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An International Journal of Experimental and Clinical Anatomy

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Correlation of the depth, medial wall and opening angle of the bicipital groove and the dimensions of long head of the biceps tendon

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Abstract

Objectives: The aim of this study was to investigate the relationship between the morphological measurements of bicipital groove and long head of biceps tendon and determine the effect of age and gender on these measurements.

Methods: The study included 110 patients (60 females, 50 males) aged 18–50 years, who underwent magnetic resonance imaging of the left shoulder between January and December 2020. The patients had stable biceps tendons, and did not have a rotator cuff tear. The bicipital groove morphology was evaluated based on depth, opening angle, medial wall angle and the biceps tendon morphology was assessed based on thickness (anteroposterior length) and width (transverse length).

Results: There was no difference between the females and males in terms of age, opening angle and medial wall angle (p>.05). The bicipital groove depth was lower in the females than in the males (p<.001), while the biceps tendon was thicker in the males compared to the females (p<.001). There was no correlation between age and the sizes of bicipital groove and the biceps tendon. A negative correlation was observed between the bicipital groove depth and opening angle (r=-0.55), and a positive correlation between medial wall angle (r=0.51), tendon thickness (r=0.50) and tendon width (r=0.34). Bicipital groove depth had a positive correlation with tendon thickness (r=0.54) in women and tendon width in men (r=0.28).

Conclusion: The morphological measurements of bicipital groove and the biceps tendon showed correlations. There were also gender differences in these morphological measurements.

Keywords: bicipital groove; long head of the biceps tendon; magnetic resonance imaging; measurement

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Introduction

The bicipital groove (BG) is an indentation formed between the lesser and greater tubercles in the proximal part of the humerus. The lateral edge of the lesser tubercle forms the medial border of BG. This groove includes the long head of the biceps (LHB) tendon, its synovial sheath, and the ascending branch of the anterior circumflex humeral artery. BG is also transformed into a canal by the fibrous transverse humeral ligament that runs between the lesser and greater humeral tubercles.[1–6]

One of the causes of shoulder pain and immobility is abnormalities of the LHB tendon and its synovial sheath. The relationship between the instability of the LHB tendon and the morphology of BG was investigated in some previous studies.[7–10] In these publications, the BG morphology was evaluated based on depth, angle of opening (OA), and medial wall angle (MWA). However, to the best of our knowledge, there is no study investigating the relationship between the morphological measurements of BG and the LHB tendon in individuals with stable LHB tendons.

The aim of this study was to investigate the correlation between the measurements of BG and the LHB tendon and determine the effect of age and gender on these measurements.

Materials and Methods

Patients who underwent left shoulder magnetic resonance imaging (MRI) for shoulder pain between January and December 2020 were retrospectively evaluated. The exclusion criteria were as follows: age below 18 or above 50 years, rotator cuff and LHB tendon partial/full-thickness tear, LHB tendon subluxation/dislocation, history of trauma and operation, mass lesions in bone or soft tissue at shoulder level, cyst in the lesser tubercle region, inflammatory arthritis; inability to evaluate MRI images due to motion artifacts and low quality. After applying the exclusion criteria, 110 patients (60 females, 50 males) were included in the study.

The MRI images (Signa Explorer, GE Medical System, Milwaukee, WI, USA) of the patients were taken with a 1.5T unit using extremity coil. A standardized MRI examination protocol was used and the following five sequences were performed for each patient as oblique coronal T1-weighted fast spin echo (FSE) (repetition of time (TR): 521 ms; echo of time (TE): 15.8 ms; thickness: 3 mm; matrix: 224×224; and field of view (FOV): 16×16 cm), oblique coronal fat-suppressed T2-weighted FSE (TR: 5178 ms; TE: 85 ms; thickness: 3 mm; matrix: 224×224, and FOV: 16×16 cm), oblique sagittal T1-weighted FSE (TR: 575 ms; TE: 15.7 ms; thickness: 3 mm; matrix: 224×224; and FOV: 16×16 cm), oblique sagittal fat- suppressed T2-weighted FSE (TR: 5825 ms; TE: 75 ms; thickness: 3 mm; matrix: 224×224; and FOV: 16x16 cm), oblique axial fat-suppressed proton-density FSE (TR: 2250 ms; TE: 38 ms; thickness: 3 mm; matrix: 224×224; and FOV: 16×16 cm).

As described in previous publications, morphological measurements were performed from the deepest part of the BG midline in each patient.[7–10] The necessary lines and angles were drawn using PACS Viewer (Teknoritma PACS Viewer, v5, Teknoritma Software, Ankara, Türkiye) by a single radiologist (SD).

The morphology of BG was evaluated based on depth, OA, and MWA. The BG depth was defined as the vertical distance between the line connecting the highest points of the greater and lesser tubercles and the line passing through the deepest point of the groove[7,8] (**Figure 1a**). OA represents the angle between the line joining the deepest point of the groove and the highest point of the greater tubercle and the line connecting the deepest point of the groove and the highest point of the lesser tubercle[7,8] (**Figure 1b**). MWA represents the angle between the line connecting the deepest point of the groove to the highest point of the lesser tubercle and the line passing through the deepest point of the groove[7,8] (**Figure 1c**). Lastly, the LHB tendon width (transverse length) and thickness (antero-posterior length) were measured in the same plane (**Figures 2a** and **2b**).

Data were analyzed using IBM SPSS Statistics Standard Concurrent User v. 26 (IBM Corp., Armonk, NY, USA).

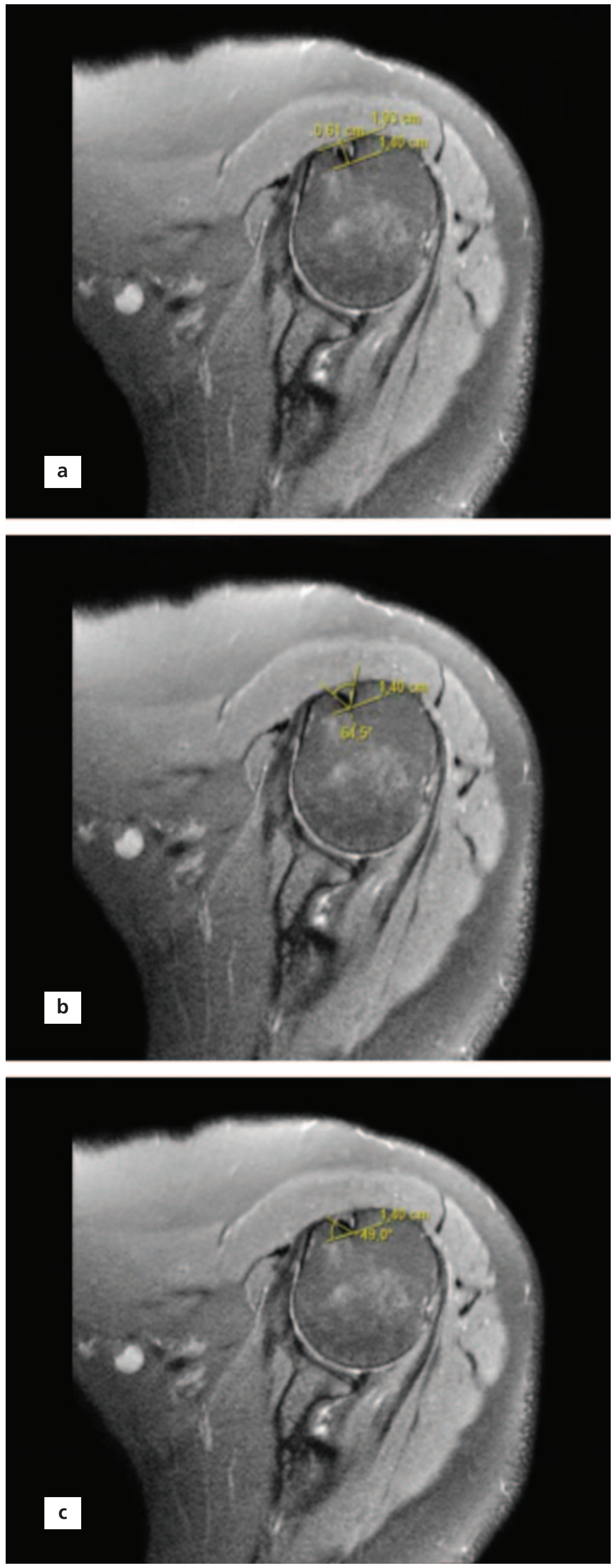

Figure 1. Measurement of the bicipital groove depth (**a**), opening angle (**b**) and medial wall angle (**c**) in a patient on the MR images.

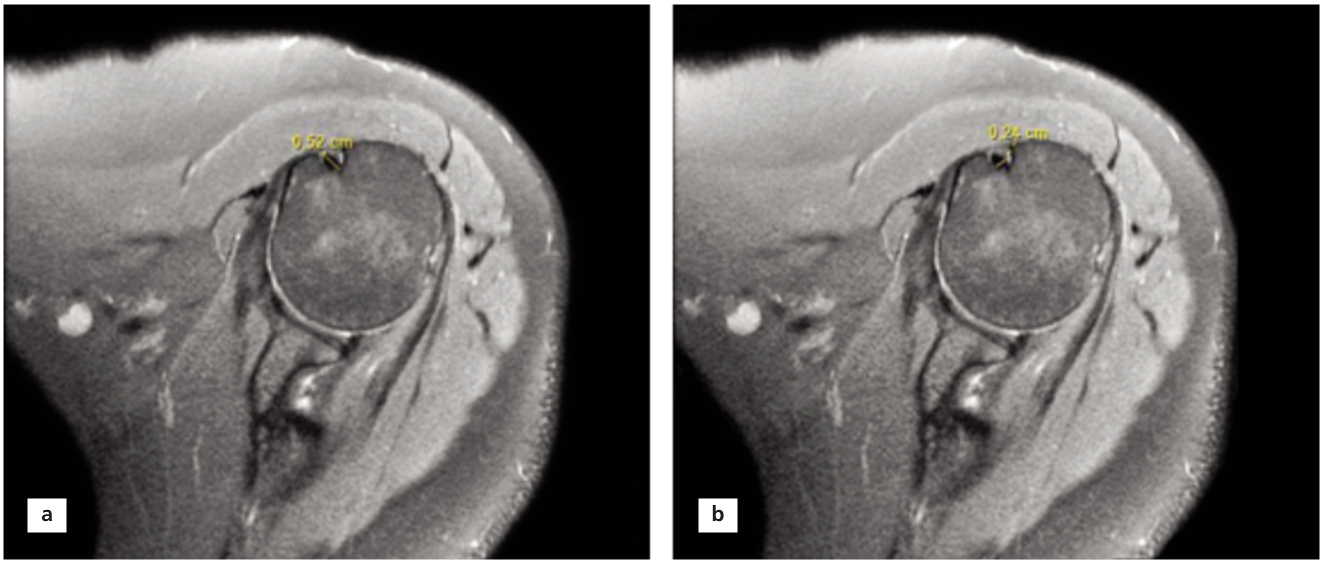

Figure 2. Measurement of the long head of the biceps tendon thickness (**a**) and width (**b**) on the axial MR images.

Descriptive statistics were given as mean±standard deviation ($\overline{X}$±sd) values. The normal distribution of the data belonging to numerical variables was evaluated using the Shapiro-Wilk test of normality, and the homogeneity of the variances was evaluated with the Levene test. The independent-samples t-test was used for the comparisons between gender and age, BG depth, OA, MWA, and LHB tendon thickness and width. Relationships between numerical variables were analyzed with the Pearson correlation analysis. A p-value of <0.05 was considered statistically significant.

Results

The results of the morphological measurements in the study group and the distribution of these measurements by gender are given in **Table 1**.

Of the 110 patients, 60 were females (54.5%) and 50 were males (44.5%). The mean age of the cases was 44.4±11.7 years (44.4±10.1 for the females and 44.5±13.3 years for the males) with no significant difference between the genders.

There was no statistically significant gender difference in terms of OA (p=0.262) and MWA (p=0.054). The BG depth was statistically significantly lower in the females than in the males (p<0.001). The LHB tendon thickness (p<0.001) and width (p=0.001) were statistically significantly lower in the females compared to the males.

No correlation was found between age and the morphological measurements of BG and the LHB tendon for the whole sample. There was a negative correlation

Table 1

Distribution of morphological measurements according to gender and all patients (mean±SD).

		Gender		
	All patients (n=110)	Female (n=60)	Male (n=50)	p-value
Age (year)	44.4±11.7	44.4±10.1	44.5±13.3	0.950
BG depth (mm)	4.78±0.54	4.51±0.54	5.06±0.54	<0.001
Opening angle (0)	79.63±8.30	80.53±8.71	78.73±7.90	0.262
Medial wall angle (0)	48.86±5.60	47.91±5.70	50.01±5.55	0.054
LHB tendon thickness (mm)	4.50±0.43	4.12±0.35	4.88±0.52	<0.001
LHB tendon width (mm)	2.46±0.31	2.35±0.28	2.57±0.37	0.001

BG: bicipital groove; **LHB tendon:** long head of the biceps tendon.

between the BG depth and OA (r=-0.55), and a positive correlation between MWA (r=0.51) and the LHB tendon thickness (r=0.50) and width (r=0.34). In the female patient group, there was also a negative correlation between the BG depth and OA (r=-0.62), and a positive correlation between MWA (r=0.51) and the LHB tendon thickness (r=0.54). A negative correlation was observed between the BG depth and OA (r=-0.50), and a positive correlation between MWA (r= 0.46) and the LHB tendon width (r=0.28) for the male patient group. **Table 2** presents the detailed results of the correlation analysis.

Discussion

One of the findings of the current study is the positive correlation between depth of BG and the LHB tendon. In the current study, the BG depth/LHB tendon thickness ratio was 91% in women and 96% in men.

The BG morphology is important both as an anatomical landmark for LHB tendon stability. The literature contains studies on the anatomical features of BG,[1–6,11,12] of which most have been conducted in cadavers and cadaveric bone collections. In these studies, the BG depth has been commonly measured, and this value is reported to range from 4 to 7 mm.[1–6,11,12] In the current study, we found the BG depth to be 4.78±0.54 mm, which is consistent with previous studies.[1–4,6,12]

Studies on OA and MWA are very limited.[1–3] The measurement of OA was previously reported as 78.31±21.85° by Rajani and Man[1] and 82.58±24.3° by Arunkumar et al.[3] In our study, the mean OA was 79.63±8.3°, which was consistent with the former study. MWA was previously determined as 50.85±10.93° by Rajani and Man,[1] 49.63±10.41° by Arunkumar et al.,[3] and 55.83±4.21° by Ventakesen et al.[2] In the current study, we found the mean MWA to be 48.86±5.6°, which is in agreement with the studies of Rajani and Man[1] and Arunkumar et al.[3]

Different from the studies in the literature, we also investigated the correlation between the morphological measurements of BG. We detected a negative correlation between the BG depth and OA, indicating that OA would be larger in a shallower groove. In contrast, there was a positive correlation between the BG depth and MWA; i.e., MWA would be expected to be lower in a shallower groove.

To the best of our knowledge, there is no publication in the literature investigating the effect of gender on the morphological measurements of BG. Pfahler et al.[13] showed that the BG width and depth differed by gender on X-ray films. The mean width of BG was smaller in women than in men. Khan et al.[5] reported that the BG depth was greater in women compared to men, but this was statistically non-significant. Kavak et al.[7] revealed that women with unstable LHB tendons had a smaller MWA than men. In our study, the BG depth was statistically significantly lower in the females compared to the males. OA was greater and MWA was smaller in the females compared to the males, but there were no statistically significant differences in these parameters.

The morphology of BG should be considered as a potential factor affecting the stability of the biceps tendon.[8] There are publications in the literature reporting that a shallow bicipital groove, defined based on a larger OA, smaller MWA, and shallower depth, may be a predisposing factor for biceps tendon instability.[7,8] In our study, we showed that the women had shallower grooves. There is a need for further studies to determine whether women are more prone to LHB tendon instability.

There are very few publications in the literature investigating the effect of gender on the LHB tendon sizes.[14–16] Walton et al.[14] demonstrated that this tendon had an ovoid cross-sectional shape. In a cadaver study, Khan et al.[15] revealed that the LHB tendon width was

Table 2
Correlation between the morphological measurements of BG and the LHB tendon.

		Opening angle		Medial wall angle		LHB tendon thickness		LHB tendon width		BG depth	
		r	p	r	p	r	p	r	p	r	p
All patients	Age	-0.151	0.115	0.065	0.501	0.137	0.154	0.029	0.761	0.082	0.395
	BG depth	**-0.557**	**< .001**	**0.518**	**<.001**	**0.505**	**<.001**	**0.344**	**<.001**		
Female patients	Age	-0.249	0.055	0.055	0.504	0.121	0.357	0.181	0.166	0.076	0.412
	BG depth	**-0.627**	**<.001**	**0.517**	**<.001**	**0.543**	**<.001**	0.186	0.156		
Male patients	Age	-0.059	0.685	-0.138	0.341	0.207	0.146	-0.077	0.597	-0.119	0.411
	BG depth	**-0.501**	**<.001**	**0.468**	**0.001**	0.134	0.352	**0.283**	**0.046**		

BG: bicipital groove; **LHB tendon:** long head of the biceps tendon; **r:** Pearson's correlation coefficient.

higher in women than in men, but this was not statistically significant. Kim et al.[16] measured the sagittal and transverse diameters of the LHB tendon in the right shoulder on ultrasound and reported these values as 2.65±0.86 mm and 5.60±1.57 mm, respectively. The authors noted that the LHB tendon of the males was thicker compared to the females. In our study, we found the mean LHB tendon width as 4.5±0.43 mm and thickness as 2.46±0.31 mm. The tendon sizes were statistically significantly smaller in the female patients than in the males. Our findings are consistent with those reported by Kim et al.[16]

In our study, there was a positive correlation between the BG depth and the LHB tendon measurements. In cases where the BG depth was greater, the LHB tendon was thicker. We also showed that the BG depth was correlated with the LHB tendon thickness among the women and the LHB tendon width among the men. In cases where the BG depth was greater, the LHB tendon was thicker in the female patient group.

In the current study, the BG depth/LHB tendon thickness ratio was 91% in women and 96% in men. This shows the effectiveness of soft tissue stabilizers in maintaining the stability of the tendon. The superior glenohumeral ligament, subscapularis and supraspinatus tendons are known as the main soft tissue stabilizers of the LHB tendon and prevent the subluxation of the LHB tendon during the multidirectional biomechanical movements of the arm.[1] Further studies are needed to demonstrate the effect of the LHB tendon morphology on its stability.

No correlation was found between age and the morphological measurements of BG and the LHB tendon for the two gender. Bone morphology of the bicipital groove has an impact on the development of LHBT pathologies. BG depth, MWA and OA are the parameters to be used in the evaluation of this morphology. By determining the predisposition to LHB tendon pathologies, programs for strengthening soft tissue stabilizers can be applied.

Our study has certain limitations. First, it had a retrospective design and a small sample size. Second, the dominant side of the patients included in the study was unknown. Lastly, information on the physical and sports activities of the patients could not be obtained.

Conclusion

The morphological measurements of BG and the LHB tendon showed correlations. There were also gender differences in these morphological measurements. These findings may provide useful information in orthopedic surgery and clinical anatomy.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

SD: project development, data collection and analysis, manuscript writing, editing; EG and VC: data collection and analysis, manuscript writing.

Ethics Approval

The study was approved by the of Yüksek İhtisas University Clinical Research Ethics Committee (No: 2022/05/03) and carried out in accordance with the Helskinki declaration of principles.

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Magnetic resonance imaging evaluation of coccyx morphology and morphometry in childhood

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Abstract

Objectives: Pain around the coccyx is referred to as coccydynia. Inter coccygeal and sacrococcygeal angles as well as some types of coccyx may be associated with idiopathic coccydynia. The aim of this retrospective study was to evaluate the morphology and morphometry of the coccyx using MRI and to determine whether morphologic-morphometric features are associated with coccydynia in the pediatric population.

Methods: This study was performed retrospectively on children aged 10–17 years who underwent pelvic and sacral magnetic resonance imaging for non-trauma related reasons. Inter coccygeal-sacrococcygeal angles and coccyx types were determined using sagittal T1- and T2-weighted images. Gender-specific assessments were made for intercoccigeal and sacrococcygeal angles as well as coccyx types based on Postacchinni and Massobrio classification. In statistical analysis, a p-value less than 0.05 was considered statistically significant.

Results: One hundred and fifty-six children were included in the final analysis (108 girls, 48 boys). The mean age of the cases was 13.8 years (10–17). Type 1 was the most common type overall, accounting for 57.7% of the population. The sacrococcygeal angles of boys were significantly higher than those of girls. A significant negative correlation was found between age and sacrococcygeal angle. In children with Type 1 and Type 2 coccyx, girls had significantly higher intercoccigeal angles than boys. The intercoccigeal angle varied significantly in each coccyx type and the intercoccigeal angles increased significantly as the coccyx type increased (from Type 1 to Type 4). The most common coccyx type in the coccidynia group was Type 2, while the most common type in the control group was Type 1. The mean intercoccigeal angles of children with coccidynia were significantly higher than those of the control group.

Conclusion: Coccydynia is a symptom with many possible reasons rather than a diagnosis. Coccyx morphology and morphometry can be associated with idiopathic coccydynia. To better understand these morphological and morphometric features, especially in the pediatric population, larger population studies are required.

Keywords: coccyx; intercoccygeal angle; MRI; sacrococcygeal angle

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Introduction

The coccyx is thought to be named after its resemblance to the beak of the cuckoo bird.[1] It is the triangular terminal bone of the spine and consists of three to five segments with different disc spaces. Except for the first intercoccygeal joint, the intercoccygeal disc spaces are normally fused.[2,3] The coccyx faces inferiorly and anteriorly from the sacral apex.[1] It is very important for maintaining weight support while sitting.[4] It provides an attachment surface for the sacro-coccygeal, sacro-spinous and sacro-tuberous ligaments, such as the levator ani and iliococcygeus muscles.[2]

Coccydynia is a term used to describe pain around the coccyx. The causes of coccydynia have been demonstrated by various studies. It may be idiopathic or caused by tumor, inflammation, trauma or disc degeneration.[5–7] It is known that women are affected by coxidynia four to five times more than men.[6,7] The morphology of the coccyx varies considerably in the population. Four types of morphological variants have been described by

Postacchinni and Massobrio: Type 1, found in more than 50% of the population, is characterized by a slight ventral curvature with a caudally tapering apex of the coccyx; Type 2 involves a more pronounced ventral curvature with an anteriorly directed apex, found in 8–32% of the population; Type 3 has an acute anterior angulation without subluxation and is found in 4–16% of the population; Type 4 is characterized by subluxation at the sacro-coccygeal or inter-coccygeal joint.[8]

Compared with normal individuals, the incidence of Type 1 coccyx is lower and the incidence of Type 2, 3 and 4 coccyx is higher in patients with coccidynia.[2] Similarly, Woon et al.[9] showed that the incidence of coccidynia was higher in patients with marked ventral curvature of the coccyx. However, the Postacchinni and Massobrio classification is based on description rather than any measurement that can objectively show the differences between the groups.[10]

The intercoccigeal angle is the angle between the first and last segment of the coccyx.[10] According to Kim and Suk[11] this angle is a useful radiologic assessment that can accurately determine the increased angular deformity of the coccyx. In their study, they also found that patients with coccydynia and asymptomatic population differed significantly in terms of intercoccigeal angles.

Magnetic resonance imaging (MRI) is a useful technique to evaluate the anatomic and morphometric features of the sacrococcygeal region.[4,9] Many studies have investigated the relationship between coccidin and morphologic-morphometric features of the coccyx in adults using computed tomography (CT) and MRI.[1,2,4,6,9] To our knowledge, there is no previous study investigating the relationship between coccygeal morphology-morphometry and coccydynia in the pediatric population. In this study, MRI was used to investigate coccyx morphology and morphometry in children to understand the relationship between different coccyx types and intercoccigeal-sacrococcygeal angles in relation to coccydynia.

Materials and Methods

This study was performed retrospectively in a pediatric population aged 10–17 years who underwent pelvic and sacral MRI for any reason other than trauma in the Radiology Clinic of Erzincan Binali Yıldırım University Mengücek Gazi Training and Research Hospital between January and December 2019, and those with coccydynia were identified through the hospital information system. Exclusion criteria included history of trauma, bone dysplasia, skeletal immaturity (not allowing measurement of the intercoccigeal or sacrococcygeal angle) and incomplete penetration of the coccyx into the imaging field. Thus, among 170 children screened with pelvic or sacral MRI; 14 were excluded and 156 children (48 boys, 108 girls) were included in the final analysis.

A 1.5 Tesla MRI scanner (Magnetom Aera, Siemens Healthcare GmbH, Erlangen, Germany) was used. Evaluation of the coccyx type and measurement of the intercoccigeal-sacrococcygeal angles were performed using sagittal T1- and T2-weighted images. After acquisition, the images were sent to the workstation where two expert radiologists performed the morphologic evaluation and morphometric measurements in consensus. The type of coccyx was determined for each patient according to the Postacchinni and Massobrio categorization:[8]

- **Type I:** Slight ventral curvature of the coccyx with a caudally tapering apex
- **Type II:** More pronounced ventral curvature with apex facing anteriorly
- **Type III:** Acute anterior angulation without subluxation
- **Type IV:** Subluxation of the sacro-coccygeal or inter-coccygeal joint

Coccyx types and the intercoccigeal-sacrococcygeal angle were evaluated according to gender groups. The angle formed between the lines drawn at the midpoints of the first and last coccygeal vertebrae was used to calculate the inter coccygeal joint angle.[12] Inter coccygeal angle measurement is shown in **Figure 1**. To determine the sacrococcygeal angle, a line through the middle of the superior and inferior tips of S1 and another line through the middle of the superior and inferior tips of the first coccygeal vertebrae were used.[12] Sacrococcygeal angle measurement is shown in **Figure 2**.

Data analysis was performed using SPSS version 20 (Social Sciences Software for Windows, IBM Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to determine whether the data were normally distributed. Mean and standard deviation were used to present normally distributed numerical variables. Categorical variables were reported using numbers and percentages. Fisher's chi-square test was used to compare the percentages of coccidine between coccyx types. Inter coccygeal and sacrococcygeal angles were compared between sexes and between coccidynia and non-coccidynia groups using Student's t-test. The presence of coccidynia was compared between genders using Fisher's chi-square test. The difference in the intercoccigeal angle between the four coccyx type subgroups was tested with one-way ANOVA test. Possible correlations between age and intercoccigeal and sacrococcygeal angles were tested with Pearson's correlation. A p-value less than 0.05 was considered statistically significant.

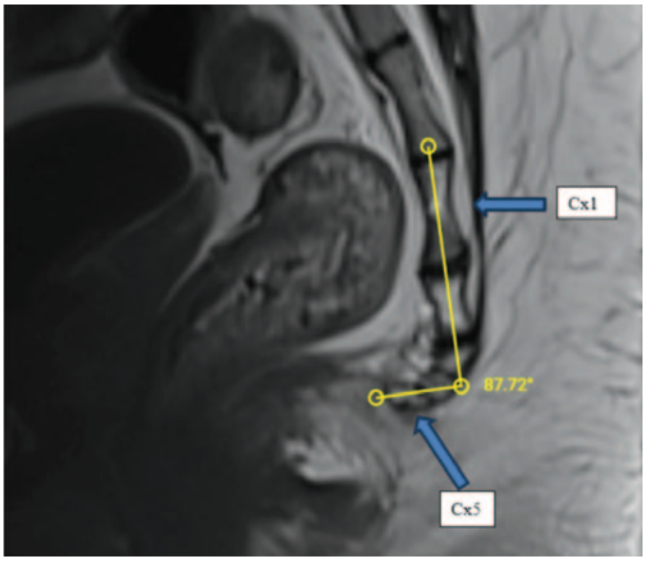

Figure 1. T1-weighted sagittal MRI section. The **intercoccigeal angle** was measured as the angle formed between the lines drawn through the midpoints of the first and last coccygeal vertebrae. The first coccygeal (C×1) and fifth coccygeal vertebra (C×5) are indicated by **blue arrows**.

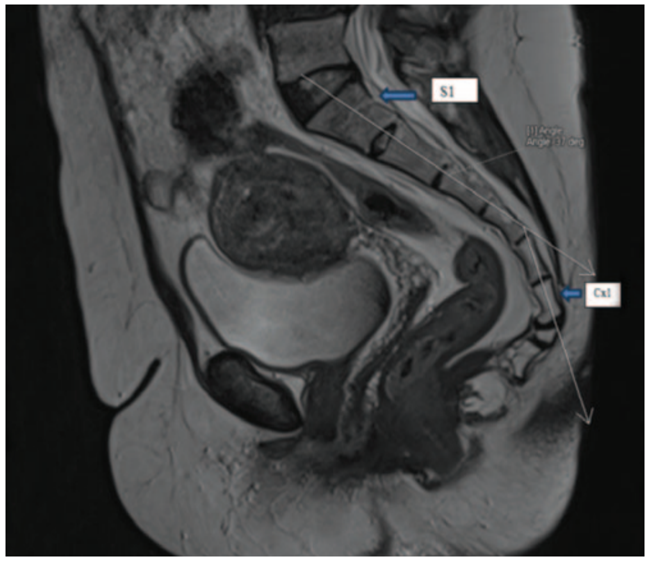

Figure 2. T1-weighted sagittal MRI section. The **sacrococcygeal angle** was measured as the angle between a line through the middle of the upper and lower endplates of S1 and another line through the middle of the upper and lower endplates of the first coccygeal vertebra. The first sacral (S1) and first coccygeal vertebra (C×1) are indicated by **blue arrows**.

Results

One hundred and fifty-six children were included in the final analysis. One hundred and eight of the children were girls (69.2%) and 48 were boyes (30.8%). The mean age was 13.8 years (mean: 10–17 years).

In the whole group, 90 children (57.7%), 61 girls and 29 boys, had Type 1 coccyx. This was the most common type observed in our study. **Table 1** shows the distribution of coccyx types by gender in the general population (including subjects with and without coccydynia). **Figures 3** and **4** show the four different types of coccyx seen in the subjects. The mean sacrococcygeal angle was found to be 92.2°±14.0, with a range of 40.0° to 140.0°. The mean sacrococcygeal angle in males and females was 98.3°±13.4 and 80.1°±14.1, respectively. The sacrococcygeal angle in male children was found to be significantly higher than that in females ($p<0.05$). A significant negative correlation was found between age and sacrococcygeal angle ($r=0.79$).

The mean intercoccygeal angle in overall population was 43.2°±10.5 with a range of 0° to 93.0°. The mean intercoccygeal angle in males and females was 37.7°± 10.2 and 46.9°±9.1, respectively. In the children who had Type 1 and Type 2 coccyx, the intercoccygeal angle in girls was significantly higher than that in boys ($p<0.05$). The intercoccygeal angles were significantly increased with increasing coccyx type (from Type 1 to Type 4) ($p<0.05$). The mean, minimum and maximum intercoccygeal angles in different coccyx types were shown in **Table 2**.

In girls who had Type 1 and Type 2 coccyx, the mean intercoccygeal angles were 40.1°±10.5 and 55.1°±10.3; and in boys who had Type 1 and Type 2 coccyx they

Table 1
Distribution of coccyx types according to gender.

Coccyx types	Females (n, %)	Males (n, %)	Total (n, %)
Type 1	61 (56.4%)	29 (60.4%)	90 (57.7%)
Type 2	32 (29.6%)	12 (25%)	44 (28.2%)
Type 3	10 (9.2%)	5 (10.4%)	15 (9.6%)
Type 4	5 (4.6%)	2 (4.1%)	7 (4.4%)
Total	*108*	*48*	*156*

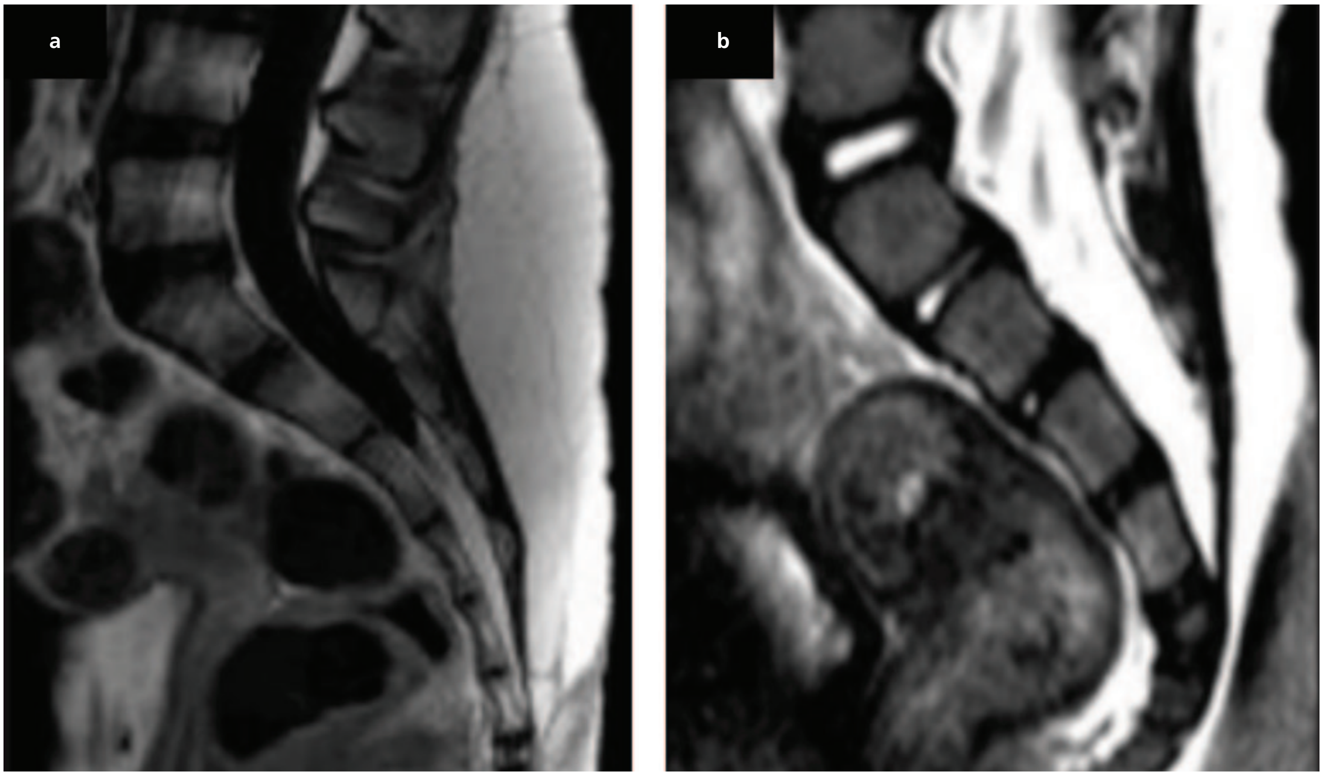

Figure 3. Type 1 coccyx (**a**) and Type 2 (**b**) coccyx are shown on sagittal MRI section.

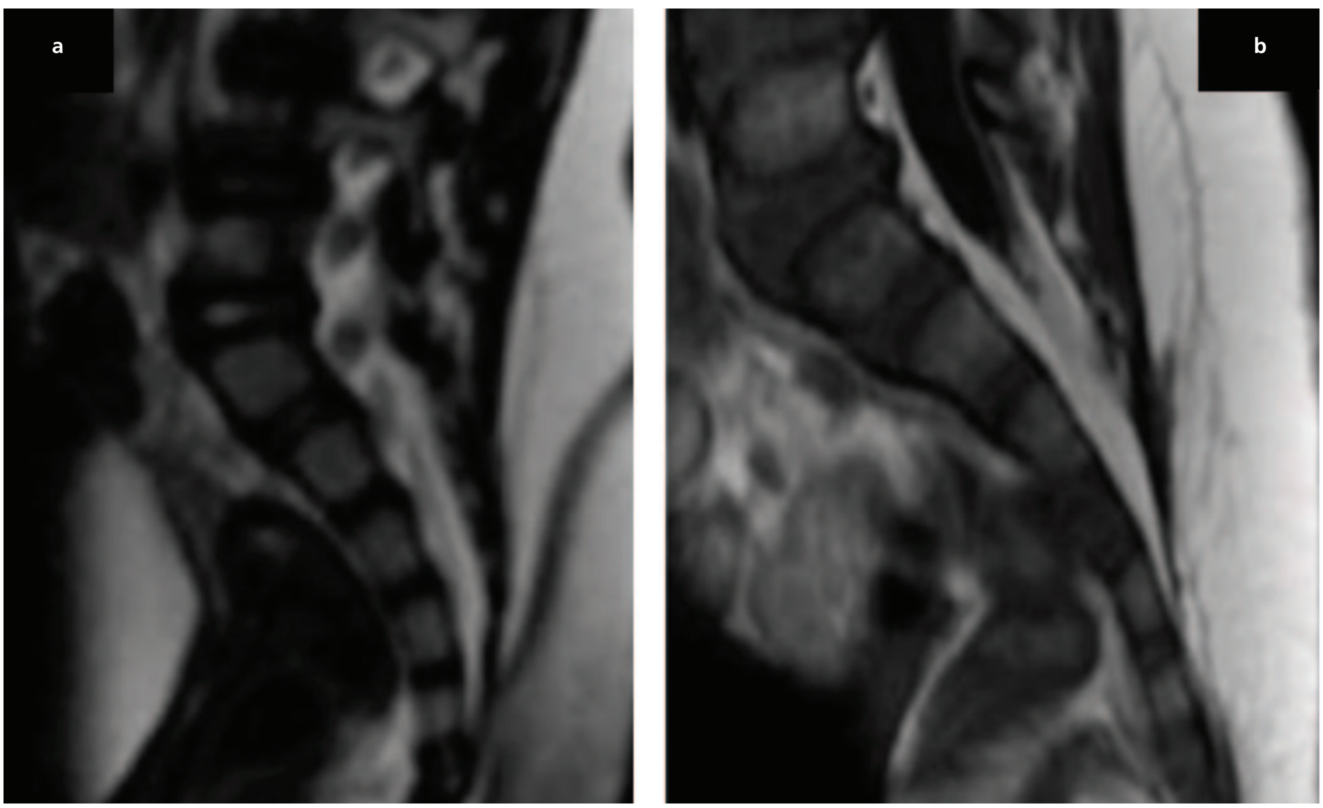

Figure 4. Type 3 coccyx (**a**) and Type 4 (**b**) coccyx are shown on sagittal MRI section.

were 33.0°± 9.6 and 46.2°±11.0; respectively. Due to the restricted number of patients who had Type 3 and 4 coccyx, we combined the subjects in these groups and assessed the mean intercoccygeal values for the female and male groups, which were 82.2°±8.1 and 79.1°±11.3; respectively. There was no statistically significant difference between boys and girls who had Type 3 and Type 4 coccyx (p=0.12).

The hospital information system revealed the presence of coccydynia in 47 children, consisting of 30 girls and 17 boys. Additionally, the system detected 109 children, comprising of 78 girls and 31 boys, who did not have coccydynia. **Tables 3** and **4** demonstrate the distribution of coccyx types based on gender in children with and without coccydynia, respectively. The mean intercoccygeal angles of children with and without coccydynia were 66.2°±9.5 and 36.2°±10.8; respectively. Intercoccygeal angles of children with coccydynia were significantly higher than those without coccydynia (p<0.05).

The mean sacrococcygeal angle in children with and without coccydynia was found to be 75.2°±13.0 and 76.3°±15.1; respectively. No significant difference was found between coccydynia and the control group in terms of sacrococcygeal angle (p=0.13).

Table 2
The mean, min and max intercoccygeal angles in different coccyx types.

Intercoccygeal angle	Mean±SD	Min-Max
Type 1	35.8°±10.5	0°–44°
Type 2	51.6°±10.8	20°–61°
Type 3	70.1°±10.8	44°–81°
Type 4	80.1°±12.7	59°–93°

Discussion

Most previous research has focused on the management of coccydynia as well as its diagnosis and radiological categorization in adult populations. This study provides a comprehensive evaluation of coccyx types and intercoccigeal-sacrococcygeal angle measurements in children. The study included children with idiopathic coccidynia and healthy individuals. There are several studies evaluating coccyx types and coccygeal morphometry in the adult population.[1,2,4,6,8–13]

In the study by Geneci et al.[13] the mean sacrococcygeal angle measured in CT scans of adult cadavers was found to be 23.6°±16.50°. However, in our study with pediatric subjects, we observed that the mean sacrococ-

Table 3
Distribution of coccyx types according to gender in children with coccydynia.

Coccyx types in children with coccydynia	Females (n, %)	Males (n, %)	Total (n, %)
Type 1	5 (16.6%)	3 (17.6%)	8 (17.0%)
Type 2	12 (40.0%)	7 (41.1%)	19 (40.4%)
Type 3	8 (26.6%)	5 (29.4%)	13 (27.6%)
Type 4	5 (16.6%)	2 (11.7%)	7 (14.9%)
Total	*30*	*17*	*47*

Table 4
Distribution of coccyx types according to gender in children without coccydynia.

Coccyx types in children with coccydynia	Females (n, %)	Males (n, %)	Total (n, %)
Type 1	56 (71.7%)	26 (83.8%)	82 (75.2%)
Type 2	20 (25.6%)	5 (16.1%)	25 (22.9%)
Type 3	2 (2.5%)	0 (0%)	2 (1.8%)
Type 4	0 (0%)	0 (0%)	0 (0%)
Total	*78*	*31*	*109*

cygeal angle was significantly higher being 92.2°±14.0. This suggests that muscle tone surrounding the coccyx and sacrum may play a role in shaping this angle. Our study also supported the findings of three previous studies showing that the sacrococcygeal angle was significantly higher in males compared to females.[1,14,15]

Tetiker et al.[1] did not observe any gender difference in intercoccigeal angle. In our study, intercoccigeal angles of girls with Type 1 and Type 2 coccyx were found to be significantly higher than boys. Previous studies have suggested that these types of coccyxes are less prone to coccydynia.[11] There was no statistically significant difference between boys and girls in terms of intercoccigeal angle in Type 3 or 4 coccyxes. This may indicate that the intercoccigeal angle alone may not be the sole determinant of women's propensity to develop coccydynia.

Shams et al.[4] compared a group with coccidine with a control group in a study using MRI in adults and found that the most common coccyx type was Type 2 in both groups. Kim and Suk[11] also reported that the most common type in adult patients with coccidynia was Type 2. Yoon et al.[6] reported that the most common coccyx type in asymptomatic Korean adults was Type 2 and Kerimoğlu et al.[6,10] reported that the most common coccyx type in asymptomatic Turkish adults was Type 1. In our study, while Type 1 coccyx was the most common type in the control group, Type 2 coccyx was found to be the most common type in the coccydynia group. The fact that the rates of Type 3 and 4 were higher in coccydynia patients compared to the control group in our study suggests that Type 3 and 4 patients are more likely to develop coccidynia. On the other hand, we found only 2 children with Type 3 or Type 4 coccyx but without coccydynia. Shams et al.[4] and Kim and Suk[11] found a significant difference in intercoccigeal angles between the coccydynia group and the control group, which is compatible with our results. The increase in intercoccigeal angles in the coccidine group means that the coccyx exhibits more anterior curvature in coccidine patients compared to the control group. These findings suggest that forward curvature of the coccyx may cause compression and compression of adjacent tissues and nerves. Shams et al. and Gupta et al.

Shams et al.[4] and Gupta et al.[12] did not observe a statistically significant difference between the group with coccidynia and the control group in terms of sacrococcygeal angle, which is in agreement with our findings. These findings suggest that the sacrococcygeal angle may not have an important role as a cause of coccydynia.

Inter coccygeal angles were found to be significantly higher in the female pediatric population compared to males. This may explain the higher incidence of idiopathic coccidynia in females. However, in contrast to our findings, Yoon et al.[6] reported that the intercoccigeal angle was significantly higher in males than in females. All the studies we compared our results were carried out in adults. To the best of our knowledge, this study on coccyx morphology and morphometry is the first study undertaken in pediatric population.

Our study has some limitations. We did not assess the number and length of coccygeal vertebrae because of the large age-related variation in ossification and bone growth in the pediatric population. Other limitations include the retrospective nature of the study, the relatively small number of patients, and the consensus assessment of types and angles rather than interobserver agreement. Furthermore, weight, height and BMI were not included in our data, although they have been associated with certain morphologic or morphometric parameters of the coccyx in previous studies.[14] Furthermore, it was not possible to assess changes in the intercoccigeal angle and sacrococcygeal angle with the patient in a sitting or standing position.

Conclusion

Although the most common coccyx type in patients with coccidynia was found to be Type 2 in our study as well as in previous studies in the literature, coccidynia was present in almost all cases with Type 3 and Type 4 coccyx. These findings emphasize the relationship between coccyx types and coccidynia. In addition, intercoccigeal angles were significantly higher in patients with coccidynia, indicating that there is a relationship between intercoccigeal angle and coccidynia formation. However, the lack of a defined cutoff value for the intercoccigeal angle may hinder objectivity. Based on our research and other studies, if coccydynia patients have a Type 3 or Type 4 coccyx or a high intercoccigeal angle, it would be useful to consider these factors as potential causes of coccydynia. This will help avoid unnecessary examinations and investigations, saving both time and money. If a child is diagnosed with coccydynia, taking angle measurements and determining the type of coccyx can provide information about the cause. Taking these measurements routinely and determining the type of coccyx is very important as it can potentially prevent the need for extensive examinations and enable appropriate treatment to be started early. Further research with larger population samples is needed to study these morphologic and morphometric features of the coccyx, especially in pediatric demographics.

The results of this study once again emphasize that coccydynia is a symptom with many possible causes rather than a diagnosis. Idiopathic coccydynia appears to be associated with coccyx morphology and morphometry. The coccyx may show morphologic and morphometric abnormalities associated with coccidynia. A thorough understanding of these features will help in the diagnosis of idiopathic coccidynia.

Conflict of Interest

There are no conflicts of interest to be disclosed.

Author Contributions

MÖÖ: designed the research study, performed the research, analyzed the data and wrote the manuscript; BU: designed the research study; KBM: performed the research, analyzed the data and wrote the manuscript; SA: designed the research study, contributed towards analytic tools, analyzed the data and wrote the manuscript. All authors have read and approve the final manuscript.

Ethics Approval

Approval for this study was obtained from the institutional ethics committee (Ethics Committee of Erzincan Binali Yıldırım University, Erzincan, Turkey, decision number: EBYU-KAEK-2022-11-E1457.3027-003, 17/11/2022).

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Evaluation of the morphometric features of Achilles tendon with tendinopathy: an MRI study

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Abstract

Objectives: The Achilles tendon, the biggest tendon in the body, transmits the mechanical force received from the body to the ankle through the calcaneus. The aim of this study was to evaluate the effects of morphometric characteristics of the soleus and gastrocnemius muscles that make up the Achilles tendon on tendinopathy by MRI.

Methods: Foot magnetic resonance images of 128 patients (121 males and 107 females) were retrospectively analyzed. The cases were divided into two groups, the tendinopathy group and the control group. The length and the thickness of the Achilles tendon and the distance of the maximum thickness from the calcaneal insertion were measured in both groups and evaluated for differences between the groups and between genders.

Results: In the comparison between genders, the thickness of the Achilles tendon and the distance of the maximum thickness to the calcaneal insertion were higher in males than in females. The length and the thickness of the Achilles tendon was significantly increased in the tendinopathy group compared to the control group.

Conclusion: In this study, we investigated the relationship between Achilles tendinopathy and the morphometric properties of the muscles forming the Achilles tendon. The results of our study showed that Achilles tendon length and tendon thickness increased in patients with tendinopathy compared to the control group.

Keywords: Achilles tendon; gastrocnemius; soleus; tendinopathy

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Introduction

The Achilles tendon is the common tendon of the triceps surae formed by the two heads of the gastrocnemius and soleus and is the largest tendon in the body.[1,2] The name Achilles tendon was first mentioned in Verheyen's book "Corporis Humani Anatomiae" written in 1693.[3]

The Achilles tendon is very important in ankle motion because it transmits mechanical force from the triceps surae to the calcaneus.[4] The posterior part of the tendon is formed by the medial layer of the triceps surae. The anterior part of the tendon is formed by the lateral layer of the gastrocnemius. The middle and medial parts are formed by the soleus.[1,2] The vascularization in the middle part of the tendon is weaker. The nutrition of this segment is more variable compared to other segments. This is thought to affect the progression of tendinopathy.[5]

Tendinopathy is a multipathological condition characterized by tendon dysfunction, pain and decreased exercise capacity.[6] The human body contains hundreds of muscles and tendons. However, tendinopathy most commonly affects the shoulders, elbows, hips, knees and ankles.[7] Foot and ankle pathologies, including the Achilles tendon, are common in the elderly and athletes.[8] Furthermore, recent studies have revealed that Achilles tendinopathy is becoming more common in amateur and professional athletes. Consequently, identification and elucidation of risk factors for tendinopathy is of critical importance. Determination of the anatomy of the Achilles tendon and variations in tendon anatomy will help research in this area.[9]

With the advancement of magnetic resonance imaging (MRI) studies, new information about the anatomy of the Achilles tendon and surrounding soft tissues has been obtained. The presence of morphologic and signal changes in the tendon has increased the accuracy of tendinopathy diagnosis.[10,11] Furthermore, understanding the anatomy and variations of the Achilles tendon and surrounding soft tissues improves surgical techniques and reduces the risk of iatrogenic injury.[12] The aim of this study was to demonstrate the morphologic features and anatomic variations of the gastrocnemius and soleus tendons and the relationship between these variations and tendinopathy using magnetic resonance imaging.

Materials and Methods

The study was conducted retrospectively at Erzincan Binali Yıldırım University Faculty of Medicine Mengücek Gazi Training and Research Hospital between January 1, 2020 and January 1, 2022. Exclusion criteria included Achilles tendon rupture, any disease that disrupts the anatomy and physiology of the musculoskeletal system (malignancy, soft tissue infections), history of ankle surgery, calcaneal fracture, and inability to obtain appropriate images due to diffuse motion. Patients who did not meet the exclusion criteria in contrast-enhanced and non-contrast-enhanced ankle MRI examinations performed for any reason and who had good anatomic and pathophysiologic image quality related to the musculoskeletal system were included in our study.

The ankle was imaged on a 1.5T 32-channel MRI machine (Siemens magnetoma aera, Erlangen, Germany) using 18-channel coils. Images from the PACS (Picture Archiving Communication System) archive were analyzed using the Siemens Somatom Sensation-Syngo.via software program (Siemens Healthineers, Erlangen, Germany) and evaluated by a radiologist with 6 years of musculoskeletal experience.

All patients in the study underwent T1-weighted sequences in the coronal and sagittal planes, T2-weighted sequences in the axial and sagittal planes, and PD-weighted fat-suppressed sequences in the axial and coronal planes. The most commonly used protocol is PD-weighted TSE (turbo spin echo) TE (echo time) 21 ms, TR (repetition time) 2400 ms. T2-weighted (TSE) TE 56 ms, TR 3920 ms. T1-weighted: TE 10 ms, TR 797 ms. Voxel 0.8×0.8×3.5 mm, slice thickness 4 mm, FOV (Field of view) 200 mm. The diagnosis of Achilles tendinopathy was based on the presence of high signal on T2-weighted and proton density-weighted fat-suppressed axial and sagittal images, tendon thickness exceeding 6 mm on axial images, and convex anterior edge of the tendon.[13]

The most distal part of the soleus fibers was determined on axial images and the length between this point and the most proximal-superior point where the Achilles tendon attaches to the calcaneus on sagittal images was calculated as the free Achilles tendon length (SPM) (**Figure 1**). Similarly, the distance between most distal part the soleus fibers which was determined on axial images, and the most distal point where the Achilles tendon attaches to the calcaneus was measured on sagittal images and recorded as the total Achilles tendon length (SDM) (**Figure 2**).

In the axial section, the thickest part of the free portion of the Achilles tendon in the anteroposterior plane was measured. Sagittal sections were also used to confirm this (APM) (**Figure 3**). The distance from the point where the tendon reached maximum thickness to the proximal insertion of the Achilles tendon into the calcaneus was measured (MKPM) (**Figure 3**). Then, the ratio of maximum tendon thickness to proximal calcaneal insertion (MKPM/SPM) was calculated and recorded.

SPSS version 21 (Social Sciences Software for Windows, IBM Inc., Chicago, IL, USA) was used for statistical analysis. The Kolmogorov-Smirnov test was used to assess the conformity of the variables to normal distribution. The t-test was used to examine differences in the mean values of the measurements between groups, genders and sides, as well as independent values. Pearson correlation was used to investigate the relationship between length and age. Statistical significance was defined as a p value less than 0.05.

Results

Our study included 121 male patients aged 18–71 years with a mean age of 42.1±15.1 years and 107 female patients aged 18–70 years with a mean age of 41.3±13.2 years. A total of 228 ankle MRI examinations, including 114 right ankle and 114 left ankle, were performed in our study (**Table 1**). In addition, 27 patients were excluded due to exclusion criteria. The study group consisted of 2 groups. Group 1 included 114 MRIs with clinically suspected tendinopathy and confirmed tendinopathy diagnosis by MRI. Group 2 was the control group and included 114 MRI studies performed for pathologies other than pathologies related to the Achilles tendon. Group 1 consisted of 50 women and 64 men with a mean age of 49.8±9.8 (30–70) years and included MRI sections of 56 right and 58 left ankles. Group 2 consisted of 57 female and 59 male patients with a mean age of 33.6±12.2 (18–71) years and included MRI sections of 58 right and

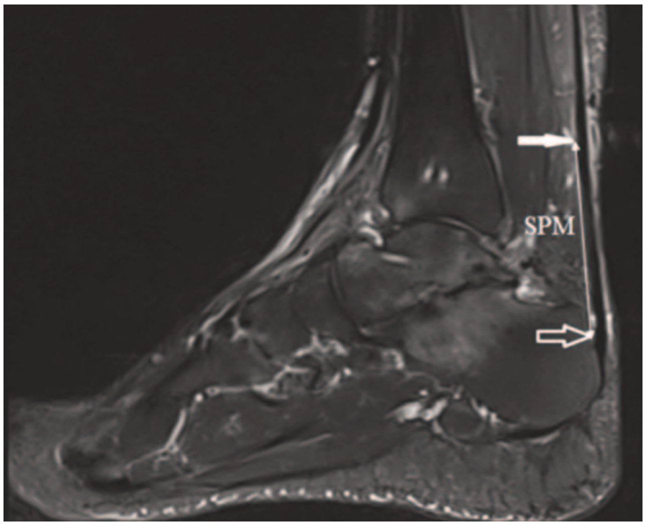

Figure 1. T2 fat-suppressed sequence showing the Achilles tendon. The most distal part of the soleus (**white paint filled arrow**) and the most proximal anterior calcaneal insertion of the Achilles tendon (**hollow white arrow**). The distance between the two arrows is defined as the SPM distance (free tendon length).

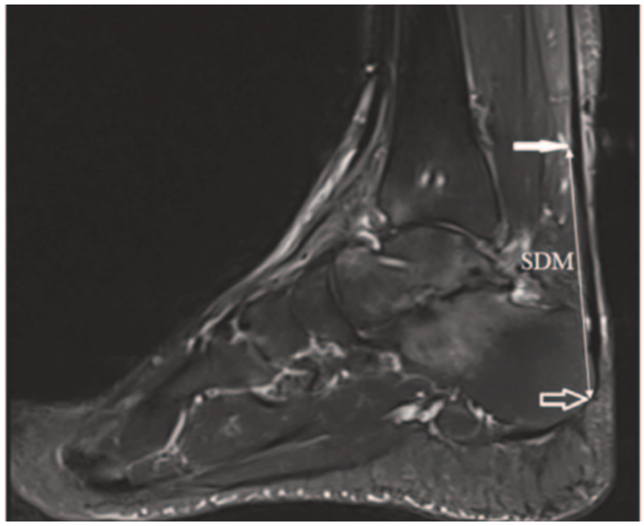

Figure 2. T2 fat-suppressed sequence showing the Achilles tendon. The most distal part of the soleus (**white paint filled arrow**) and the most distal calcaneal insertion of the Achilles tendon (**hollow white arrow**). The distance between the two arrows is defined as the SDM distance (total tendon length).

56 left ankles (**Table 1**). None of the patients included in the study were athletes. Gender and side comparison of patients with tendinopathy are shown in **Tables 1** and **2**.

The free Achilles tendon length between the most distal part of the soleus fibers and the proximal calcaneal insertion of the Achilles tendon, called the SPM distance, was

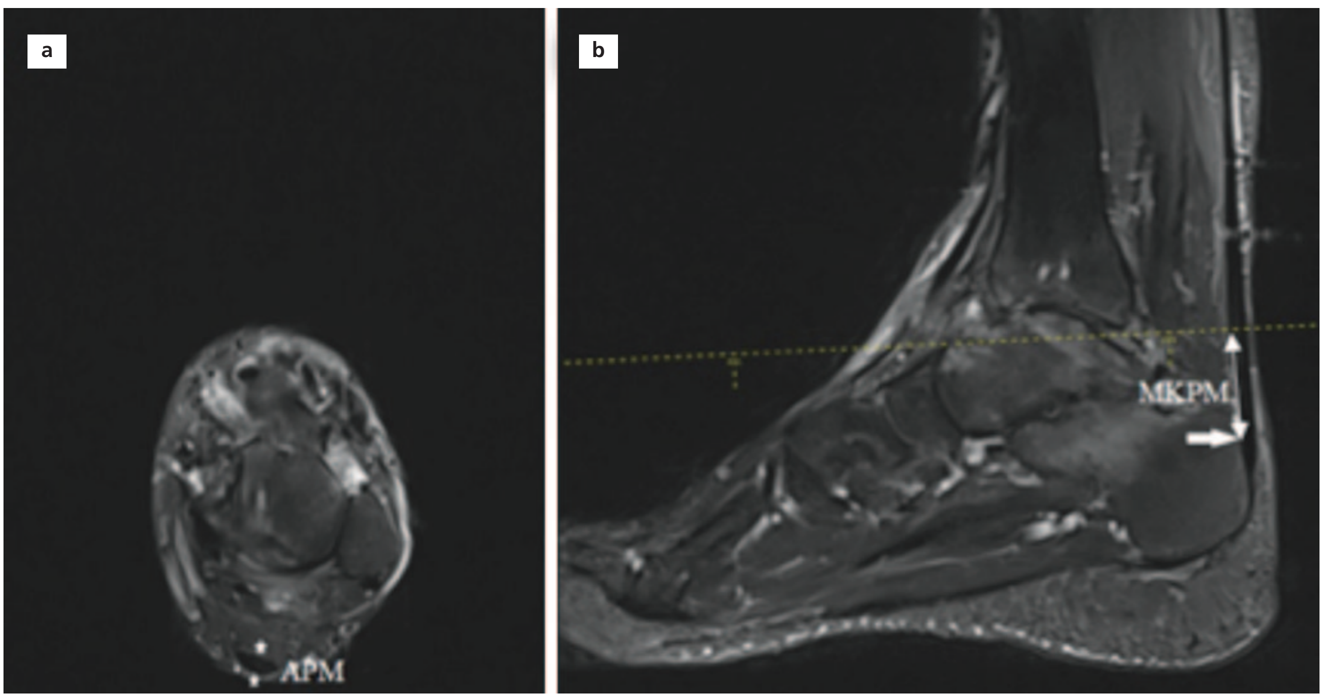

Figure 3. Axial (**a**) and sagittal (**b**) sections of the Achilles tendon in T2 fat-suppressed sequence. The thickest part of the Achilles tendon in the axial sections (**the distance between the two white stars**) was determined, and the anteroposterior thickness of the tendon at this level was defined as the APM distance. In addition, this level was determined in sagittal sections (**dashed yellow line**), and the distance from the point determined in sagittal sections to the calcaneus antero-proximal insertion of the Achilles tendon (**white paint filled arrow**) was defined as the MKPM distance.

Table 1
Demographic characteristics of the Group 1 (tendinopathy group) and Group 2 (control group).

	Age (years) Mean±SD (range)	Gender (female/male)	Side (right/left)
Total	41.7±14.2 (18-71)	107/121	114/114
Group 1	49.8±9.8 (30-70)	50/64	56/58
Group 2	33.6±12.2 (18-71)	57/59	58/56

SD: standard deviation.

53.9±16.7 (range: 25.9–103) mm. The total Achilles tendon length between the most distal part of the soleus fibers and the distal calcaneal insertion of the Achilles tendon, referred to as the SDM distance, was 78.2±18.2 (range: 45.1–125.8) mm. The thickest part of the free Achilles tendon in the anteroposterior plane, called the APM distance, was 9.69±3.1 (range: 4.8–19.9) mm. The distance from the point where the Achilles tendon reached maximum thickness to the proximal insertion of the calcaneus, called the MKPM distance, was measured as 23.8±3.39 (range: 15.1–299) mm. The ratio of the distance from the maximum tendon thickness to the proximal calcaneal insertion, called MKPM/SPM, was 44.2± 15.45% (range: 15.5–98.2 mm) (**Table 2**). There was no statistically significant difference between the measurements made in terms of gender and direction in the group with tendinopathy ($p>0.05$).

In the control group, SPM was 38.1±12.8 (range: 7.2–68.6) mm, SDM was 59.5±12.4 (range: 26–91.1) mm, APM was 4.8±0.5 (range: 3.6–5.7) mm, and MKPM was 18.5±4 (range: 3.9–22.6) mm. The MKPM/SPM ratio was calculated as 48.5±17.2% (range 21.2–94.3) (**Table 3**).

The results of the comparison between the control group and patients with tendinopathy according to gender and side are given in **Tables 2** and **Table 3**. In both patients with tendinopathy and the control group, there

Table 2
Gender and side comparison of the measured distances (mean±standard deviation) of the patients with tendinopathy (Group 1).

	Side			Gender		
Distances	Right (mm)	Left (mm)	p-value	Male (mm)	Female (mm)	p-value
SPM	55.1±16.4	52.8±17	>0.05	54.1±16.4	53.7±17.1	>0.05
SDM	80.6±16.5	76±19.9	>0.05	82.1±17.5	82.2±19.1	>0.05
APM	9.9±2.8	9.5±3.4	>0.05	10.8±2.9	10.5±2.8	>0.05
MKPM	24.8±3.6	23±3.2	>0.05	22.8±3.8	24.2±3.2	>0.05
MKPM/SPM (percent)	45.0±15.1	43.5±15.8	>0.05	42.1±16	45.0±14.7	>0.05

Table 3
Gender and side comparison of the measured distances (mean±standard deviation) of the control group (Group 2).

	Side			Gender		
Distances	Right (mm)	Left (mm)	p-value	Male (mm)	Female (mm)	p-value
SPM	36.5±11.9	39.9±13.8	>0.05	39.6±11.6	35.3±13.6	>0.05
SDM	58.2±12.1	60.9±12.9	>0.05	62.8±12.9	54±11.6	>0.05
APM	4.8±0.5	4.8±0.6	>0.05	4.9±0.5	4.5±0.5	0.002
MKPM	18.1±4.1	19±3.9	>0.05	18.9±3.6	17.5±4.2	0.005
MKPM/SPM (percent)	49.5±19.3	47.6±15.2	>0.05	47.7±17.7	49.5±16.2	>0.05

was no statistically significant difference in the measurements between the right and left ankles. In the control group, APM and MKPM distances were statistically significantly greater in males than females (**Table 3**). There were no other differences in the measurements between the two genders.

Table 4 shows the comparison of the mean values of measurements in the control and tendinopathy groups. The SPM distance (mean free length of the Achilles tendon) was 53.9 mm in patients with tendinopathy and 38.1 mm in the control group and was significantly higher in the tendinopathy group (p=0.002). SDM distance (mean total length of the Achilles tendon) was 78.2 mm in patients with tendinopathy and 59.5 mm in the control group and was significantly higher in the tendinopathy group (p=0.001). APM (maximum thickness of the tendon) was 9.6 mm in the tendinopathy group and 4.8 mm in the control group and was significantly greater in the tendinopathy group (p=0.001). The distance between the level of maximum thickness of the tendon and the proximal calcaneal insertion was 23.8 mm in the tendinopathy group and 18.5 mm in the control group, and this value was significantly greater in the tendinopathy group (p=0.001). The MKPM/SPM ratio, which expresses the relative distance of the maximum thickness area to the proximal calcaneal insertion, was 44.2% in patients with tendinopathy and 48.5% in the control group (p=0.001).

Discussion

The Achilles tendon, which is composed of fibers from the gastrocnemius and soleus muscles, is the thickest of the tendons in the body.[2] The Achilles tendon is one of the most common sites of tendinopathy and Achilles tendon injury is a condition characterized by decreased function, tendon pain and decreased exercise.[6,7,13] Achilles tendinopathy causes thickening of the tendon, roughening of its surface and a brownish color. Histopathologic examination of patients with tendinopathy may show macrophages, neutrophils and other immune cells. There are no visible inflammatory cells. Consequently, the term tendinitis would be inappropriate when discussing tendinopathy.[14]

When we look at the different types of Achilles tendon degeneration in the literature, four different types of degeneration stand out. These four types are hypoxic degenerative tendinopathy, mucoid degeneration, tendolipomatosis and calcified tendinopathy. Kannus and Jozsa[15] discovered that patients with hypoxic degenerative tendinopathy and mucoid degeneration were more prone to spontaneous rupture. When the patients were analyzed, it was found that these pathologic conditions were seen together rather than separately.[15,16]

The natural history of Achilles tendinopathy is unknown and there is little clear information about its clinical course. While the disease may be self-limiting in many individuals, treatment options include physical therapy and surgery. The data obtained from the literature for the comparative evaluation of conservative and surgical methods in Achilles tendinopathy seems to be insufficient for the time being. Numerous guidelines on Achilles tendinopathy have been published. However, none of these guidelines, which often reflect expert opinion, have been rigorously tested for efficacy.[17,18]

Achilles tendinopathy has recently become more common in athletes. The anatomy and anatomical variations of the Achilles tendon will help research on this subject. In this study, morphometric differences in measurements of the Achilles tendon were compared in patients with tendinopathy and in the control group. In our study, when the length of the free Achilles tendon was compared between patients with tendinopathy and the control group, it was observed that the length of the Achilles tendon was significantly increased in patients with tendinopathy compared to the control group. This may mean that as the length of the Achilles tendon increases, its stability decreases. Similar to our study, Drakonaki et al.[10] found that Achilles tendon length (59.7 mm) was significantly higher in patients with tendinopathy compared to the control group (38.5). Weber et al.[19] measured Achilles tendons in pathologic and control groups and found 83.2 mm

Table 4

Comparison of the measurements of the group with tendinopathy (Group 1) and the control group (Group 2).

	SPM (mm)	SDM (mm)	APM (mm)	MKPM (mm)	MKPM/SPM (percent)
Group 1	53.9±16.7 (25.9–103)	78.2±18.2 (45.1–125.8)	9.69±3.1 (4.8–19.9)	23.8±3.39 (15.1-29.9)	46.6±15.45 (15.1–29.9)
Group 2	38.1±12.8 (7.2–68.6)	59.5±12.4 (26–91.1)	4.8±0.5 (3.6–5.7)	18.5±4 (3.9–22.6)	52.5±17.2 (21.2–94.3)
p-value	0.002	0.001	0.001	0.001	0.001

in the pathologic group and 45.9 mm in the control group. When compared with the control group, it can be said that it increased significantly in the pathologic group. Soila et al.[20] measured the length of tendons with changes in morphologic properties due to any pathology and found the tendon length to be 52 mm in pathologic tendons, similar to our study. In our study, unlike Weber et al.,[19] the distance between the distal soleus fibers and the proximal insertion of the calcaneus was measured while calculating the tendon length, and the difference was thought to be due to the difference in the measurement method.

The free Achilles tendon is the part of the tendon that is not covered with muscle and is covered with Kager fat. According to research, the free portion of the Achilles tendon is more sensitive to mechanical changes caused by the tendon and is more exposed to stresses and mechanical effects during exercise than the muscularized tendon portion.[21] During exercise, the free portion of the Achilles tendon is subjected to 2–3 times more strain than the gastrocnemius tendon.[22] According to these studies, the free portion of the Achilles tendon is more sensitive to acute changes in mechanical behavior in response to exercise. Stresses experienced during exercise are more important in determining the long-term adaptation of the tendon.[23] Szaro et al.[1] discovered that Achilles tendon injury is related to the muscle from which the damaged tendon fibers originate. Since tendinopathy is most common in the middle of the Achilles tendon, it is possible that it originates from the soleus muscle rather than the gastrocnemius muscle. The level of tendinous attachment of the muscle may also have an effect on tendinopathy as a result of the influence of the musculus soleus. Kager's fat is thought to play a role in the development of tendinopathy because it envelops the free portion of the Achilles tendon and has a springing effect on the tendon.[24]

According to the results of our study, the maximum thickness of the free portion of the Achilles tendon was 3.6 to 5.7 mm and was statistically significantly thicker in men in gender comparison. Achilles tendon thickness was similar between the same sexes. In studies on Achilles tendon thickness in the literature, Soila et al.[20] found Achilles tendon thickness to be 5.2 mm and Drakonaki et al.[10] found Achilles tendon thickness as 5.2 mm and 4.8 mm, which is similar to our study. It should also be kept in mind that the thickness of the Achilles tendon may increase physiologically. Rosager et al.[25] found that Achilles tendon thickness increased four times in athletes compared to the general population. The fact that there were no athletes in both groups in our study is important in terms of not affecting tendon thicknesses. Astrom et al.[26] reported that in some individuals the distal gastrocnemius and soleus muscles may appear thickened on axial MR images, but this should not be confused with focal thickening. On imaging, a false anterior thickening may be seen if the course of the tendon is not parallel to the sagittal planes.[20] In our study, the mean Achilles tendon thickness in the tendinopathy group ranged from 4.8 to 19.9 mm and was significantly greater than in the control group. Similar to our study, Haims et al.[16] found that tendon thickness increased in conditions that cause tendon degeneration such as tendinopathy. Nuri et al.[27] compared tendons with tendinopathy to contralateral tendons in their study and found that tendon thickness increased significantly on the tendinopathy side. Similar to our study, Drakonaki et al.[10] revealed increased tendon thickness in all subgroups of patients with tendinopathy. Volume loss in tendinopathic tendons during exercise may be due to fluid movement into the peritendinous space or a decrease in tendon blood volume due to tendinopathy and associated contraction of the tendon.[28]

In our study, MKPM/SPM ratio was used to calculate the ratio of tendon maximum thickness to proximal calcaneal insertion. The MKPM/SPM ratio was 44.2% in the tendinopathy group and 48.5% in the control group. The fact that this ratio was lower in the tendinopathy group suggests that the part of the tendon affected and thickened by tendinopathy is more distal to the tendon. Although the number of studies on this subject is limited, Drakonaki et al.[10] found that this rate was lower in patients with tendinopathy, which is consistent with our findings. The confirmation of these findings in our study increases the reliability of the results and is important in terms of its contribution to the literature. However, when compared to our study, Drakonaki et al.[10] revealed that the proportional data for the Achilles tendon were lower compared to the control and tendinopathy groups. This may be due to individual differences between the patients included in the study.

Our study has some limitations. The first limitation of our study is that it was retrospective. In addition to this, the number of patients in our study is relatively small. Detailed anamnesis and laboratory values of the patients were not available. Therefore, conditions that increase tendon thickness such as hyperlipidemia could not be determined. Since only one person performed the measurements at a time, inter- and intra-observer consistency data are not available. Height and BMI values of the patients were not recorded, so these values could not be included. If similar studies are performed in larger patient populations in the future, the reliability of our results will be confirmed.

Conclusion

Achilles tendinopathy is a multipathological clinical syndrome characterized by pain, swelling and decreased performance. Our findings show that patients with Achilles tendinopathy have various anatomical and physiopathologic abnormalities. Our study showed that SPM, SDM, APM and MKPM distances were significantly higher in the tendinopathy group. Although the number of patients in our study was higher than in the literature, what is known about Achilles tendinopathy is limited and further research is needed.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

TK: conceptualization, data acquisition, data analysis or interpretation, drafting the manuscript, approval of the final version of the manuscript; DCS and MK: drafting the manuscript, critical revision of the manuscript, approval of the final version of the manuscript; SA and MS: conceptualization, critical revision of the manuscript, approval of the final version of the manuscript.

Ethics Approval

This study involving human participants complies with the ethical standards of the institutional and national research committee and the 1964 Declaration of Helsinki and subsequent amendments or comparable ethical standards. This study was approved by Ethics Committee of Erzincan Binali Yıldırım University Clinical Research Ethics Committee (protocol E-21142744-804.99-150727.).

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Unlocking nasal angle anthropometry and nasolabial angle preferences: a key to achieve the perfect rhinoplasty

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Abstract

Objectives: Determining the ideal nasolabial angle is very important for setting aesthetic goals in rhinoplasty. By knowing the demographic data of the three main nasal angles, which are the key to facial balance, indications, planning and peroperative evaluations of surgery can be better applied. The aim of this study was not only to measure nasal angles but also to find out the nasolabial angle preferences of the Anatolian population.

Methods: 142 participants had their nasal angles (nasolabial, nasofrontal, nasofacial angles) measured both digitally and manually and a questionnaire was administered. Each participant was asked about their ideal nasolabial angle preferences and their propensity for rhinoplasty. The results were then compared between each other, age and gender.

Results: According to digital measurements, the mean nasolabial angle was 99.51±9.51° in men and 100.49±9.37° in women. The mean nasofacial angle was 32.35±3.44° mm in men and 32.54±3.17° in women. The mean nasofrontal angle was 138.49±9.29° in men and 141.64±8.10° in women. Manual measurements were similar. The mean ideal nasolabial angle in women (91.32±6.11°) was lower than the mean ideal nasolabial angle in men (94.78±4.47°). It was observed that the aesthetic perception of the participants was similar whether they had rhinoplasty or not. Participants aged less than 24 years were more likely to prefer higher nasolabial angles.

Conclusion: The nasal angles and preferred nasolabial angle results presented in this study may be useful in planning and evaluating rhinoplasty operations.

Keywords: ideal nasolabial angle; nasofacial angle; nasofrontal angle; nasolabial angle; photogrammetry; rhinoplasty

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Introduction

Located in the middle part of the facial profile, the nose gives the face its characteristic features and is associated with facial symmetry.[1] Considering that the nose is a very important aesthetic structure, rhinoplasty is one of the most popular operations in plastic and maxillofacial surgery. Although rhinoplasty, whether surgery or filler injection, is one of the most preferred medical aesthetic procedures in the Anatolian population, information on nasal angle morphometry and the ideal optimum for nasal angles in the population is still lacking in the literature.[2]

The nose varies greatly between people in terms of shape, size and anthropometric measurements. In addition, according to some researchers, ethnic diversity is important for rhinoplasty operations.[3] These differences affect the preferred profile. The preferred profile may also vary with beauty standards, aesthetic views of the society and personal preferences.[4]

Considering the patients' complaints, which range from functional limitations to compromised aesthetics, it is clear that the final results of rhinoplasty should be considered when planning the surgery.[5] Surgery can be effective if it gets as close as possible to the patient's goal through the incorporation of computer imaging into planning and

Table 1
Number and classification of participants in surveys and evaluations.

	Participant with history of fascial/nasal trauma	Participant with history of nasal aestetic	Other participants	Total
Survey	18	9	116	142
Evaluations	-	-	116	116

intraoperative manual anthropometric measurements. However, information on the consistency between manual measurements and digital planning is lacking in the literature. The clinician performing rhinoplasty should know both the standardized norms of ideal aesthetics in nasal anthropometry and the patient's aesthetic outcome and should apply this without subjective correction. However, it is essential to know the angles used for aesthetic facial assessment; predictable guidelines are not available.[6]

Nasal angles are clearly the most important morphometric features for facial aesthetics. There are important angles for deciding what is an aesthetically pleasing nose and what is the most satisfactory nose according to personal preferences. The nasofrontal angle to define the junction of the forehead and nose, the nasofacial angle to measure the height of the nasal cartilage and nasal dorsum, the nasolabial angle to relate the tip of the nose and the lips are used in nasal analysis before rhinoplasty surgeries to achieve an aesthetic appearance because they are easy to measure.[7]

The aim of this study was to investigate the nasal angle morphometry and ideal nasolabial angle preferences of the Anatolian population. It was also aimed to provide clinicians with a new perspective, to contribute to the literature with anthropometric measurement of nasofrontal, nasofacial and nasolabial angles and to investigate whether there is a difference between digital and manual measurements.

Materials and Methods

This study was conducted on an Anatolian population consisting of 142 participants, 71 females and 71 males, aged 18–35 years. Participants were selected from Ankara University Faculty of Medicine students and research assistants. The study was conducted in the Department of Anatomy between February 2023 and May 2023. Exclusion criteria were age below 18 or above 35 years, history of facial or nasal trauma, and aesthetic surgery. Participants who had nasal trauma or nasal surgery were just asked to fill out a questionnaire to examine the differences in nasal angle preference between the surgery/trauma and non-surgery/non-trauma groups. Of the 142 total participants, 116 had their nasal angle morphometry assessed and were asked to participate in the survey, 9 had a history of plastic surgery and 18 had a history of trauma. Thus, 27 participants were only asked to participate in the survey (**Table 1**).

We studied on three different nasal angles: nasofacial, nasolabial and nasofrontal angles. Six landmarks were identified for measurements. All landmarks were demostrated on **Figure 1**.

- **Nasolabial angle (NLA):** The angle between the line connecting the pronasale (the most prominent anterior point on the tip of the nose) and subnasale (the midpoint at the base of the columella) points and the line connecting the subnasale and labialis superior points.

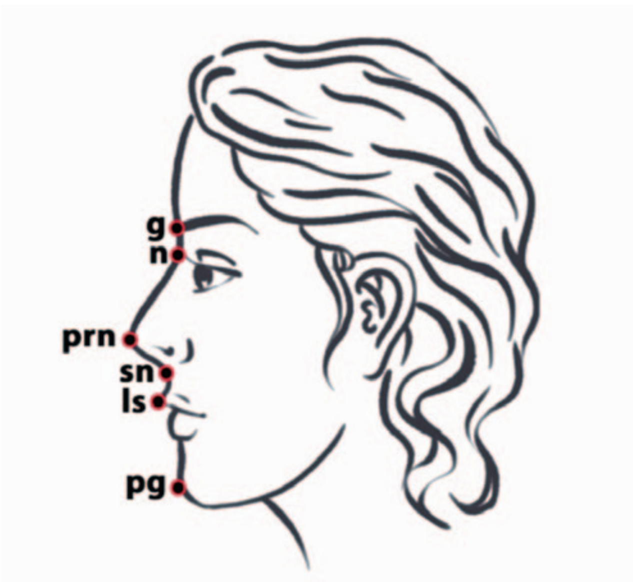

Figure 1. Six landmarks for measurements are shown. **g:** glabella (smooth prominence between the eyebrows); **ls:** labium superior; **n:** nasion (the midpoint of the frontonasal suture), **prn:** pronasale (the most prominent anterior point on the tip of the nose); **sn:** subnasale (the midpoint at the base of the columella); **pg:** pogonion (the most prominent median point on the anterior surface of the chin).

- **Nasofrontal angle (NFA):** The angle between the line connecting the glabella and nasion points and the line connecting the dorsum nasi and nasion points.
- **Nasofacial angle (NFcA):** The angle between the line connecting the glabella and pogonion points and the line connecting the pronasal and nasion points.[4,8]

Nasal angles were demostrated on **Figure 2**.

The first step was to measure the anthropometric nasal angles. We used two methods for measurements: manual and digital. Each participant was asked to hold their head at a natural head position, supported with self balance and mirror method and Frankfurt horizontal plane (FHP) parallel to the ground.[9]

Anthropometric measurements were compatible with Farkas' description.[10] A goniometer was used for manual measurements. The nasal angles of the participants were measured twice by the same researcher and the average of the two measurements was taken for the result. For photogrammetric measurements, each patient gave written consent to have their photographs taken by signing an informed consent form. Photographs of the patients were taken with a ruler to ensure photographic standardization. All photographs were taken with a camera (Canon SX10, Canon) and a tripod placed 1.5 meters away from the participant while facing away from the participants' left profile. Photoshop CS4 (Adobe Systems, Inc., San Jose, CA, USA) was used to evaluate the angles in the photographs. The photographs were reviewed and facial landmarks were identified. The facial angles and landmarks were reviewed by a co-author and both reviewers agreed on the facial angles.

In the second step, participants were asked to take a survey that consists of twelve questions (**Table 2**) Information such as whether they had undergone any previous plastic surgery or facial trauma was also included in the questions. Through this questionnaire, we asked our participants which nasolabial angle they found more attractive among six photographs of the same woman with different nasolabial angles (85, 90, 95, 100, 105, 110°) created with Photoshop CS4 (Adobe Systems, Inc., San Jose, CA, USA). This process was repeated on another group of male photographs. Participants chose which nose they preferred. The photos are shown in **Figure 3**.

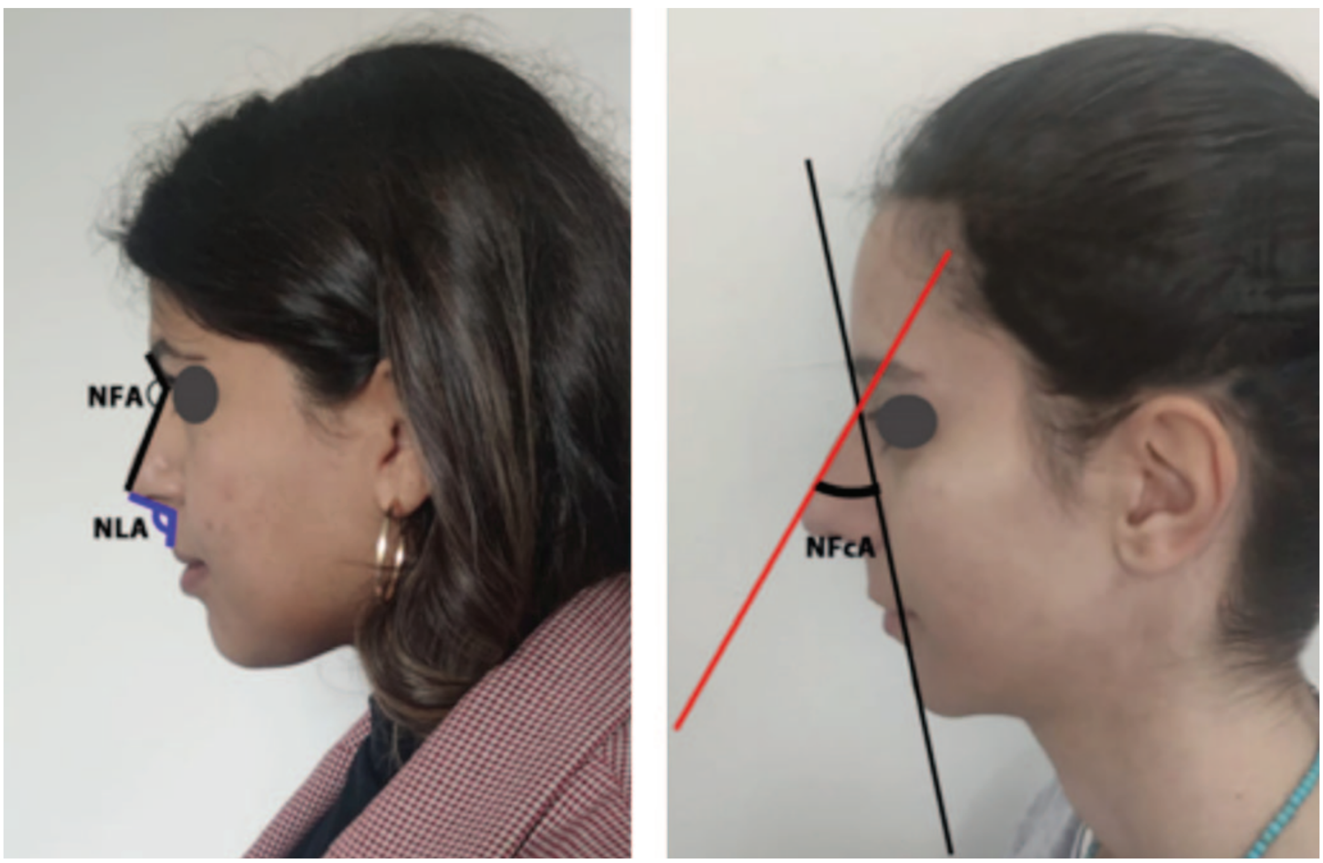

Figure 2. Nasal angle measurements are shown. **NFA:** nasofrontal angle; **NFcA:** nasofacial angle; **NLA:** nasolabial angle.

Table 2
Survey questions.

Participant Information and Approval Form
Name/Surname
Phone number
Age
Gender
Have you had a rhinoplasty operation before?
If you had, could you mention what was it and what was the content of operation?
Do you like the appearance of your nose?
Do the people around you like the appearance of your nose?
Would you consider having a rhinoplasty operation to change the appearance of your nose?
Down below, there are photos of a volunteer female's nasolabial angle modified by 5 degrees. Which one do you think is more appealing to eye?
Down below, there are photos of a volunteer male's nasolabial angle modified by 5 degrees. Which one do you think is more appealing to eye?

The statistical analyses were performed using SPSS version 26 (Statistical Package for the Social Sciences, IBM Inc., Chicago, IL, USA). Age (Mann-Whitney U p=0.83), history of rhinoplasty (χ^2=0.12, df=1, p=0.73), history of other plastic surgery (χ^2=3.06, df=1, p=0.08), and history of facial trauma (χ^2=2.29, df=1, p=0.13) were statistically unrelated. Descriptive statistics such as frequency and percentage, mean and standard deviation, and median (minimum and maximum) were calculated. Paired t-tests were used to compare mean nasal angle measurements between men and women. Except for the age variable, all other consistent variables were normally distributed in the Shapiro-Wilk normality test. A p-value <0.05 was considered statistically significant.

Results

According to digital measurements, the mean nasolabial angle was 99.51±9.51° in men and 100.49±9.37° in women. The mean nasofacial angle was 32.35±3.44° in men and 32.54±3.17° in women. The mean nasofrontal angle was 138.49±9.29° in men and 141.64±8.10° in women. The ideal nasolabial angle was 94.78±4.47° for men and 91.32±6.11° for women.

According to the manual results, the mean nasolabial angle was 96.02±10.48° for men and 98.36±8.65° for women. The mean nasofacial angle was 34.05±4.21° in men and 35.22±4.67° in women. The mean nasofrontal angle was 136.49±10.19° in men and 139.97±8.96° in women. Both digital and manual results of nasolabial and nasofrontal angles were shown to be very similar (independent t-test p=0.56), but the differences in nasofacial angle measurements were not statistically significant (p=0.03) (**Table 3**).

After anthropometric measurements and statistical analyses were performed by our team, it was calculated that the nasofrontal angle was higher in females

Table 3
The differences between digital and manual measurements by gender. The results are given as mean±standart deviation (SD).

	Male	Female	p-value
n	58	58	
Digital measurement results of the mean nasofacial angle	32.35±3.44°	32.54±3.17°	0.03 (t-test)
Manual measurement results of the mean nasofacial angle	34.05±4.21°	35.22±4.67°	0.03 (t-test)
Digital measurement results of the mean nasolabial angle	99.51±9.51°	100.49±9.37°	0.56 (t-test)
Manual measurement results of the mean nasolabial angle	96.02±10.48°	98.36±8.65°	0.56 (t-test)
Digital measurement results of the mean nasofrontal angle	138.49±9.29°	141.64±8.10°	0.59 (t-test)
Manual measurement results of the mean nasofrontal angle	136.49±10.19°	139.97±8.96°	0.59 (t-test)

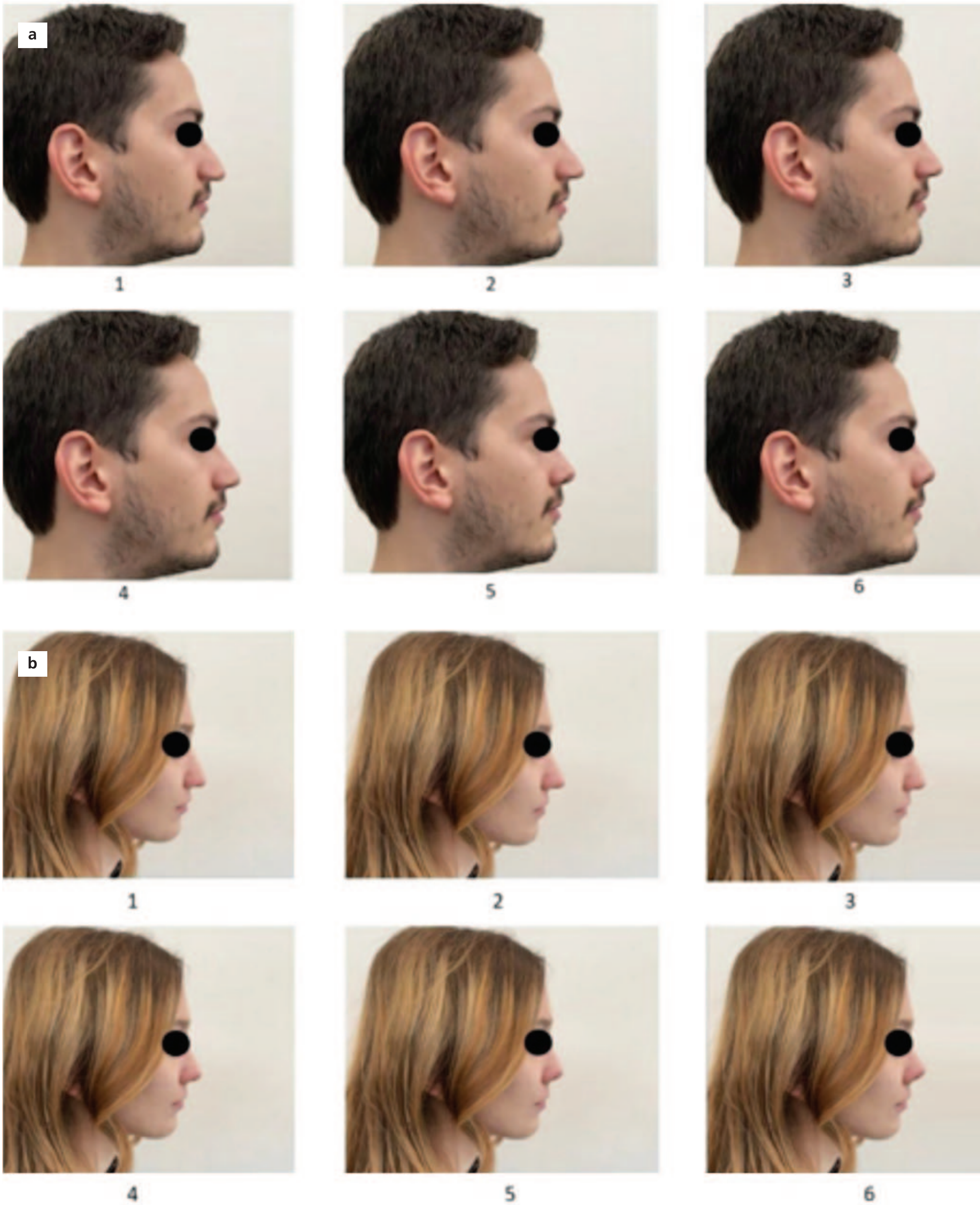

Figure 3. Photographes used for the survey of ideal nasolabial angle preference. The nasolabial angle was altered by 5 degrees (85, 90, 95, 100, 105, 110°) on the photograph of the same individuals with Photoshop CS4 (Adobe Systems, Inc., San Jose, CA, USA). (**a**) man; (**b**) woman. (**1**) 85 degrees; (**2**): 90 degrees; (**3**): 95 degrees; (**4**): 100 degrees; (**5**):105 degrees; (**6**): 110 degrees.

Table 4
Descriptive statistical analysis by gender.

	Male	Female	p-value
n	58	58	
Age			
Mean±SD	21.26±2.38°	21.21±1.9°	0.86 (MWU)
Median (min-max)	21 (18–31)	21 (18–35)	
Nasofacial angle			
Mean±SD	32.35±3.44°	32.54±3.17°	0.59 (t-test)
Median (min-max)	32 (26–42)	33 (25–39)	
Nasolabial angle			
Mean±SD	99.51±9.51°	100.49±9.37°	0.56 (t-test)
Median (min-max)	100 (68–117)	101 (81–121)	
Nasofrontal angle			
Mean±SD	138.49±9.29°	141.64±8.10°	0.03 (t-test)
Median (min-max)	137.50 (119–156)	141 (125–164)	

MWU: Mann-Whitney U test.

(32.54±3.17°) than in males (32.35±3.44°) (independent t-test p=0.03). In addition, nasofacial angles (independent t-test p=0.59) and nasolabial angles (independent t-test p=0.56) were independent of each other (**Table 4**). The mean ideal nasolabial angle in women (91.32±6.11°) was lower than the mean ideal nasolabial angle in men (94.78±4.47°) (p=9x10–8). And this difference between them is less than 5 degrees.

The tendency of the participants to rhinoplasty was calculated as 1.9 out of 5 in the population. Accordingly: participants are less likely to have a rhinoplasty. In addition, each participant's likelihood of having rhinoplasty did not change depending on whether the difference between their own nasolabial angle and their preferred nasolabial angle was above or below 5 degrees (p=0.39) Participants' aesthetic perception was similar with or without rhinoplasty (**Table 5**).

Although it was concluded that the mean ideal nasal angle preference of participants who had undergone rhinoplasty (93.89°) was higher than that of participants who had not undergone rhinoplasty (93.27°), it was statistically insignificant (independent t-test p=0.74).

It was found that there was a difference between the average ideal nasolabial angle preference of the participants who had not undergone nasal surgery and their own nasolabial angle measurements (11.76°). However, this was not statistically significant.

Our results suggest that participants under 24 years of age were more likely to prefer higher nasolabial angles, but this result was not statistically significant (p=0.14).

Discussion

Human nose consists of a lot of landmarks which reveals a wide range of measurements and angles.[10] Therefore there are a lot of components to take into account when describing and performing surgery to achieve an ideal nose shape. Nasal angles are essential shape components which provide facial aestetic and symmetry. The nasolabial angle is one of the key parameter and the most common angle used for planning and controlling the

Table 5
Impact of the difference between the preferred and present nasal angles to surgery choice.

Questionnaire	Desired nose - current difference	N	Mean	SD
Would you consider having surgery to change the appearance of your nose?	≥5	105	1.95	1.243
	<5	37	1.76	1.065

SD: standard deviation.

rhinoplasty.[11–14] While there are researches who define the ideal nasolabial angle, these definitions are broad and surgeries rely more on the subjective judgement of the surgeon rather than the literature.[14] The ideal nasolabial angle is described in the literature in a very large range as between 90 and 120 degrees.[15] But, it is also important for the operation success and patient satisfaction to know about the population's preference for that angle. Hence, present study have searched not only the Anatolian population's morphometric measurements of nasal angles but also their choices about the ideal nasolabial angle. Because of the majority of the participants of the present study are university students who come from different regions of Anatolia, the results represents the entire country. Since the common usage of nasolabial angle for the preparation and controlling of the surgery and that was founded the only parameter which has a consistency between the average and published aesthetic ideals, only the nasolabial angle were chosen for the survey in the study.[16]

Previous studies have searched for the ideal nasolabial angle preference in different ethnic groups[11,12,14,15,17–19] (**Table 6**). Brown and Guyuron[14] found the ideal nasolabial angle for men as 95.6±2.7°, for women as 98.5±2.6. The ideal nasolabial angle was found to be 94.78±6.47° for men and 91.32±6.11° for women. Brown and Guyuron[14] studied only 10 men and 10 women and a multicultural sample group. The racial difference and small sample size may account for the large difference between the ideal nasolabial angle measurements for women. In another study conducted by Alharethy et al.[11] with 506 male and 521 female Saudi Arabians, the ideal nasolabial angle for men was 89.39±3.66° and 90.62±5.15° for women. These are relatively closer to our results. However, our results are lower than the other studies in the table. This may be due to ethnic differences.

The preferences of the Anatolian population are missing in the literature. The ideal nasolabial angle preferences of the Anatolian population were evaluated for the first time in this study. We also investigated how the ideal nasolabial angle affects people's opinions about rhinoplasty. Our study is the first to evaluate three nasal angles and the ideal nasolabial angle together in both men and women. It is also the first study to show how facial trauma or undergoing rhinoplasty affects ideal nasolabial angle preferences. We compared our results between genders and ages. In the present study the main three nasal angles were evaluated: nasolabial, nasofrontal and nasofacial angle. Nasal angles are one of the most important and significant components of the nose when deciding the ideal nose shape. There are some previous studies that worked on nasal angles before[4,7,8,10,11,14–16,20–42] (**Table 7**). In a general comparison between previous studies with present study including different races the

Table 6
The ideal nasolabial angle (NLA) preference in previous studies and present study.

Study	Year	Age	Ethnicity	Sample size	Ideal NLA (degree) (women)	Ideal NLA (degree) (men)
Alshawaf et al.[12]	2023	20–39	Canadian Saudi Kuwaiti Lebanese	197	109.5±5.32	97.1±6.39
Sinno et al.[15]	2014	18–70	Caucasian African Americans Asians Native Americans	98	104.9±4.0	97.0±6.3
Patel et al.[18]	2012		Indian American	35	101.6	
Tavakoli et al.[19]	2023	<18–>65	Iranian	203	133.55±4.53	137.64±4.20
Alharethy et al.[11]*	2017	21.84±1.2	Middle Eastern	1027	Male 90.8°±5.6° Female 90.5°±4.8°	Male 89.5°±3.5° Female 89.3°±3.8°
Patel et al.[17]	2023		Multicultural	177		
Brown et al.[14]	2012		Multicultural	28	98.5±2.6	95.6±2.7
Present study	2023	18–35	Turkish	142	91.32±6.11	94.78±4.47

*In this study, participants were asked which angle they preferred for both men and women and the results were divided into two categories. NLA: nasolabial angle.

Table 7
Comparison with previous studies and present study according to the results of nasal angles.

Study	Population	n	Age	Method	NFA-degree		NFcA-degree		NBA-degree		Preferred NLA	
					M	F	M	F	M	F	M	F
Mohammed Ali[35]	Egyptians	M:500 F:500	20–70	2D	138.10±9.28	142.51±9.50	39.51±6.26	38.47±6.44				
Oghenemavwe et al.[37]	Urhobos (Nigeria)	M:60 F:60	18–35	Direct	117.75±9.07	127.85±9.50	40.77±6.29	35.60±7.46				
Fariaby et al.[29]	Iranian	M:50 F:50	20	2D	126±9	134±8	36±4	36±3	97±11	98±10		
Al-Qattan et al.[20]	Saudi Arabian	M:104 F:105	18–27	2D	135.9±9.6	145.9±6.1	41.4±6.8	33.3±4.1	100.4±16.4	102.3±10.0		
Aung et al.[23]	Chinese	M:45 F:45	3D	137.43±8.10	139.09±7.65			99.91±12.65	97.71±9.69			
Baik et al.[24]	Korean	M:30 F:30	21–27	3D	141.59±4.86	146.67±5.59	29.19±2.47	29.59±3.06				
Choe et al.[27]	Korean American	F:72	18–35	2D		136.8±6.4		32.3±5.1		92.1±9.2		
Elsamny et al.[28]	Egyptian	M:300	18–23	2D	144.0±7.2		33.1±2.9		104.5±11.2			
Farkas et al.[10]	North American Caucasian	F: 34				133.9±6.5				102.1±8.2		
Gode et al.[30]	Turkish	M:20 F:20	23.9 (19–35)	2D	143.3±8.3	140.9±7.5			103.1±5.3	119.2±9.7		
Leong and White[33]	Chinese Caucasian	54 50	18–55	2D 2D	129.3±6.5 129±10.4	136.6±6.5 135.3±3.7	34.7±6.8 36.7±7	33.7±5.5 36.6±5.2	86.2±12.5 96.8±7.8	87.6±13.7 101.8±8.8		
Leong and White[16]	Caucasian	M:24 F:26	18–55	2D	129.3±12.1	137.5±4.8	36.7±7.8	37.2±5.4	95.6±10.2	101.1±8.6		
Ofodile and Bokhari[36]	African-American	M:28 F:41	20–63		135.6±5.4	131.9±6.8			83.5±10.5	91.0±9.3		
Husein et al.[32]	Indian American	F:102	18–30	2D		138.2±8.1		31.8±4.5		97.2±10.6		
Springer et al.[38]	Caucasian	M:128 F:128	18–30	2D	130	137	34	32	114	106		
He et al.[31]	Chinese	M:56 F:63	18–25	2D	138.15±8.43	147.71±5.48			98.50±10.54	100.05±11.33		

Table 7 *[Continued]*

Comparison with previous studies and present study according to the results of nasal angles.

Study	Population	n	Age	Method	NFA-degree		NFcA-degree		NBA-degree		Preferred NLA	
					M	F	M	F	M	F	M	F
Amini et al.[21]	Persian	M:50 F:50	18–30						97±8.9	94.6±10.5		
Borman et al.[26]	Turkish	M:525 F:525	20–30		136.49±5.80	137.02±5.37			97.79±9.13	95.07±10.42		
Maral[8]	Turkish	M:63 F:63	18–29	3D	150.19±8.93	151.25±9.06	30.30 ±3.49	31.10±3.49	110.62±10.50	113.03±10.65		
Alharethy[11]	Saudi Arabian	M:506 F:521							95.96±2.57	97.7±2.32	89.39±3.66	90.62±5.15
Uzun et al.[40]	Turkish	M:108	18–30	2D	134.96±7.78				90.32±11.88			
Tabrizi et al.[39]	Iranian	M:27 F:35	24.32±4.02	2D	125.23±3.76		32.35±1.97		83.95±3.10			
Sinno et al.[15]	Caucasian-Asian	M:32 F:66									97.0±6.3	104.9±4.0
Ese Anibor et al.[22]	Nigeria	M:50 F:50	18–25	2D	132.0± 7.5	100.56±7.6	39.6±5.0	37.4±4.9				
Li et al.[34]	Chinese	M:399 F:501	17–24	2D	132.6± 9.06	138.7 ±7.51	100.99±15.33	98.97±9.7				
Wang et al.[41]	Korean	M:11 F:10	25–31	2D	126.0±6.3	133.6±5.2			78.5±11.1	82.7±12.7		
Ballin[25]	Caucasian	M:37 F:63	18–55	2D	133.71±6.43	139.14±8.17			107.75±9.82	104.03±10.65		
Youn and Seo[42]	Korean	F:242	22–40	2D		138.7±6.1		30.2±4.6		87.4±10		95-100
Mulafikh et al.[7]	Arabian	F:150	18–50	2D		145.9 ±6.1		33.3±4.1		102.3±11		
Brown and Guyuron[14]	Multi ethnical	M:10 F:10	37–38	2D							95.6 ± 2.7	98.5±2.6
Bahşi et al.[4]	Turkish	M:100 F:100	18–25	2D	135.66±9.70	142.95±6.62	36.75±4.95	35.07±3.73	102.92±10.91	104.03±10.35		
Our study	**Turkish**	**M:71 F:71**	**18–35**	**2D**	**138.49 ±9.29**	**141.64±8.10**	**32.35 ±3.44**	**32.54±3.17**	**99.51±9.51**	**100.49±9.37**	**94.78**	**91.32**

F: female; **M:** male; **NFA:** nasofrontal angle; **NfcA:** nasofacial angle; **NLA:** nasolabial angle.

results are similar. Only Leong et al.[33] from their chinese study and Ofodie et al.[36] from their african-american study have relatively lower results of nasolabial angle and two korean studies of Wang et al.[41] and Youn and Seo[42] have lower results of all three angles than our results. A wider nasolabial angle might cause the nostrils to be more apparent from the front and cause an undesirable appearance. A lower nasofrontal angle is associated with a low radix and also contributes to a nasal profile that appears short. On the other hand, a greater nasofrontal angle could make the nose seem too long in some situations.[43] The current study has similar results with the other studies which evaluated the Turkish population too.[4,8,26,30,40] Only Uzun et al.[40] have lesser than average nasolabial angle results which is because they just made the measurements on male participants (**Table 5**). Most of the previous studies were evaluated the angles with digital photogrammetry. The angles were also measured directly or manually in present study. Even though manual measurements are more subjective than digital measurements on photographs, there was no statistically significant differences between the results. This reveals that digital plannings can be correlated with intraoperative manuel measurements. We believe that we present a comprehensive study to the literature.

Previous rhinoplasty surgery did not change the choice of the ideal nasolabial angle. Due to the small number of participants with previous surgery, the results may be the same as in the non-operated group. We also found age and gender differences in ideal nasolabial angle preference, which may be useful for planning a personalized surgery.

Most surgeons change the patient's nasolabial angle on a photograph via digital applications before surgery and ask the patient if this is suitable for them. After surgery, they can check the result with the same method. Therefore, manual control techniques during surgery are still common. This study has shown that digital and manual measurements of nasolabial and nasofrontal angles are similar, so whether or not one of these techniques is used may obscure the results. However, the difference in nasofacial angle is statistically significant. If the two techniques could be used together for nasofacial angle measurement, the results would be more confidential. The difference between these two angles and the nasofacial angle may be due to the fact that the nasofacial angle is very difficult to measure manually. In our opinion, digital measurement is more reliable for nasofacial angle because of this situation.

This study has some limitations. We did not investigate preferences for nasofrontal and nasofacial angles in our questionnaire. Also, although we studied angles, there are other important components that contribute to the aesthetic appearance of the nose, such as length and width.[4,10] Another limitation is the total number of participants. Although our data supports our hypotheses, this may be the reason why some of our hypotheses were not statistically significant. Further studies are needed to investigate ideal nasal measurements and preferences in a larger population.

Conclusion

It is widely recognized that nasal distances and angles vary widely by population and ethnicity. It is important to understand the effects of demographic characteristics on ideal nasolabial angle preference. The rhinoplasty surgeon plays a crucial role in satisfying patients by identifying and understanding the specific nasal angle characteristics desired. Although there are studies on these lengths and angles in the literature, there are no standardized values related to varying aesthetic opinions and different preferences. In this study, the average nasal angle anthropometric values and ideal nasolabial angle of the Anatolian population were determined. We believe that our results will be useful in rhinoplasty preparation and planning.

Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

NPÇY: project development, data collection and management, data analysis, manuscript writing; CB: data collection and management, data analysis, manuscript writing; İNY: data collection, manuscript writing; OK: data collection, manuscript writing FNO: data collection, data analysis; AA: data collection, data analysis; ED: data collection; İT: project development, manuscript editing.

Ethics Approval

Informed consent was taken from each patient. Ethical permission was obtained from the Ankara University Faculty of Medicine Human Research Ethics Committee (Approval code: 2023/250).

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Annual distribution of body donation application rates in Istanbul, Türkiye

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Abstract

Objectives: Body donation is infrequent in Türkiye. Therefore, understanding body donation behavior becomes vital for managing existing awareness activities. Studies on donor profiles and motivations provide valuable data that could be used to shape the content of awareness activities. The timing of awareness activities is also important for increasing the effectiveness. Although annual differences in donation registrations have been reported, studies investigating the monthly changes within a calendar year are limited. This study aimed to investigate the official records of two departments of anatomy in Istanbul for outlining the monthly changes of body donation registrations.

Methods: The official records of 450 body donors who registered between 2012 and 2019 to the body donation programs of two departments of anatomy were evaluated. Annual and monthly registration numbers were recorded and analyzed.

Results: For the 2012-2019 period, 154 female (34.2%) and 296 male (65.8%) donors were registered to both programs. In general, the registrations were more frequent in May, November and December (χ^2=51.28; p<0.001). Interestingly, female donors preferred to register in May, June, November, and December (χ^2=40.961; p<0.001), while males preferred to register in March, April, May, September, and December (χ^2=24.757; p=0.01).

Conclusion: Currently, existing awareness activities in Türkiye are organized at the end of October which falls just before the Autumn peak of donor registrations. Therefore, planning awareness activities prior to the Spring peak might contribute to a more focused conduct of body donation awareness in Türkiye.

Keywords: body donation; body donation program; donor recruitment; registration; Türkiye

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Introduction

Human cadavers are an important part of the anatomy training and medical education.[1] The use of cadavers in anatomical education provides a broad spectrum of opportunities for medical students and improves their manual dexterity, recognition of body structures, understanding of human variation, teamwork abilities, professional attitudes, interdisciplinary communication, reflections on death and dying, and empathy skills.[2–4] For this reason, procuring an adequate number of bodies, i.e. the success of body donation programs, maintains its importance in anatomical sciences.[5]

In countries with well-developed body donation programs,[6] a campaign or promotion to raise body donation awareness in the society is not needed.[7] On the other hand, in countries where social awareness is low, such as Türkiye, awareness activities have vital importance for body donation programs.[8–10] Although countries with well-developed body donation programs provide good examples for different awareness activities, cultural differences between countries suggest modifications or implementation of novel methods to those activities.[9,11] Therefore, working with well-analyzed data and to keep the workforce-benefit balance at optimum in order to reach out to people who are more inclined to body donation becomes crucial.

Research studies aimed to increase the public awareness on body donation and body procurement rates provide valuable data for daily anatomy practice. These studies usually collect survey data from living individuals who consider body donation, registered body donors, or the public for understanding body donation behavior.[12–14] Quantitative and qualitative data obtained from these studies constitute the basis for determining the working strategies in awareness campaigns on body donation.[9,15]

Official records of anatomy institutions could be another important data source for obtaining information on body donation. These records could provide data on living individuals who decided to register for body donation and deceased individuals whose bodies are used as cadavers for medical education and research. For example, previous studies that used official records showed that the population registered for body donation may differ from the general population in terms of demographic features or motivations.[9,16–20]

These research studies provide an opportunity for anatomists to reach out to individuals with similar traits, be better prepared for individuals' concerns regarding body donation, and focus on distinctive motivations for body donation to recruit more body donors.

Similarly, temporal changes in official registrations have also been reported.[21] Unlike profiling studies, these studies provide a timeframe for anatomists to focus their awareness activities to certain periods within a year and increase the effectiveness of given awareness activities.

For obtaining a more detailed understanding on the body donation behavior in Türkiye, this study aimed to discover the temporal relationships of official body donation registrations and to determine whether there are seasonal behavioral patterns.

Materials and Methods

A reported increase in body donation registrations since 2012 has led the authors to investigate the official registrations between 2012–2019 for outlining any temporal changes. Official consent forms of 450 citizens registered for body donation who applied to the donation programs of Istanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine (CFM) and Istanbul University, Istanbul Faculty of Medicine (IFM) between 2012 and 2019 were included in the study. The time (month and year) of registration and sex of the registered citizens were recorded.

Chi square test was used to compare categorical groups such as institutions and sex. The null hypothesis was there were no temporal changes among donation registrations. Therefore, a simulated control group was created for comparison with the assumption that the total registrations were equally distributed over each year and month. Temporal changes of donation registrations were compared with McNemar's test. SPSS v.21 (IBM Corp., Armonk, NY, USA) was used for statistical evaluation.

Results

Among 450 individuals who were registered for the 2012–2019 period, 154 (34.2%) (IFM: 71; CFM: 83) were female and 296 (65.8%) (IFM: 138; CFM: 158) were male. There were no significant differences between both institutions regarding the sex ($p=0.917$), the number of annual applications ($p=0.167$), the number of applications per month ($p=0.551$), or the distribution of sex for annual registrations ($p=0.361$).

McNemar's test showed that there was a significant gradual increase for annual body donation registrations from 2012 to 2019 ($\chi^2=21.822$; $p=0.003$). Similarly, the annual number of registrations for females increased significantly within the study period ($\chi^2=17.532$; $p=0.014$). Despite a numerical increase in the number of registrations for males, no significant difference was found for the 2012–2019 period ($\chi^2=11.892$; $p=0.104$) (**Figure 1**).

For the 2012–2019 period, formal registration times showed significant monthly differences ($\chi^2=51.28$; $p<0.001$). Registrations were more frequent in May, November, and December (**Figure 2**).

Significant monthly increases were observed in the number of registrations for females ($\chi^2=40.961$; $p<0.001$) and males ($\chi^2=24.757$; $p=0.01$). Females were more frequently registered in May, June, November, and December, while males preferred to register March, April, May, September, and December (**Figure 2**).

When the institutions were analyzed individually, the annual number of registrations increased at IFM over the years ($\chi^2=24.455$; $p=0.001$). In contrast, there was no significant increase for annual registrations at CFM ($\chi^2=8.129$; $p=0.321$) (**Figure 1**).

Similarly, monthly registrations were significantly increased at CFM in March, September, November, and December ($\chi^2=36.095$; $p<0.001$) and at IFM in April, May, and December ($\chi^2=25.660$; $p=0.007$) (**Figure 2**).

Discussion

This study showed the presence of temporal changes in body donation registrations in Türkiye for the first time and provided an insight into body donation behavior. It also confirmed that there was a significant increase in annual body donation registrations in Istanbul between 2012 and 2019.[9] Within a year, individuals who consider body donation frequently applied in May, November, and

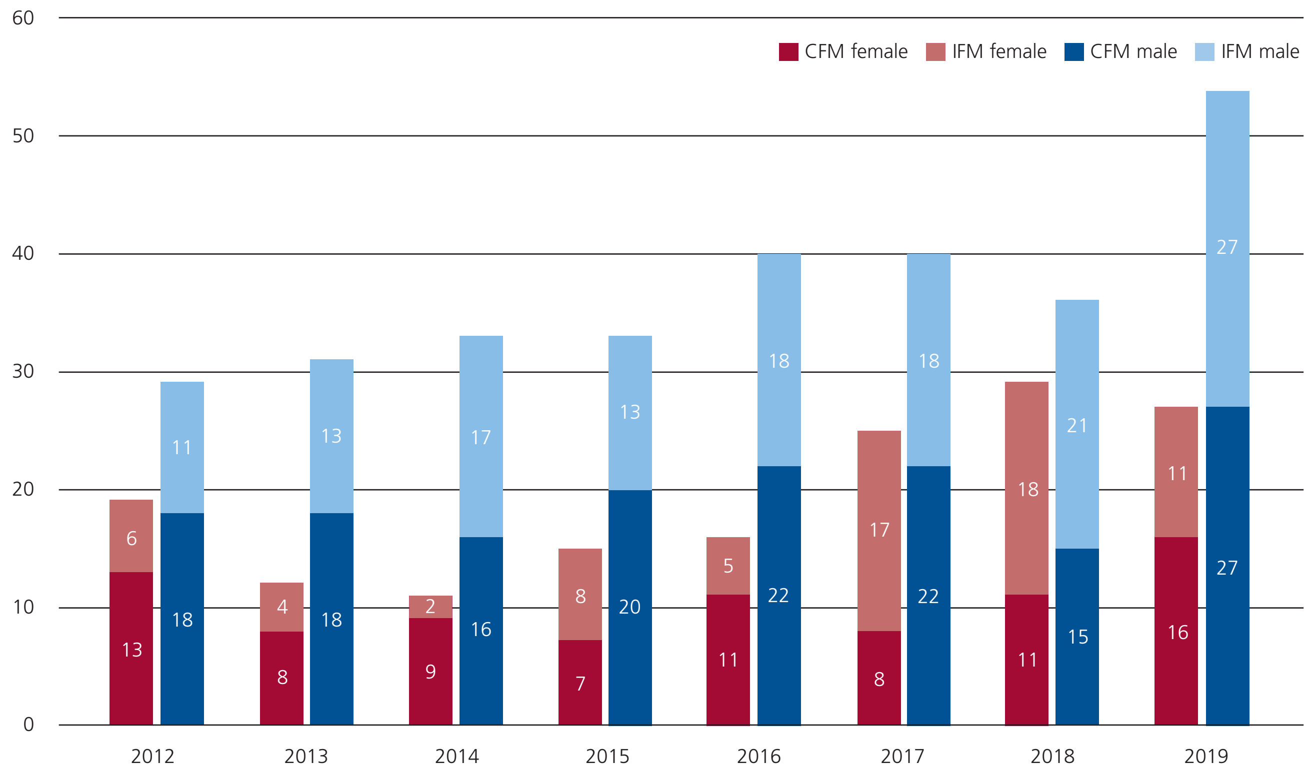

Figure 1. Clustered stacked bar chart showing the distribution of individuals who register for body donation for Cerrahpaşa Faculty of Medicine (**CFM**) and Istanbul Faculty of Medicine (**IFM**) by gender between 2012 and 2019.

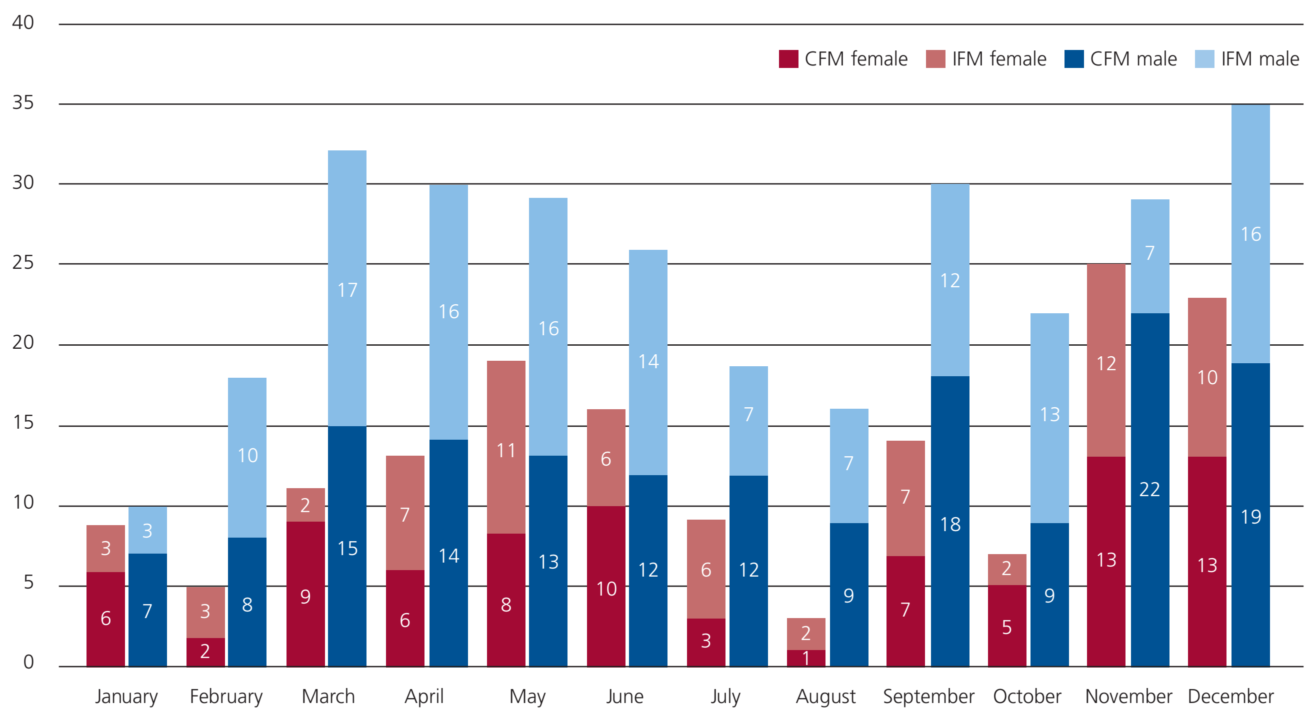

Figure 2. Clustered stacked bar chart showing the distribution of individuals who register for body donation for Cerrahpaşa Faculty of Medicine (**CFM**) and Istanbul Faculty of Medicine (**IFM**) by gender by month.

December. Interestingly, females and males frequently registered at different months. The data provided with this study might be useful for countries like Türkiye that need active and effective campaigns for increasing public awareness on body donation.

Although there are numerous studies that outline donor profiles and motivations, the temporal changes reported in these studies cover years or decades and lack data on registrations within a year.[9,12,16–20,22,23] Interestingly, temporal behavior of individuals, who consider or register for body donation, between months is scarcely studied. Cornwall,[21] investigated the records of 1352 registered body donors in New Zealand and reported that registrations in August, September, and October constituted nearly one third (32%) of all registrations. This period corresponds with the transition into spring for the southern hemisphere.[21] The onset of spring was related with neuroendocrine and behavioral changes in individuals. The amounts of melatonin and serotonin are highest during the spring.[24] Similarly, mood alterations and drastic decisions that involve significant or extreme behavior, such as suicide, is more frequent at the beginning of spring.[25,26] Nevertheless, the effects of seasonal changes on body donation decisions remain unexplored. Similarly, the first peak in donor registrations in Istanbul was prominent during May, which marked the end of spring for the northern hemisphere. Despite the speculative data, temporal behaviors of two registered body donor cohorts at diverse geographical locations are similar.

As for low numbers of registrations, Cornwall[21] reported that the lowest number of registrations were observed in the December–January period and July. In New Zealand, summer months of December and January constitute the major public and school holiday period over the Christmas period. In Türkiye, body donor registrations significantly decreased during the summer months of July and August which are the major public, school, and university holiday periods. Similar to the increase in spring transition, major holiday seasons seem to affect body donation decisions negatively. Cornwall[21] suggested that the registration decrease in New Zealand during the winter in July may be related to an opposite process of the increase in spring. Interestingly, donation registrations in Istanbul were the least during January and February which are winter months. Additionally, the end of January and beginning of February is the semester holiday season for primary schools and universities in Türkiye. It is known that, despite their diverse cultural and geographical differences, body donors tend to have similar traits in demographics and motivations.[9,13] This study and the study of Cornwall[21] show that individuals that decide to donate their bodies seem to have similar temporal behaviors for registering to a donation program, despite their cultural and geographical differences.

The Turkish Society of Anatomy and Clinical Anatomy (TSACA) had published the "Report on the Cadaver Problem in Turkey and Recommendations for a Solution" in 2013 for underlying the cadaver shortage at Turkish medical faculties.[27] In order to increase the number of bodies procured for education and research, the TSACA suggested promoting body donation in Türkiye by an awareness campaign. The last week of October was selected as the National Anatomy Week to highlight the current cadaver problem, emphasize the importance of cadavers, and publicly promote the idea of body donation.[11,28] The encouragement of the TSACA resulted in press releases,[29] interviews,[30] and official commemorations for body donors[31] within the last decade. Ok and Gürses[11] suggested that these activities significantly increased the average annual donation registrations to CFM and IFM for the 2012–2019 period when compared to the 2000–2012 period.[9,11] Similarly, Erdoğan et al.[8] demonstrated that the public awareness on body donation had reached a critical level where citizens are aware of what body donation means despite their lack of motivation to donate and knowledge on how. Additionally, the highest body donation registration rate was observed in November and December, just after the National Anatomy Week activities. This suggests that there might be temporal correlation between selected awareness campaign timeframe and registration months. On the other hand, the activities of the National Anatomy Week do not explain the increase in body donation registrations in September. Therefore, it needs further research to explain the increase in November and December whether it was caused by the National Anatomy Week, the seasonal effect of Autumn, or their cumulative effect.

A significant registration peak was also observed in May. Therefore, a second group of activities organized before May might further improve awareness among the population and increase registrations. Commemoration services might be an example for implementing the newly observed temporal behavior.[32–34] Interestingly most commemorations performed in Türkiye were organized within the National Anatomy Week which falls into the middle of the first semester of an academic year where most medical schools are only a few months into anatomy laboratories and cadaver exposure. Although student opinions on the timing of a commemoration ceremony favor before the laboratory starts,[35] most commemorations around the world are done at the end of the anatomy course.[36–40] The end of term commemorations might give the students to reflect their empathy and gratitude towards the donors[37,40] and provide a closure for students as well as donor relatives.[41,42] Therefore, organizing commemorations services during a later time within the academic year, such as April or May might have a positive effect on the ongoing awareness efforts in Türkiye.

Both CFM and IFM had no differences for sex distribution of registered individuals, annual registrations, and monthly registration rates for the 2012–2019 period. Conversely, while the CFM received a relatively regular registration rate, the number of registrations to the IFM significantly increased over the years. Additionally, both institutions differed for highest registered months. This study showed that the temporal behavior of registered body donors differed in two institutions in Istanbul. This finding suggests that neither institution might not represent the city of Istanbul due to the small number of applications per year. This also implies that a second timeframe for additional awareness activities might differ among institutions or cities. Therefore, for the time being each institution in Türkiye might perform a similar analysis and determine an appropriate time for their additional awareness activities.

Although this study detected an alternative timeframe for awareness activities, it has limitations. The number of registrations to both institutions was limited to 450 for an eight-year period. Despite both institutions being located in the same city and district, the small sample size has led to significant differences in annual registration numbers and behavior of female and male donors. Therefore, the results might not reflect the city of Istanbul or Türkiye in general.

Conclusion

The number of body donation registrations are increasing in Türkiye. The individuals who consider body donation choose to register at certain months within a year. Peaks in registrations are observed during Autumn and end of Spring. Current awareness activities in Türkiye fall within the Autumn peak. Therefore, planning awareness activities in the Spring might contribute to a more focused conduct of body donation awareness in Türkiye. Nevertheless, due to the limited number of registrations per year, institutions might need to analyze their records for detecting appropriate timing.

Conflict of Interest

No conflict of interest was declared by the authors.

Author Contributions

AE: project development, data collection, data analysis, manuscript writing; OC: data collection, data management, data analysis; ÖID: data collection, data analysis, manuscript writing; İAG: project development, data analysis, manuscript editing.

Ethics Approval

Ethical approval was not needed for this study.

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Op. Dr. İlhami Güneral (1914–2006), author and illustrator of the first original dissection manual in Turkish and his contributions to anatomy

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Abstract

Objectives: İlhami Güneral was a Turkish physician and surgeon whose contributions to anatomy education and medical illustration remained under-appreciated until this day. This study aims to outline his achievements throughout his career and acknowledge his unreported contributions to anatomical sciences in Türkiye.

Methods: A series of interviews were conducted with his surviving family, relatives, and friends. Additional documents were also collected from various national and international institutions.

Results: İlhami Güneral was born in 1914 in Anadolu Kavağı, İstanbul. He attended İstanbul University Faculty of Medicine and graduated in 1942. Upon graduation, he published his first book titled "Diseksiyon Atlası" which he also illustrated himself. His illustrations were later used in Prof. Dr. Zeki Zeren's dissection handbook published in 1953. He visited and worked with renowned neuropathologist Philipp Schwartz between 1958 and 1960 in Warren, Pennsylvania. During his stay, he co-constructed a detachable "Transparent Brain Model" for teaching brain anatomy which was awarded with the Billings Gold Medal at the 109th Annual Meeting of the American Medical Association. After his return to Türkiye, he published his final illustrated anatomy atlas in 1972, the "Atlas Cerebri Humani". He spent the remaining days of his life in his long standing home in Ödemiş, İzmir, as a private physician and surgeon. He was diagnosed with prostate cancer in 1993, and passed away due to his illness in 2006.

Conclusion: This interesting and unique dramatis persona is the author and illustrator of the first original dissection manual printed in Turkish.

Keywords: anatomy; anatomy education; dissection; medical illustration

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Introduction

İlhami Güneral was a surgeon who late in his career became popular and rather controversial with his books on alternative/complementary treatment of cancer in the late 1990s and early 2000s. This rather sensational aspect of his career, mostly shadows his contributions to anatomy. This paper aims to outline his achievements throughout his career and acknowledge his unreported contributions to anatomical sciences in Türkiye.

In order to collect data on this figure, different sources were contacted and utilized. Mrs. Ejide Tanık, the daughter and only surviving relative of Dr. Güneral was contacted for information on his life, personal documents, and his original works. Mrs. Tanık was interviewed on two different occasions and additional correspondence was established for receiving relevant documents and obtaining written permission for the use of personal documents. For comparison of Dr. Güneral's reused illustrations, Istanbul University Press, Printing and Publication Office was contacted. The American Medical Association Archives (AMA Archives) was contacted for documents regarding the award he received in 1960.

His Life

İlhami Güneral was born in Anadolu Kavağı district of Istanbul in 1914. Due to the independence war at the time, he had to change numerous schools, including Şems-ül Mekâtip, along with Saint-Joseph, Saint Benoît, and Esayan High Schools, for his elementary and high school education. He graduated from Bursa Erkek Lisesi (**Figure 1**).

From a very early age, he had a talent for drawing and sculpting. Initially, this led him to apply to the Academy of Fine Arts, which later became the Mimar Sinan Fine Arts University, after his graduation from high school for his training in architecture. Unfortunately, he had a passion for medicine. Therefore, he dropped out from the Academy of Fine Arts a year later and enlisted to the Faculty of Medicine of Istanbul University despite his father's wishes. This reluctance from his father financially burdened him and he had to work and study throughout his medical training. He graduated from the faculty of medicine in 1942 (**Figure 2**). Following his military service, he started his surgery residency and completed his training in 1950. As part of his mandatory medical service, he was appointed to the Ödemiş State Hospital in İzmir, where he later became the chief of staff.

In late 1957, he received an invitation from the world renowned neuropathologist, Professor Philipp Schwartz, who was a beloved lecturer of his from medical school in İstanbul. In the letter of invitation, Professor Schwartz asked him to come and work in the United States, and help him to produce an educational model for studying the human brain. Güneral produced a small vax model of the brain and sent it to Schwartz so that he could apply for a fund. Once the project was approved, he traveled first to Erie, Pennsylvania in early 1958. About six months later, his family joined him in Warren, Pennsylvania, where professor Schwartz was currently working as a pathologist at the Warren State Hospital and chaired a research department there. For the next two and a half years he modeled and sculpted detachable and transparent brain models for neuroanatomy education. In June 1960, he and Prof. Schwartz took the finished models and exhibited them at the 109th Annual Meeting of the American Medical Association which was held in Miami Beach, Florida. The exhibit titled "New Ways in Teaching Brain Anatomy: The Transparent Brain" was awarded with the Billings Gold Medal (**Figure 3**).[1]

He returned to Türkiye in September 1960. Upon his return, he visited his professors at Istanbul University in order to convince them to produce another model for Istanbul University. Unfortunately, they could not secure necessary funds for the project.

After his return to Ödemiş, he resigned from his official post at the State Hospital and worked as a private physician/surgeon for the remainder of his life. In 1993 he was diagnosed with prostate cancer. This experience has increased his curiosity in complementary medicine, which he also authored three books titled "Kanserden Korkma Modası Geçmiş Tedaviden Kork", "Doktorunuzun Söyleyemedikleri", and "Kalp – Damar Hastalıklarında ve Kanser'de Ölümcül Oyunlar". He lost his more than a decade long battle with cancer, and passed away in 2006.

He had three marriages and three children.

Figure 1. During his studies at Bursa Erkek Lisesi as a high school student, young Dr. Güneral served a short time in Bursa Penitentiary. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

His Contributions to Anatomy

His first contribution to anatomical sciences in Türkiye was a small dissection atlas, which was published in 1942, just after his graduation from the faculty of medicine (**Figure 4**).[2] The book was 96 pages long and had 104

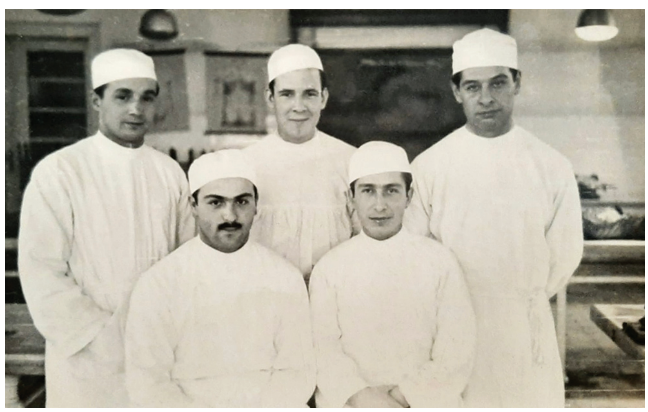
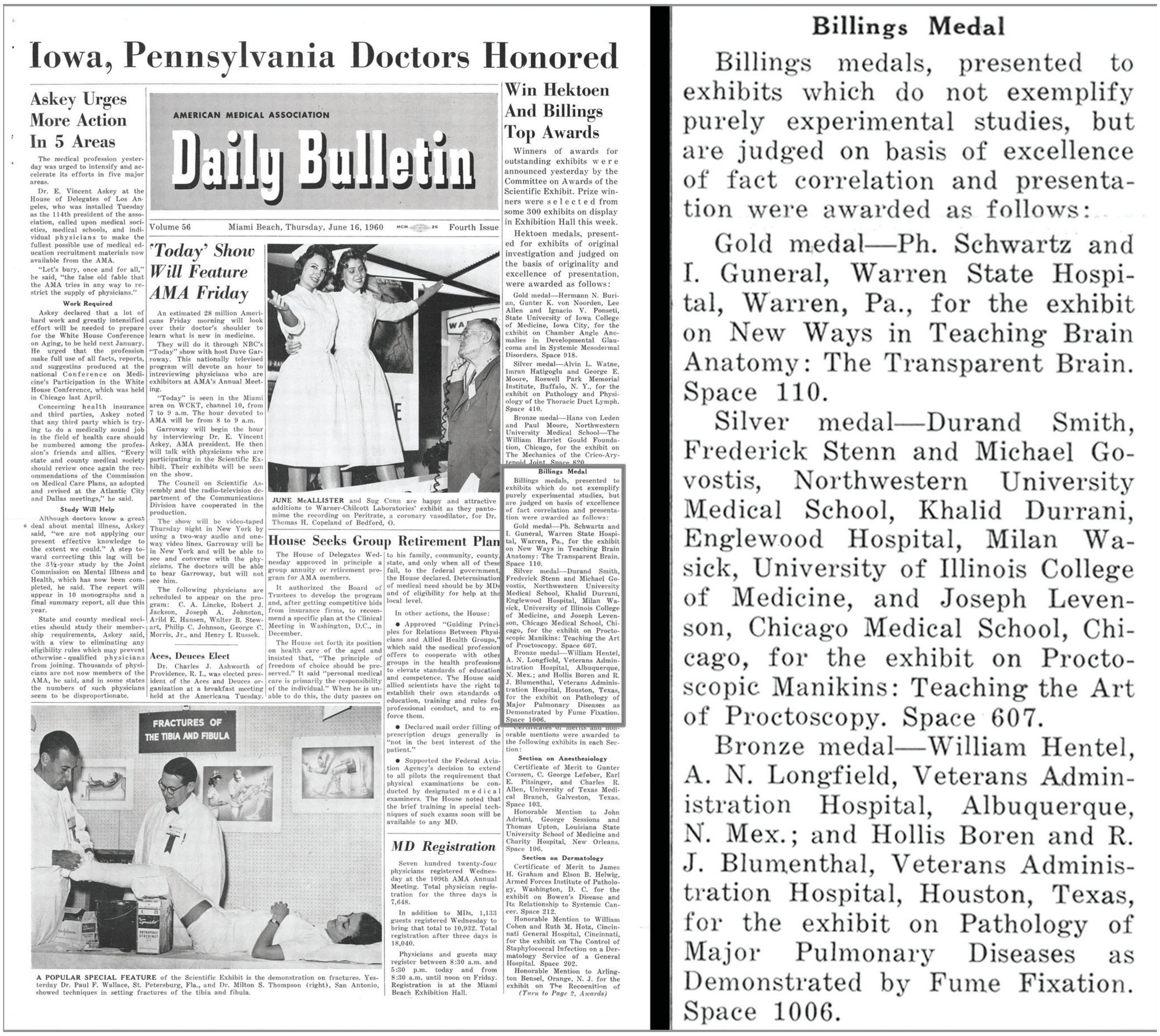


Figure 2. Dr. Güneral (upper row, first from right) and his peers from İstanbul University Faculty of Medicine during a dissection course at the Morphology building in Beyazıt Campus. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.


Iowa, Pennsylvania Doctors Honored

AMERICAN MEDICAL ASSOCIATION

Daily Bulletin

Volume 56 Miami Beach, Thursday, June 16, 1960 Fourth Issue

Askey Urges More Action In 5 Areas

'Today' Show Will Feature AMA Friday

Win Hektoen And Billings Top Awards

House Seeks Group Retirement Plan

Aces, Deuces Elect

MD Registration

Billings Medal

Billings medals, presented to exhibits which do not exemplify purely experimental studies, but are judged on basis of excellence of fact correlation and presentation were awarded as follows:

Gold medal—Ph. Schwartz and I. Guneral, Warren State Hospital, Warren, Pa., for the exhibit on New Ways in Teaching Brain Anatomy: The Transparent Brain. Space 110.

Silver medal—Durand Smith, Frederick Stenn and Michael Govostis, Northwestern University Medical School, Khalid Durrani, Englewood Hospital, Milan Wasick, University of Illinois College of Medicine, and Joseph Levenson, Chicago Medical School, Chicago, for the exhibit on Proctoscopic Manikins: Teaching the Art of Proctoscopy. Space 607.

Bronze medal—William Hentel, A. N. Longfield, Veterans Administration Hospital, Albuquerque, N. Mex.; and Hollis Boren and R. J. Blumenthal, Veterans Administration Hospital, Houston, Texas, for the exhibit on Pathology of Major Pulmonary Diseases as Demonstrated by Fume Fixation. Space 1006.

Figure 3. A clipping from the American Medical Association Daily Bulletin (June 16, 1960) reporting that Dr. Ph. Schwartz and Dr. İ. Güneral were awarded with the Billings Gold Medal for their exhibit on new ways in teaching brain anatomy. The gray frame is zoomed in for providing detail of the bulletin. The image was used with the written permission of the AMA Archives. Courtesy of AMA Archives.

original illustrations that showed different steps of the dissections and important dissection tips (**Figure 5**). The book heavily relied on original illustrations that were drawn by himself. The main motivation for him to create this book was actually financial, since his father did not support his medical training. The book did not receive much interest at first and was only published in one edition. About a decade later, the Chair of the Institute of Anatomy at Istanbul University Faculty of Medicine, Professor Zeki Zeren, used some of Güneral's illustrations in his dissection manual which was published in 1953. Prof. Zeren acknowledged Güneral's contribution and included his kind permission in the forwards of his book.[3] The manual of Zeki Zeren used 68 of Güneral's illustrations (**Figure 6**).

His second seminal work was the transparent brain models that he constructed during his stay in Warren, United States. During his stay, he worked to create a multi pieced detachable brain model made out of copper wires and colored epoxy resin and multiple section mod-

Figure 4. Cover (**a**) and front matter (**b**) of Dr. Güneral's "Diseksiyon Atlası", published in 1942. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

els. His creative process was a multi step approach. He first acquired serial slices from different regions of the brain, stained them, and investigated them under a light microscope. This helped him to visualize and follow major ascending and descending fiber systems and nuclei layer by layer. The step was basically a manual segmentation of the entire sections he evaluated. Later he drew sketches and full colored illustrations that will create the base of the constructed model. In the final step, he created different sized molds to be filled with transparent epoxy resin. In the scientific programme of the 109th Meeting of the American Medical Association held in Miami Beach, Güneral was reported as a co-creator for the exhibit titled "New Ways in Teaching Brain Anatomy: The Transparent Brain".[4] With this exhibit, Dr. Schwartz and Dr. Güneral were awarded with the Billings Gold Medal (**Figures 3**, **7** and **8**).[1] Interestingly, despite being reported in the scientific programme and

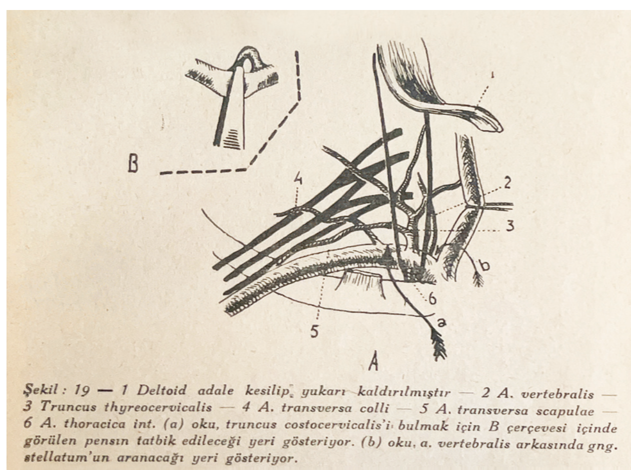


Figure 5. An example of a dissection step showing the dissection of the root of the neck. The illustrations usually provide small dissection tips and tricks. In this image, the black curved arrow (**b**) guides students to the inferior cervical (stellate) ganglion just posterior to the vertebral artery. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

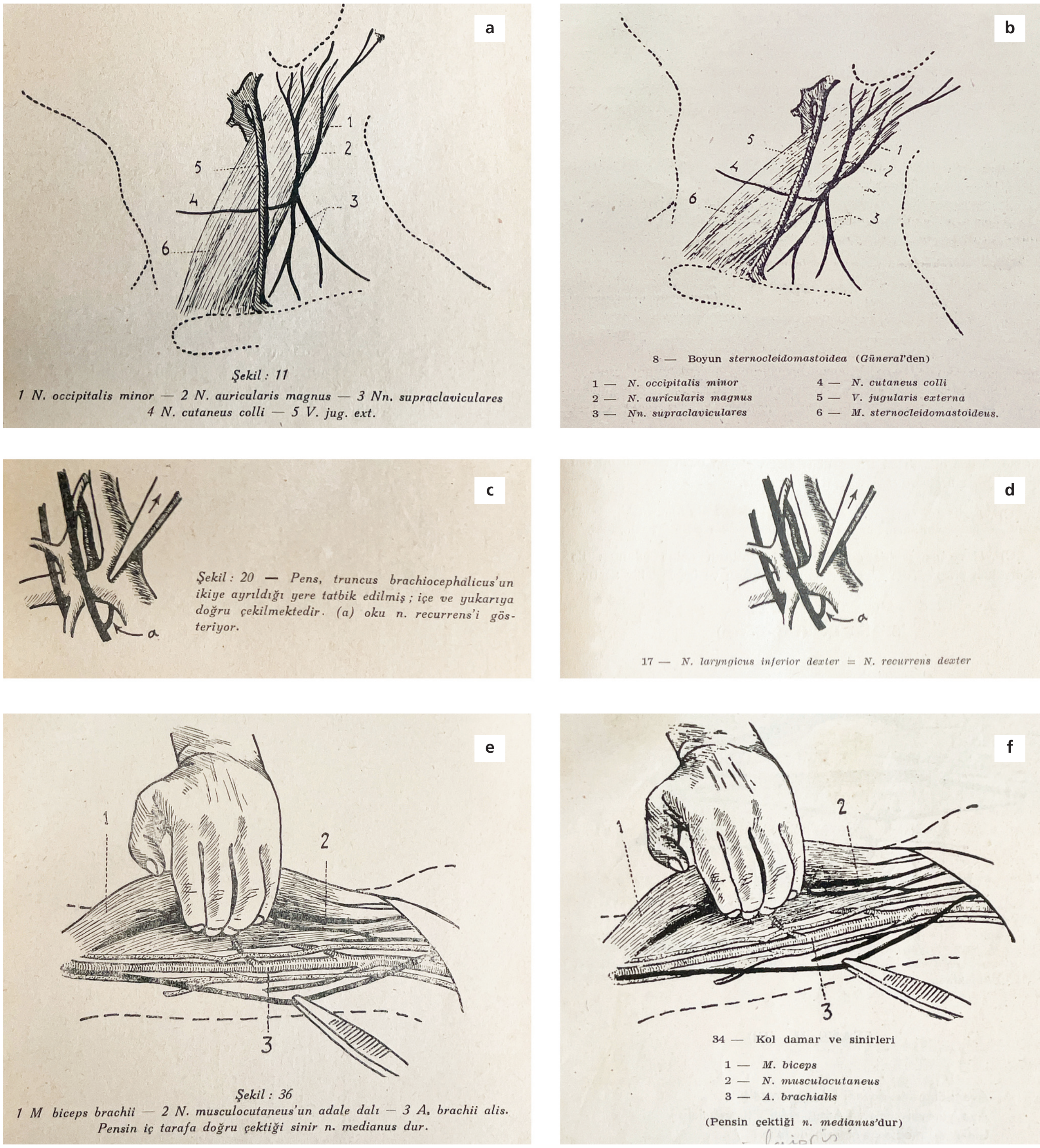


Figure 6. Comparison of some images from the books of Drs. Güneral and Zeren. The images on the left (**a**, **c**, **e**) and right (**b**, **d**, **f**) are from Güneral's and Zeren's books, respectively. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

in numerous news articles as a co-creator of the model and co-recipient of the gold medal, later publications on the life of Professor Schwartz that mention this award mostly do not mention Güneral's contributions,[5,6] and some report that Dr. Schwartz cooperated with a sculptor, Mr. Seymour Couzyn, from the American Museum of Natural History in New York to construct the three dimensional anatomical brain models.[7,8] Therefore, his

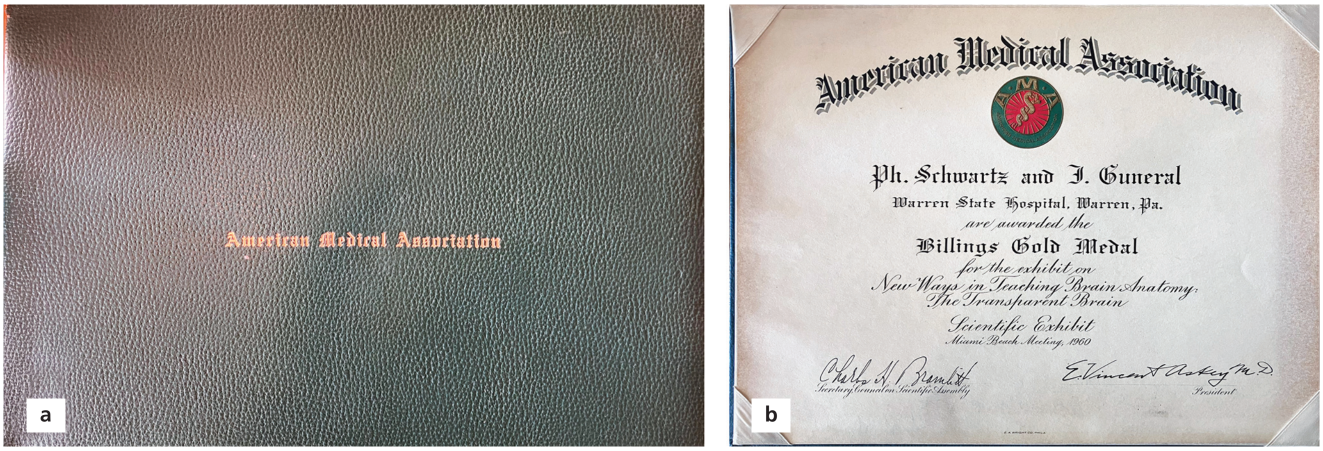


Figure 7. The cover (**a**) and the certificate (**b**) of the Billings Gold Medal given to Ph. Schwartz and İ. Güneral for the exhibit on New Ways in Teaching Brain Anatomy: The Transparent Brain presented by the American Medical Association. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

contributions to this seminal work mostly stayed uncredited up until today. There is only a single piece of the original brain model, the right half of a hemisected brain stem, in the possession of Güneral's surviving family members (**Figure 8**).

His final book was published in 1972. The book was titled "Güneral's Atlas Cerebri Humani" and contained 25 hand drawn and signed illustrations depicting major brain stem and cerebellar nuclei, and ascending and descending pathways (**Figure 9**).[9] The striking detail of the images resemble as if the nuclei and corresponding tracts were dissected and portrayed in the white matter dissection technique of Klingler.[10] Although there is no information on whether Güneral had experience in Klingler's dissec-

Figure 8. The only piece, a sagittal hemisection of the brainstem, from the transparent brain model that Dr. Güneral's surviving family has in their belongings. (**a**) lateral aspect of the brain stem; (**b**) close up on the lateral aspect of the bulbus for details; (**c**) medial aspect of the sagittal section of the brain stem. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

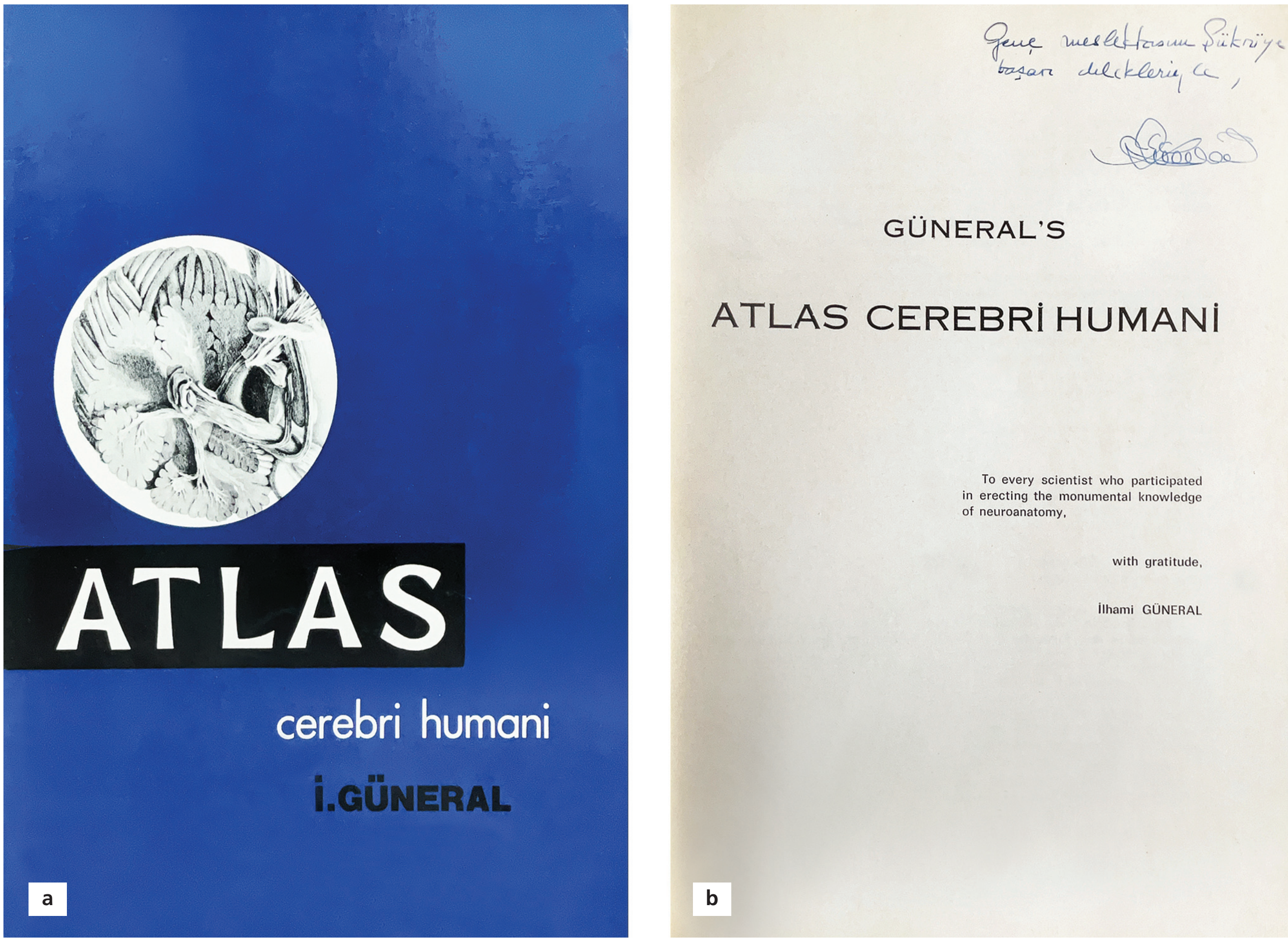
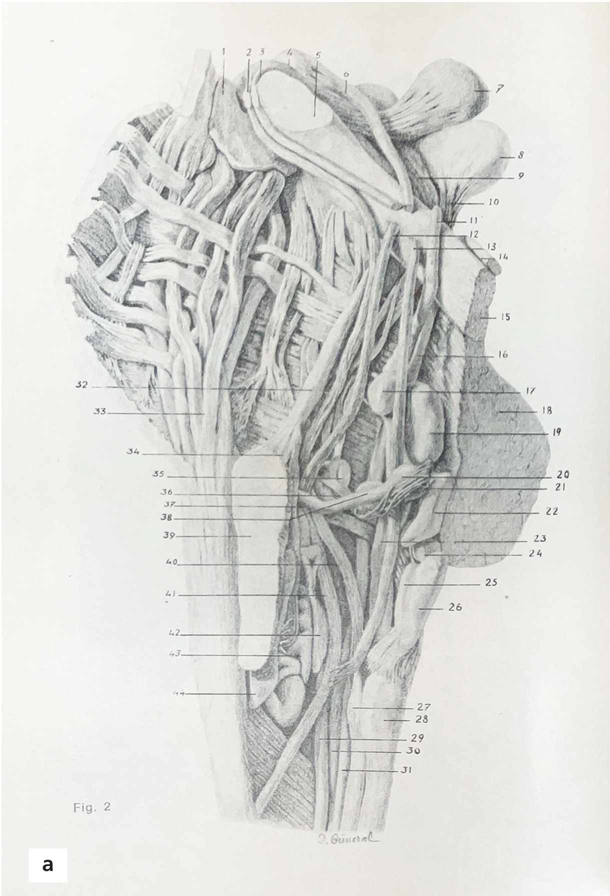


Figure 9. Cover (**a**) and front matter (**b**) of Güneral's "Atlas Cerebri Humani", published in 1972. From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

tion method or he had access to human specimens to work on during the production of the atlas. It seems like he illustrated relevant structures depending only on his previous experience when he worked on the transparent brain model back in Warren, United States. The book was written in English and aimed at an international audience. Despite not being popular, and limited to a single edition, the book provided very fine imagery of brainstem and cerebellar fiber systems, and nuclei, which depicted detailed neuroanatomy similar to the work of Klingler (**Figures 10** and **11**).

Conclusion

Although he was not an anatomist, or enrolled or completed a PhD/residency program in human anatomy, Dr. İlhami Güneral's contributions to anatomical sciences and anatomy education in Türkiye are relevant. During the late Ottoman and early Republic period, many anatomy books and atlases were printed in Ottoman Turkish or Modern Turkish. Most of these works, however, are translations from a single work (book or atlas) or collations of translations from various works.[11–13] The first illustrated human anatomy atlas in Ottoman Turkish is the "Teşrîh-i Miftâh" by Hristo Stambolski.[13,14] Although this atlas, which is an anatomy atlas rather than a dissection manual/book, is the first anatomy atlas printed in Ottoman Turkish, is a direct translation of "Petit Atlas Complét d'Anatomie Descriptive du Corps Humain" by Joseph-Nicolas Masse.[15] The first reported original dissection book in Ottoman Turkish is the Usul-ü Teşrih (method of anatomy/dissection), which is the unfinished work of Hasan Mazhar Paşa.[14] Since this unfinished work, there is no report of a dissection book published in Ottoman

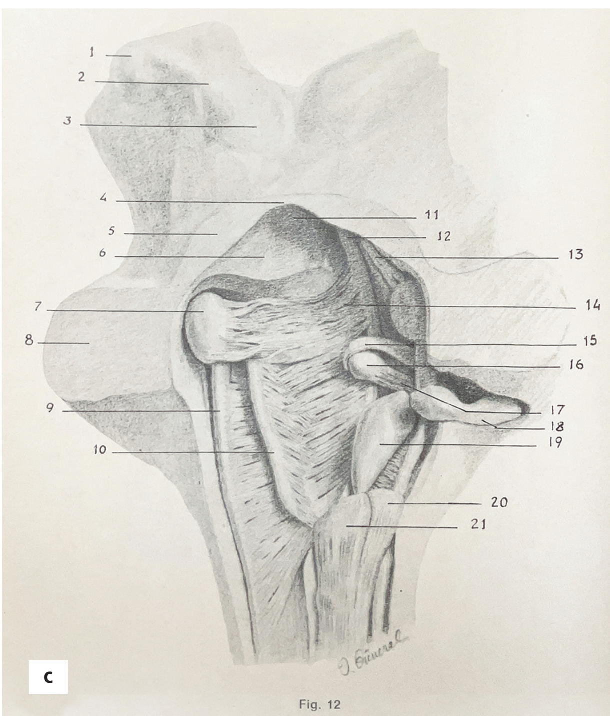


b

Fig. 2

Dissection of medulla oblongata, pons and pedunculus cerebri (medial aspect). Some of the nuclei and fiber tracts are removed for a better demonstration of the underlying or neighboring elements.

1 — Substantia nigra.
2 — Rubrospinal tract (before decussation).
3 — Tectospinal tract (before decussation).
4 — Nucleus of Darkschewitsch.
5 — Decussation of brachium conjunctivum.
6 — Medial longitudinal fasciculus.
7 — Superior colliculus.
8 — Inferior colliculus.
9 — Medial lemniscus.
10 — Leteral lemniscus.
11 — Mesencephalic root of trigeminal nerve.
12 — Thalamo-olivary tract (central tract of the tegmentum).
13 — Dorsal secondary trigeminal tract.
14 — (also 16) Ventral spinocerebellar tract.
15 — Brachium conjunctivum.
17 — Nucleus masticatorius.
18 — Middle cerebellar peduncle.
19 — Main sensory nucleus of trigeminal nerve.
20 — Nucleus abducentis
21 — Internal genu of n. facialis
22 — Nucleus vestibularis superior.
23 — Nucleus of the spinal tract of trigeminal nerve.
24 — Nucleus cochlearis dorsalis.
25 — Inferior vestibular nucleus.
26 — Medial vestibular nucleus.
27 — Accessory cuneate nucleus.
28 — Nucleus gracilis.
29 — Lateral spinothalamic fasciculus.
30 — Ventral spinocerebellar tract.
31 — Dorsal spinocerebellar tract.
32 — Lemniscus medialis.
33 — Pyramidal tracts.
34 — Area of junction of the trigeminal lemniscus to lemniscus medialis.
35 — Nucleus olivaris superior.
36 — Trapezoid fibers.
37 — Nervus abducentis.
38 — Nucleus facialis.
39 — Decussation of the internal arcuate fibers.
40 — Rubrospinal fasciculus.
41 — Ventral spinothalamic fasciculus.
42 — Dorsal accessory olivary nucleus.
43 — Nucleus olivaris inferior.
44 — Medial accessory olivary nucleus.



d

Fig. 12

Dorsal dissection of medulla oblongata and pons. Formation of the dorsal secondary trigeminal tract.

1 — Medial geniculate body.
2 — Brachium of inferior colliculus.
3 — Inferior colliculus.
4 — Velum medullare anterius.
5 — Superior cerebellar peduncle.
6 — Rostral part of fossa rhomboidea.
7 — Main sensory nucleus of trigeminal nerve.
8 — Middle cerebellar peduncle.
9 — Spinal tract of trigeminal nerve.
10 — Dorsal secondary trigeminal tract.
11 — Aquaductus cerebri (Sylvii).
12 — Dorsal secondary trigeminal tract. The dissection at the right side is prolongated more rostrally to demonstrate the tract.
13 — Mesencephalic root of trigeminal nerve.
14 — Fibers from the main sensory nucleus.
15 — Internal genu of facial nerve.
16 — Nucleus abducentis.
17 — Nervus abducentis.
18 — Dorsal and ventral cochlear nuclei.
19 — Medial vestibular nucleus.
20 — Nucleus cuneatus.
21 — Nucleus gracilis.

Figure 10. Detailed images in the Güneral's Atlas Cerebri Humani depicting the detailed anatomy of major brainstem nuclei and pathways (**a** and **c**) and accompanying figure legends (**b** and **d**). From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

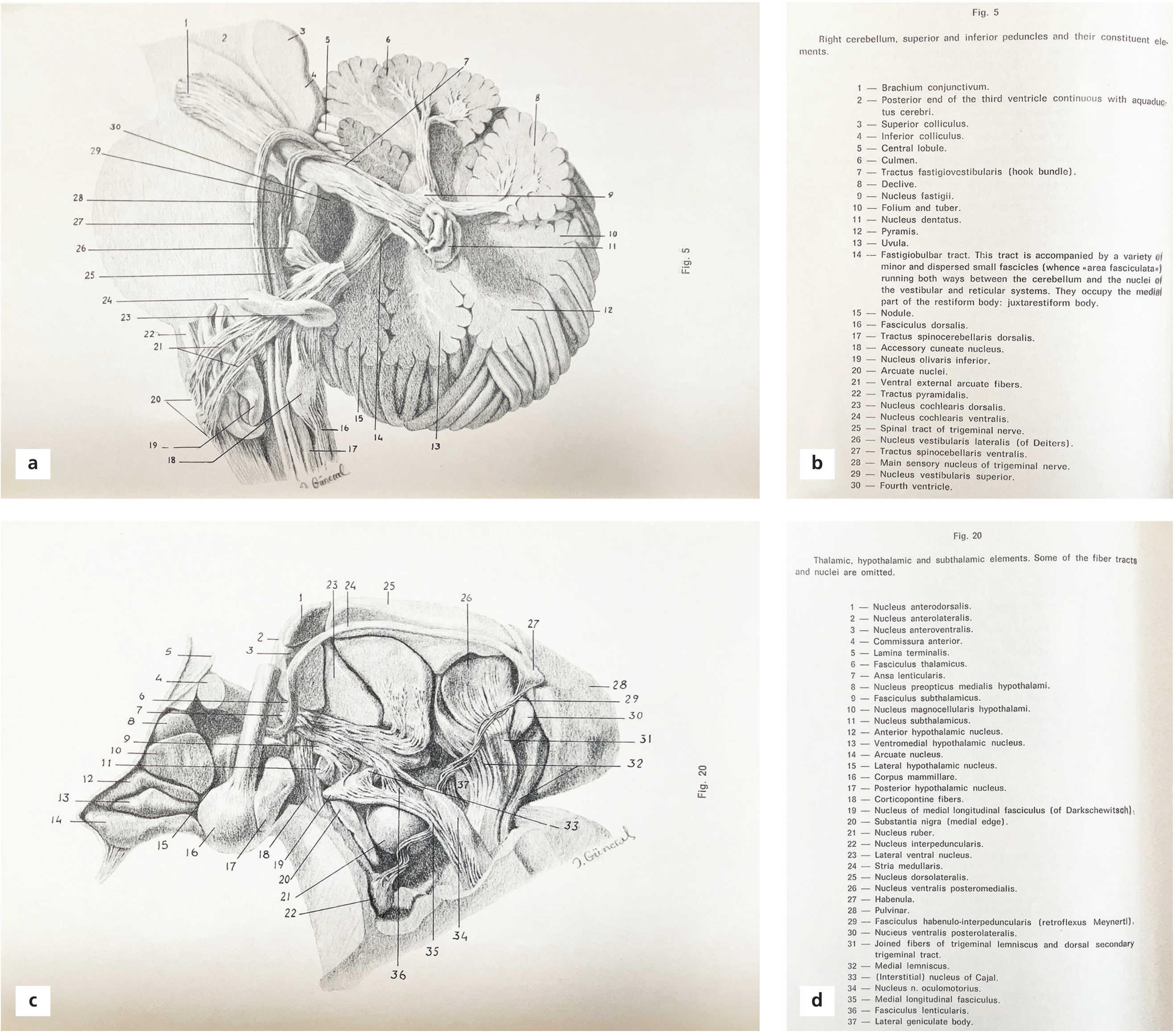


Fig. 5

Right cerebellum, superior and inferior peduncles and their constituent elements.

1 — Brachium conjunctivum.
2 — Posterior end of the third ventricle continuous with aquaductus cerebri.
3 — Superior colliculus.
4 — Inferior colliculus.
5 — Central lobule.
6 — Culmen.
7 — Tractus fastigiovestibularis (hook bundle).
8 — Declive.
9 — Nucleus fastigii.
10 — Folium and tuber.
11 — Nucleus dentatus.
12 — Pyramis.
13 — Uvula.
14 — Fastigiobulbar tract. This tract is accompanied by a variety of minor and dispersed small fascicles (whence «area fasciculata») running both ways between the cerebellum and the nuclei of the vestibular and reticular systems. They occupy the medial part of the restiform body: juxtarestiform body.
15 — Nodule.
16 — Fasciculus dorsalis.
17 — Tractus spinocerebellaris dorsalis.
18 — Accessory cuneate nucleus.
19 — Nucleus olivaris inferior.
20 — Arcuate nuclei.
21 — Ventral external arcuate fibers.
22 — Tractus pyramidalis.
23 — Nucleus cochlearis dorsalis.
24 — Nucleus cochlearis ventralis.
25 — Spinal tract of trigeminal nerve.
26 — Nucleus vestibularis lateralis (of Deiters).
27 — Tractus spinocebellaris ventralis.
28 — Main sensory nucleus of trigeminal nerve.
29 — Nucleus vestibularis superior.
30 — Fourth ventricle.

Fig. 20

Thalamic, hypothalamic and subthalamic elements. Some of the fiber tracts and nuclei are omitted.

1 — Nucleus anterodorsalis.
2 — Nucleus anterolateralis.
3 — Nucleus anteroventralis.
4 — Commissura anterior.
5 — Lamina terminalis.
6 — Fasciculus thalamicus.
7 — Ansa lenticularis.
8 — Nucleus preopticus medialis hypothalami.
9 — Fasciculus subthalamicus.
10 — Nucleus magnocellularis hypothalami.
11 — Nucleus subthalamicus.
12 — Anterior hypothalamic nucleus.
13 — Ventromedial hypothalamic nucleus.
14 — Arcuate nucleus.
15 — Lateral hypothalamic nucleus.
16 — Corpus mammillare.
17 — Posterior hypothalamic nucleus.
18 — Corticopontine fibers.
19 — Nucleus of medial longitudinal fasciculus (of Darkschewitsch).
20 — Substantia nigra (medial edge).
21 — Nucleus ruber.
22 — Nucleus interpeduncularis.
23 — Lateral ventral nucleus.
24 — Stria medullaris.
25 — Nucleus dorsolateralis.
26 — Nucleus ventralis posteromedialis.
27 — Habenula.
28 — Pulvinar.
29 — Fasciculus habenulo-interpeduncularis (retroflexus Meynerti).
30 — Nucleus ventralis posterolateralis.
31 — Joined fibers of trigeminal lemniscus and dorsal secondary trigeminal tract.
32 — Medial lemniscus.
33 — (Interstitial) nucleus of Cajal.
34 — Nucleus n. oculomotorius.
35 — Medial longitudinal fasciculus.
36 — Fasciculus lenticularis.
37 — Lateral geniculate body.

Figure 11. Detailed images in the Güneral's Atlas Cerebri Humani depicting the detailed anatomy of major cerebellar, thalamic, and hypothalamic nuclei and pathways (**a** and **c**) and accompanying figure legends (**b** and **d**). From the personal collection of Mrs. Ejide Tanık, with her kind written permission.

Turkish or Modern Turkish in the known literature.[16] Therefore the dissection atlas of İlhami Güneral is the first original dissection book ever written, illustrated, and printed in Turkish. Similarly, the transparent brain models he produced have shown his profound knowledge in anatomy, his competence in relevant anatomical museum techniques, and his mastery in fine arts. In conclusion, it is imperative to acknowledge the contributions of Dr. İlhami Güneral to anatomical sciences and medical illustration in Türkiye.

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Conflict of Interest

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Ethics Approval

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Case Report

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Unilateral mandibular atrophy in neurofibromatosis-1: case report

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Abstract

Neurofibromatosis is an autosomal dominant neurocutaneous syndrome characterized by skin lesions and central or peripheral nervous system tumors. Although neurofibromatosis is a neurocutaneous disease, it also involves multiple systems. For example, bone lesions have been reported in 40% of patients. As in this case, pathologies associated with the mandible and temporomandibular joint in neurofibromatosis are rarely reported in the literature. In our case, we aimed to emphasize that skeletal malformations may also be present in the rich clinical picture of neurofibromatosis. Maxillofacial computed tomography of a 24-year-old female patient who was followed up at Selçuk University Hospital with a diagnosis of neurofibromatosis revealed an appearance compatible with atrophy in the right half of the mandible. The mandibular ramus was 41.27 mm on the right and 53.44 mm on the left; the diameter of the condyloid process was 10.31 mm on the right and 15.71 mm on the left. The joint distance was increased on the right. Radiologic examinations in neurofibromatosis syndrome should be performed considering the possibility of bone lesions. These examinations are especially important for the prevention of pathologic fractures in bones.

Keywords: bone lesion; mandible; neurofibromatosis

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Introduction

Neurofibromatosis (NF) is a genetically inherited heterogeneous disease. The clinical findings and pathological structures of neurofibromas were first described by von Renklinghausen in 1882. For this reason, NF-1 is also referred to as Von Renklinghausen disease.[1] Riccardi classified NF into 7 types.[2] However, two definitions are generally used: NF-1, known as the peripheral or generalized form, and NF-2, known as the central form. Among these types, NF type 1 is the most common (90%) and is an autosomal dominant neurocutaneous syndrome that occurs in 1 in 3000 live births. Despite autosomal inheritance, de novo cases have also been reported. Half of the cases develop due to spontaneous mutations. The NF-1 gene is located on chromosome 17q11.2 (long arm of chromosome 17).[3,4] This gene encodes the neurofibromin protein. Neurofibromin protein exerts a tumor suppressor effect by controlling cell proliferation through the Ras signaling pathway (negative regulation). Neurofibromin hydrolyzes GTP to GDP, generating Ras signaling and thus exerting a tumor suppressive effect. Therefore, the absence of neurofibromin function leads to uncontrolled cell growth.[5–7] During the disease process, ectodermal and mesodermal derivatives are affected due to defects in embryonic neural crest cells.[8] Since patients with NF-1 may have significant bone lesions, lesions in the mandible are especially important in dental procedures and oral and maxillofacial surgeries.[1] It can also cause aesthetic concerns as it can create facial asymmetry.

Case Report

A 24-year-old woman diagnosed with NF-1 presented to the clinic with a mass on the left upper eyelid. Preoperative maxillofacial computed tomography showed marked facial asymmetry (**Figure 1**) and an appearance consistent with atrophy on the right side of the mandible. Considering the patient's past clinical history, facial asymmetry was not previously present. It is thought that the reduction in mandibular size occurred later. Therefore, the case was evaluated as atrophy. A neurofibroma with a diameter of approximately 1 cm was found in the subcutaneous soft tissue in the left orbital preseptal area (**Figure 2**). There was thinning of the bony cortex connecting the orbital borders on the left side due to neurofibroma compression. The maxilla and zygomatic bone had normal anatomical structure. The mandibular ramus measured 41.27 mm on the right and 53.44 mm on the left (**Figure 3a**); the diameter of the condyloid process measured 10.31 mm on the right and 15.71 mm on the left (**Figure 3b**). The joint distance was increased on the right. Therefore, the patient had facial asymmetry. Left mandibular cortex and medullary bone density were normal.

Discussion

NF-1 is an autosomal dominant neurocutaneous syndrome occurs in 1 in 3000 live births. Skin involvement is characteristic in NF-1. Café au lait spots are the most common skin findings and are among the diagnostic criteria (**Table 1**). They should be larger than 5mm for diagnosis and larger than 5 mm before puberty and larger than 15 mm after puberty.[9,10]

The presence of 2 or more findings in the table of diagnostic criteria is necessary for the diagnosis. Other cardinal findings: Neurofibromas, axillary-inguinal freckles and iris hamartomas called lish nodules. There is a wide variety of clinical presentations in NF-1. Although inherited as an autosomal dominant disease, symptoms and severity can vary even among affected family members. Skeletal involvement is among the diagnostic criteria in NF-1 and occurs in 40–50% of cases. Skeletal defects such as dysplasia, aplasia or local bone atrophy are thought to result from abnormalities of tissues originating from neuroectoderm and mesoderm.[11,12] Hunt and Pugh,[13] in a study of 192 cases in 1961, suggested that skeletal defects develop as a result of mesodermal dysplasia. According to some scientists, abnormal bone formations may develop as a result of a mesodermal defect in the periosteum.[14] Furthermore, decreased bone mineral density (reported in 90% of cases) and increased osteoclast activity also cause bone destruction. Local factors such as genetic etiology, physical activity and presence of tumors also influence bone malformations.[15] The most common skeletal anomalies are macrocephaly (20–50%) and scoliosis (5–10%).[16] Deformities such as dysplasia of the sphenoid bone, spina bifida, pseudoarthrosis, thinning of the long bone cortex, local bone growth and absence of patella may also be seen. Pseudoarthrosis is

Figure 1. Three dimensional image of facial asymmetry on computed tomography.

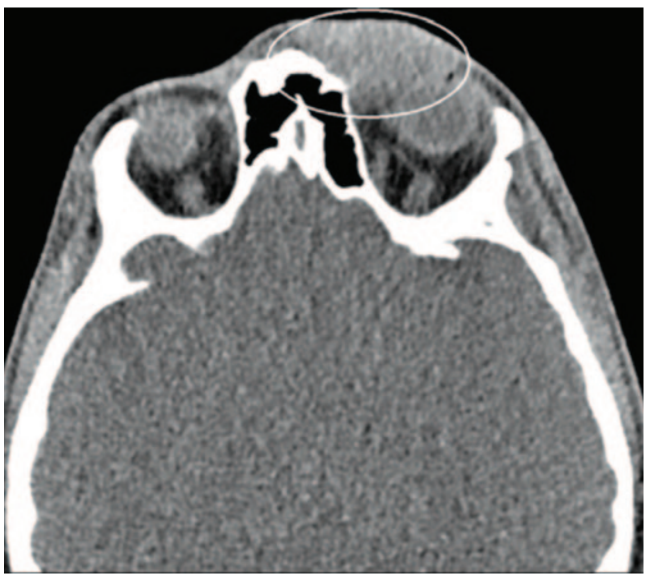

Figure 2. Computed tomography image of neurofibroma in the left orbital preseptal area in the axial plane.

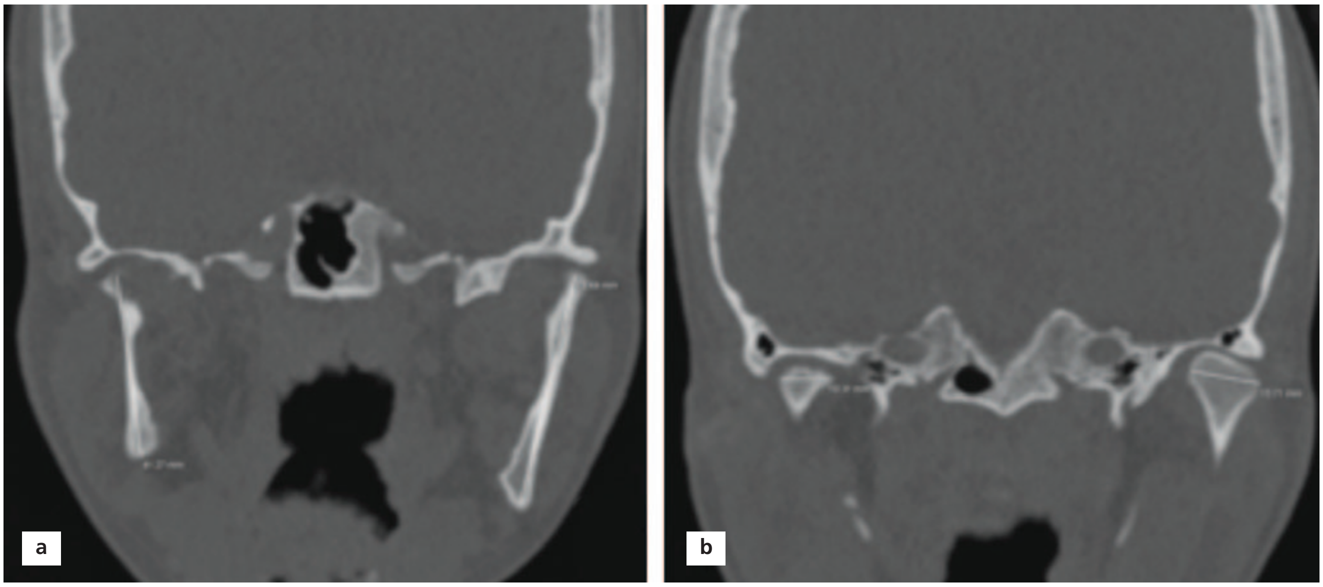

Figure 3. (**a**) mandibular ramus measurements; (**b**) condyloid process measurements in the coronal plane on computed tomography.

highly diagnostic, but it is very rare and starts with bending, especially in the tibia.[3,17,18]

Cutaneous, subcutaneous and plexiform variants of neurofibromas can be seen in NF-1. Plexiform neurofibromas are seen in 25% of patients. These can cause hypertrophy of soft tissue and bone, leading to bending of the head, neck and extremities. Neurologic problems may also occur as a result of pressure on the nerves. Especially when the trigeminal nerve is compressed, pain accompanies clinical findings.[19]

Previous studies have revealed that approximately 70% of NF-1 patients have oral pathologies. The tongue, buccal mucosa, labial mucosa and palate are usually affected and neurofibromas are frequently located in these areas. As neurofibromas grow in the mouth over time, the patient may develop gingival and dental problems, especially facial asymmetry, and bone lesions such as hypoplasia, aplasia or atrophy. Although oral pathologies are common, the rate of NF-1 patients with jaw malformations has been reported to be 28%.[19,20]

Cases involving the temporomandibular joint are rarer and occur in 4–7% of cases. Koblin and Reil[20] reported that temporomandibular joint hypoplasia and related joint dysfunction may develop in neurofibromatosis. Van Damme et al.[21] reported that mandibular atrophy in neurofibromatosis may result in early molar tooth loss and facial asymmetry due to transposition of the temporalis muscle. This may cause dysfunction and pain in the temporomandibular joint. Medial depression of the mandibular ramus was reported in another case of neurofibro-

Table 1
Clinical criteria for the diagnosis of neurofibromatosis-1.

Six or more cafe au lait spots, >0.5 cm diameter at prepubertal age and >15 mm diameter at postpubertal age
Two or more neurofibromas of any kind or a plexiform neurofibroma
Axillary or inguinal freckles - Crowes sign
Optic glioma
Two or more Lisch nodules: pigmented bilateral hamartomas, that appear as copular elevations on iris surface
Distinctive bone lesion, sphenoidal dysplasia, dysplasia or thinning of long bones cortical
Relatives in first degree with NF-1

matosis.[22] In a study evaluating the images of 10 patients with neurofibromatosis, it was found that the mandibular angle was reduced in 6 cases. Deformity of the condyles was also observed.[23] Neurofibromas in the cheek, ear or similar areas may grow directly into the joint. In 1988, Sailer et al.[24] reported 12 pathognomonic changes related to mandibular involvement. These changes include deviation of the mandible on the affected side, minimal swelling of the cheeks or intraoral soft tissue, coronoid notch deformity, pseudo-elongation of the condyles, ramus hypoplasia, increased mandibular angle, mandibular body deformity or hypoplasia, impacted tooth on the affected mandibular side, atrophy of the ipsilateral maxilla and zygomatic bone, impacted tooth in the ipsilateral maxilla, external ear deformity. According to the literature, the most common jaw malformations are bony lesions, thickened mandibular canal and enlarged foramen mandible. When bone lesions are present in oral pathologies, it becomes difficult to maintain oral hygiene.[24–26]

Conclusion

Bone lesions can be seen in neurofibromatosis. These lesions may cause pathologic fractures. In addition, bone dysplasia in the facial region may cause dysfunction in the temporomandibular joint and facial asymmetry.

Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

BS: data collection, manuscript writing; NÜD: project development, manuscript editing; AB: data collection, data analysis, editing; BP: data analysis, manuscript writing; ZF: project development, manuscript editing.

Ethics Approval

This case report was written in accordance with ethical principles and informed consent was obtained from the patient prior to the CT examination.

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On the Front Cover:

The only piece, a sagittal hemisection of the brainstem, from the transparent brain model that Dr. Güneral's surviving family has in their belongings. (**a**) lateral aspect of the brain stem; (**b**) close up on the lateral aspect of the bulbus for details; (**c**) medial aspect of the sagittal section of the brain stem. From the personal collection of Mrs. Ejide Tanık, with her kind written permission. From Gürses İA. Op. Dr. İlhami Güneral (1914–2006), author and illustrator of the first original dissection manual in Turkish and his contributions to anatomy. *Anatomy* 2023;17(2):88–97.

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