has been found that the dimensions between male and female. [17] But this sexual dimorphisms specific to the population, as indicated by the studies related to the people of Iraq[4], Turkey [18] Brazil [19], Poland, [20] and Nigeria. [21] The dimensions of FM are influenced by genetic, environmental and social factors. With this in mind, we conducted our research on the population of the province x in the western Black Sea region in Turkey. FM completes its growth in early childhood. It does not respond to secondary sexual changes, has no effect on size and shape of muscles, and become fairly stable after puberty. [17]

When the previous studies measuring SD and TD of FM were evaluated; Murshed et al. [22] (by using CBCT) found the mean SD values to be 37.2±3.43 mm and 34.6±3.16 mm, and the mean TD values to be 31.6±2.99 mm and 29.3±2.19 mm in males and females respectively. According to the Kanchan et al. [23] SD was 34.51 mm in and 33.6 mm and TD was 27.36 mm and 26.74 mm in males and females respectively. Babu et al. [24] stated the mean value of

the SD in males and females as 35.68 mm and 32.57 mm and TD as 28.91 mm and 28.19 mm. In the study of Uthman et al. [4] (by using Helical CT) (18), the mean value of SD of FM was 34.9 mm for males and 32.9 mm for females. The mean of TD of FM was 29.5 mm and 27.3 mm in males and females, respectively.

According to the Ilgüy et al. [25] reported that on CBCT images, SD was 37.7±2 mm in males and 35.6±4 mm in females; and TD was 32.6±2 mm in males and 31.0±2 in females, close to the results reported in Murshed's [22] study. In the study of Raikar et al.[17], the mean values of SD were 34.19±3.57 mm for males and 32.49±3.17 mm for females. The means of TD were 31.77±3.59 mm in males and 29.66±2.71 mm in females. Akay et al.(by using CBCT) [2] reported the mean values of SD in males and females as 36.4 and 34.6 mm and TD as 31.2 mm and 29.8 mm, respectively. In the study of Tellioğlu et al.[26] (by using CT), in males mean SD was 34.73 ± 2.21 mm, TD was 30.47 ± 2.25 mm, in females mean SD was 32.99 ± ± 2.65 mm, TD was 28.4 ± 2.72 mm. When we evaluate the results of these studies it was noticeable that the measurement averages are higher in men and there are significant differences between the genders ($p < 0.05$). Similarly, the mean values of SD and TD in males were higher than in females in the present study. The differences in the mean values of SD and TD might be due to the difference between the anatomic methods and radiographic techniques used in the previous studies.

The area of FM was automatically calculated using the Invivo 5 (Anatomage) software program. When we examined the literature, we observed that researchers used two formulas to calculate this area: the Texeira formula and the Radinsky formula. Among the Indian studies; Kanchan et al. [23] and Babu [24] used both formulas in their work and determined that the field value obtained by Radinsky's formula was a better determinator of gender. Catalina-Herrera [27] stated the mean values of the FMA in female and male skulls as 801 $mm^2$and 888.4 mm^2, respectively. In the study conducted on Turkish skulls Gunay et al [28] found The area of FM as 909.91 ±126.02 mm^2 for males and 819.01±117.24 mm^2 for females. Uthman et al. [4] measured the The area of FM and the results showed a mean value of 670.2+93.7mm^2 for females and 765.2+98 mm^2 for males. Tellioğlu et al. [26] and Raikar et al. [17] reported The area of FM; in men as 8.17 cm^2 and 800.72 mm^2 , in women 727 mm^2 and 769.9 mm^2, respectively. These results were slightly lower than those of the present study. In the present study The area of FM was measured as 850.05±156.04 mm^2 for females and 906,05±174,04 mm^2 for males. No statistically significant difference was found between the age groups without sex difference for all measurements over FM.

Clivus matures at the age of 11 in both sexes and reaches its final length at this age. It then remains constant throughout life. Eleven years of postnatal life is very important, because the adult width of the clivus is reached at this age. According to Jehan and Kumar [9], male had higher mean clivus length and width than females and this difference was statistically significant ($p <0.0001$). In the study of Chaurasia et al.[1], mean clivus width and length was 28.8 ± 3.98 and 42.7 ± 3.98 mm respectively, regardless of age and sex. Statistically, there was no significant difference between sexes ($p > 0.05$) in clivus width. However, the clivus length in both male and female populations was statistically significant ($p <0.001$). In the male population, the clivus length was greater. Pearson's correlation between age and clivus length and width showed a significant positive correlation ($r = 0.285$, $p <0.001$ and $r = 0.465$, $p = 0.001$ respectively). These findings are summarized in the previous study of Chaurasia et al. [29]. Similar results were obtained in our study, there was a significant relationship and positive correlation between length of clivus and certain age groups ($p=0.009$, $r=0.351$). Because of the strong positive correlation between clivus length and age, clivus length has played an important role in determining age. If the length of the clivus is known, we can estimate the age of the patient. This is a very revolutionary step in the field of forensic science. The present study has also come to the conclusion that clivus length has changed significantly in both sexes.

CBCT is proposed as an alternative imaging modality that can be used to assess biological parameters such as age and sex, to assess trauma, and to predict personal identification. Compared to conventional CT units, CBCT units are cheaper; have higher spatial resolution providing isotropic images; there is a fast scan time; it provides easier access and interaction with data and ease of use and convenience by reducing the need for operation. Low dose

radiation with CBCT also provides an advantage when compared to CT because it is important to protect operators in non-specific locations such as the field or forensic sites or laboratories. For this reason, CBCT is used to compare skeletal structures in both pre-mortem and post mortem imaging phases. However, because of the inadequate soft tissue contrast and limited applications with maxillofacial region and extremities, CBCT is not completely replaceable with classic CT. [8]

In conclusion, according to the results of this study, there is a significant relationship between the gender of the individuals and the sagittal and transverse dimension and area of the foramen magnum and the length and width of the clivus. There was also a significant relationship between the length of the clivus and the ages of the individuals. These significant parameters may be reliably used for sexual dimorphism and age estimation in forensic medicine and anthropometric analysis. CBCT can be used for pre and post mortem imaging in forensic medicine applications.

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