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RESEARCH

Anatomical and radiological evaluation of sigmoid notch morphometry

Incisura sigmoideus morfometrisinin anatomik ve radyolojik olarak değerlendirilmesi

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Abstract

Purpose: Knowing the morphological variations among the extremity bones is useful in understanding the pathogenesis, or underlying mechanism, and treatment of some disorders. This study aimed to evaluate sigmoid notch type, lunate type, sigmoid C-type depth, and ulnar variance concerning gender and age.

Materials and Methods: This study included 252 subjects (88 females and 164 males) aged 18-68 years who underwent computed tomography. The mean age of the females was 46.59±14.67 years, while the mean age of the males was calculated as 43.11±14.08 years. Moreover, the sigmoid notch types were generated, and the sigmoid notch depth was measured. Lunate types and ulnar variance types were evaluated for both gender and age.

Results: Sigmoid notch types showed a significant difference between genders, whereas no significant difference was found regarding lunate types, sigmoid C-type depth, and ulnar variance. The mean sigmoid C-type depth was 2.54±0.50 mm in females and 2.40±0.41 mm in males, respectively. Sigmoid notch types, ulnar variance presence and types, and lunate types significantly differed in age ranges.

Conclusion: Comprehensive evaluation of the wrist region provides essential anatomical and morphological reference values that can inform clinical decision-making, particularly in the diagnosis and management of pathologies involving the distal radioulnar joint. Additionally, these values are critical for preoperative planning in reconstructive procedures and for addressing complex distal forearm fractures.

Keywords:.Sigmoid notch, sigmoid C-type depth, lunate types, ulnar variance, distal radioulnar joint.

Öz

Amaç: Ekstremite kemikleri arasındaki morfolojik varyasyonların bilinmesi, bazı hastalıkların patogenezinin veya altta yatan mekanizmanın anlaşılmasında ve tedavisinde yararlıdır. Bu çalışmada sigmoid çentik tipi, lunat tip, sigmoid C tipi derinlik ve ulnar varyansın cinsiyet ve yaşa göre değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Bu çalışmaya Bilgisayarlı tomografi çekilen 18-68 yaş arası 252 birey (88 kadın ve 164 erkek) dahil edilmiştir. Kadınların yaş ortalaması 46.59±14.67 yıl iken, erkeklerin yaş ortalaması 43.11±14.08 yıl olarak hesaplandı. Ayrıca, sigmoid çentik tipleri sınıflandırıldı ve sigmoid çentik derinliği ölçüldü. Lunat tipleri ve ulnar varyans tipleri her iki cinsiyet ve yaş için değerlendirildi.

Bulgular: Sigmoid çentik tipleri cinsiyetler arasında anlamlı farklılık gösterirken, lunat tipleri, Sigmoid C tipi derinliği ve ulnar varyans açısından cinsiyetler arasında anlamlı bir farklılık bulunmadı. Kadınlarda ve erkeklerde C tipi derinlik ortalaması sırasıyla 2.54±0.50 mm ve 2.40±0.41 mm olarak bulundu. Sigmoid çentik tipleri, ulnar varyans varlığı ve tipleri ile lunat tipleri, yaş aralıkları açısından anlamlı farklılık gösterdi.

Sonuç: El bileği ile ilgili değerlendirmelerin, bu bölge ile ilgilenen klinisyenlere anatomik ve morfolojik açıdan referans değerler sağlamasından dolayı bu bölgede oluşabilecek problemlerin ve tedavilerin planlanması konusunda yol göstereceğine inanıyoruz. Ayrıca, bu veriler rekonstrüktif prosedürler düşünülürken veya distal radioulnar eklemi içeren karmaşık kırıklara müdahale gerektiğinde bir rehber olabilir.

Anahtar kelimeler: Incisura sigmoideus, sigmoid C tipi derinlik, lunat tipleri, ulnar varyans, distal radioulnar eklem.

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INTRODUCTION

The joint formed by the articulation of the concave sigmoid notch (SN) of the distal radius with the convex ulnar head (UH) is called the distal radioulnar joint (DRUJ) [1]. The SN and UH are contributing parts of the DRUJ: A complex pivot joint based on a combination of soft tissue and muscle stabilizers, and osseous articulation[2]. Many structures, including the triangular fibrocartilage complex, ulnocarpal ligament complex, extensor carpi ulnaris tendon and tendon sheath, bones, etc, are responsible for joint stability. Treatment of instability in this joint is quite difficult. Because it has a complex anatomy and biomechanics [3]. DRUJ is a functionally important structure because DRUJ injuries can have significant harmful consequences if left untreated, taking into account anatomical rules. Hence, it is crucial to accurately identify and describe the anatomy of this joint [4]. A comprehensive evaluation is important for understanding the normal function of the joint. It is beneficial in reconstructive procedures such as osteotomies, notch plasty, ligament reconstruction, and arthroplasty [1].

Surgeons prefer the sigmoid notch view as a reliable method because of its many benefits. One of them is to assess the integrity of the articular surface, to ensure that no hardware is inserted into the distal radioulnar joint, and to facilitate the placement of volar locking plates. Also, the consistency of the radioscopic and anatomical markers of the SN with each other may be important for managing distal radius fractures or joint divergence [5].

Moreover, the UH widely rotates on the sigmoid notch in forearm pronation/supination, thus fractures of the SN change DRUJ mechanics. The analysis of factors leading to DRUJ instability is particularly challenging, owing to the intricate bony and ligamentous structures of the joint, and the extensive range of ulnar motion over the sigmoid notch [6].

Several articles include the DRUJ and the nearby carpal bones [7-11]. A study by Tolat et al. (1996), examining 50 cadaver wrists, defined four SN morphological variations. The least compatible and more unstable type is "flat face" (42%); followed by "ski slope" (14%), C-type notch (30%), and S-type notch (14%). They argued that these different classified types may provide an important contribution to the stability of the DRUJ [3,12]. Viegas et al. dissected 165 cadaveric wrists to evaluate the medial facet of the lunate presence or absence, and associated pathological conditions and reported that two types of lunate were defined as Type I (medial facet absence, 34.5% of dissected samples), and Type II (medial facet presence, 65.5% of dissected samples) [9].

Another study reported that scaphoid fractures were the most common carpal bone fractures seen in young men and that their incidence in women had increased in the last decade [10]. Finally, Sayit et al. analyzed the ulnar variance (height difference between the distal radius and ulna articular surfaces) by dividing the radiographs of the subjects. It was found that males had more negative ulnar variance and lower ulnar variance than females in all age groups. It was also concluded that no age-related change in ulnar variance was found in gender/side[11]. Considering all these publications, understanding the anatomy of the DRUJ and carpal bones are critical for having an idea about the pathologies in this region.

This study evaluated the sigmoid notch type, lunate type, sigmoid C-type depth and ulnar variance presence according to gender. These evaluations will help understand the complex anatomy of the region and also facilitate the diagnosis and treatment of pathologies in the region. Our hypothesis is that morphometric characteristics of anatomical structures such as sigmoid notch type, lunate type, sigmoid C-type depth, and ulnar variance may show significant differences based on gender, and these variations may influence the diagnosis and treatment processes of related regional pathologies.

In addition, the study reveals gender-based differences in anatomical structures such as sigmoid notch type, lunate type, sigmoid C-type depth, and ulnar variance, contributing to the clinical evaluation of these variations. The data obtained support more accurate diagnosis of pathologies in the region (such as scaphoid fractures) and assist in planning treatments based on individual anatomical differences. The morphometric measurements and classifications conducted in the study provide a reference for surgeons and radiologists regarding normal anatomical variations, which is expected to reduce the margin of error, particularly in minimally invasive procedures.

MATERIALS AND METHODS

Sample

A total of 252 subjects (88 females and 164 males), aged between 18 and 68 years, were included in the study. All CT scans were performed using a 128-slice multidetector CT scanner (Siemens Somatom Definition AS, Siemens Healthcare). The data were categorized by sex into adult female and male subjects, and further divided into five age groups: 18–30 years, 31–40 years, 41–50 years, 51–60 years, and 61–68 years. Also, gender-based variations of the parameters: sigmoid notch type, lunate type, sigmoid C-type depth, and ulnar variance in Table 1. The distribution of sigmoid notch types according to lunate types is shown in Table 2, while the ulnar variance according to sigmoid types is presented in Table 3. Table 4 presents the distribution of sigmoid notch types, ulnar variance (presence and types), lunate types, and C-type depth across different age groups.

The sample size calculation for our study was determined by including individuals who met the inclusion criteria and excluding those with unclear images. All measurements were performed on a computer screen using an electronic caliper and expressed in millimeters (mm). This study was a retrospective observational study conducted in the Department of Radiology at Bozyaka Education and Research Hospital, University of Health Sciences, İzmir. CT Image analyses were performed by three observers [observer 1, a radiologist (MÖ), observer 2, a radiologist (FYÖ), and observer 3, a radiologist (MC)]. Additionally, the data were obtained from official hospital records, and all file security procedures were carried out in accordance with the protocols established by the relevant institution. The study was approved by the Clinical Research Ethics Committee of Çukurova University (Decision No: 2025/151-8).

Table 1. Gender-based variations of the parameters: Sigmoid notch type, lunate type, sigmoid C-type depth, and ulnar variance

Parameters	Sigmoid types				Lunate types		The C-type depth	The ulnar variance		
	C-type	F type	S type	Ski type	Type 1	Type 2	Means±SD	N type	P type	No variance
Females (n=88)	39	33	14	2	45	43	2.54±0.50	22	0	66
Males (n=164)	68	37	46	13	70	94	2.40±0.41	50	4	110
p value	0.010				0.233		0.116	0.195		

Table 2. The sigmoid types's distribution according to lunat types

Parameters	Sigmoid notch types				P value
Lunate types	C-types	F types	S types	Ski types	
Type 1	38	42	31	4	0.04
Type 2	69	28	29	11	

Table 3 The ulnar variance according to sigmoid types

Parameters	C-types	F types	S types	Ski types	P value
Ulnar variance presence and types					
No ulnar variance	69	63	34	10	0.020
N type	36	7	24	5	
P Type	2	0	2	0	

Table 4. The distribution of data according to age ranges

Age ranges	Sigmoid notch types				Ulnar variance presence and types			Lunat types		C-type depth (mm)
	C	F	S	Ski	No	N	P	Type 1	Type 2	
Group 1 (18-30 years)	9	19	9	5	30	12	0	18	24	2.26±0.31
Group 2 (31-40 years)	21	17	14	3	40	15	0	30	25	2.28±0.42
Group 3 (41-50 years)	21	10	14	4	31	14	4	24	25	2.54±0.49
Group 4 (51-60 years)	26	14	17	2	43	16	0	32	27	2.35±0.29
Group 5 (61-70 years)	30	10	6	1	32	15	0	11	36	2.69±0.50
P value	0.015				0.027			0.010		0.003

Data collection tools

Patients over the age of 18 who presented to the emergency department and were identified as having wrist pain, in the absence of any fracture or underlying pathology, were included in the study. The exclusion criteria were subjects with a history of neuromuscular or neurological diseases, and subjects with rheumatoid arthritis or similar autoimmune diseases. In addition, 380 images were retrospectively analysed and 252 images fulfilled the criteria.

Measurements

The sigmoid notch types were generated and listed as described by Bhat et al. The sigmoid notch depth was measured. Lunate and ulnar variance types were evaluated [1,3,7,11-19]. The shape of the sigmoid notch was assessed using the same geometrical construction applied to the CT scans and classified into four categories: C-shaped, flat, S-shaped, and ski-sloped sigmoid notches. A C-shaped sigmoid notch presents with both dorsal and volar gaps, without any projection. An S-shaped sigmoid notch features a dorsal gap and a volar projection. A flat-shaped sigmoid notch has neither gaps nor projections (Figure 1).

Also, Ski-sloped sigmoid presents with no dorsal gap and a volar projection. Moreover, lunate morphology was classified as type I or type II based on the absence or presence of a medial (hamate) facet identified on computed tomography. Ulnar variance (UV), defined as the relative length difference between the distal ulna and radius: Neutral ulnar variance (no variance), negative ulnar variance (N-type), and positive ulnar variance (P-type).

Statistical analysis

Statistical Package for the Social Sciences (SPSS) version 21.0 software was used. In all statistical analyses, a p-value under 0.05 was considered to be statistically significant. The Kolmogorov-Smirnov test was used to determine whether the study was parametric or non-parametric. Based on the analysis of the measurements, the following statistical methods were applied. The p-values for the data and means were analyzed using ANOVA, while the Chi-square test was employed for categorical classifications. A post hoc test was conducted to assess age-related changes.

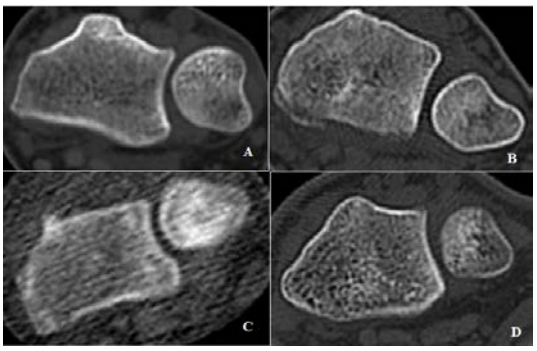

Figure 1. Sigmoid notch types
A: C-type sigmoid notch; B: F-type sigmoid notch; C: S-type sigmoid notch; and D: Ski-type sigmoid notch.

RESULTS

The study included 252 healthy individuals (88 females and 164 males) aged 18 to 68 years. Additionally, left images of 116 individuals (39 females and 77 males) and right images of 136 subjects (49 females and 87 males) were measured (p=0.791). The mean age of the females was 46.59±14.67 years, while the mean age of the males was 43.11±14.08 years (p=0.070). In Table 1, the sigmoid types are shown. According to findings, 39 females have type C, 33 females have type F; 14 females have type S, and 2 females Ski-type sigmoid notch. Moreover, the sigmoid notch types showed significant differences between genders (p=0.010). The lunate types are given in Table 1. According to findings, 45 females and 70 males have type 1, however, 43 females and 94 males have type 2. Moreover, lunate types showed no significant difference between genders (p=0.233). C-type depth values were provided for 39 female and 68 male participants with a C-type sigmoid notch. In females, the mean of C-type depth was found as 2.54±0.50mm, whereas the same value was 2.40±0.41mm in males, respectively. No significant difference was found in the C-type depth according to gender in subjects having C-type (p=0.116) (Table 1). The ulnar variance according to gender was analyzed. N-type ulnar variance was seen in 22 females and 50 males, respectively. Also, P-type ulnar variance was seen in only 4 males. 66 females and 110 males had no ulnar variance (p=0.195) (Table 1).

The distribution of sigmoid types according to lunate types is presented in Table 2. In type 1, 38 C-type, 42 F-type, 31 S-type, and 4 Ski-type sigmoid notches were found. Also, in Type 2 lunate types, 69 C-types, 28 F types, 29 S types, and 11 Ski types were seen. Moreover, a statistically significant difference was found in the distribution of sigmoid types according to lunate types (p=0.04). When the ulnar variance according to lunate types was analyzed, in Type 1 lunate type, 91 subjects had no ulnar variance, whereas 22 subjects and 2 subjects had N and P-type ulnar variance, respectively. In lunate type 2, 85 subjects had no ulnar variance, whereas 50 subjects and 2 subjects had N and P-type ulnar variance, respectively (p=0.010). Additionally, the ulnar variance according to sigmoid types is shown in Table 3. A statistically significant difference was found (p=0.002). Also, the largest number of N-type variances was recorded in the C-type sigmoid notch, followed by S-type, F-type, and Ski-type, respectively. The largest number of P-type variances was recorded in the C-type and S-type sigmoid notch. The distribution of data according to age ranges is given in Table 4. Sigmoid notch types (0.015), ulnar variance presence and types (0.027), and lunate types (0.010) showed a significant difference in terms of age ranges. "C-type depth" (p = 0.003) was analyzed across different age groups, and the findings are presented in Table 4. Additionally, the Post Hoc test revealed statistically significant differences in sigmoid notch types between Groups 1 and 2, 1 and 3, 1 and 4, 1 and 5, 2 and 4, and 2 and 5, respectively. In the ulnar variance parameter, a significance was found between Groups 1-2, Groups 1-3, and Groups 2-3, respectively. In lunat types, Groups 1-2, Groups 1-3, Groups 1-4, and Groups 1-5, Groups 2-5, respectively. In sigmoid C-type depth, there was a significance between Groups 1-3, Groups 1-4, Groups 1-5, Groups 2-3, and Groups 2-5, respectively.

DISCUSSION

Knowing the morphological variations among the wrist bones is useful in understanding the pathogenesis, or underlying mechanism, and treatment of some disorders[4]. DRUJ is accepted as one of the most complicated joints in the body[1]. Since injuries to this joint can result in significant adverse outcomes, an accurate description of its anatomy is essential [3]. In the context of ulnar impaction syndrome, ulnar shortening osteotomy (USO) is considered to pose a risk of distal radioulnar joint (DRUJ) incompatibility, and early degenerative changes of this joint shape and type. For this reason, SN shapes are a matter worthy of attention for surgeons for decision-making in arthroplasty procedures [1]. On the other hand, in cases such as wrist injuries with an intact SN but comminuted fractures of the UH, analysis of the ipsilateral intact SN will provide to design of a suitable-sized UH prosthesis [13]. On the other hand, in cases such as wrist injuries involving an intact SN but comminuted fractures of the ulnar head (UH), analysis of the ipsilateral intact SN can aid in the design of a suitably sized UH prosthesis." Additionally, Bhat et al. reported that the SN shape information can be critical in subjects having DRUJI before deciding on surgical choices like ligament reconstruction (LR) and USO. If the notch isn't stable, like a flat-faced notch, LR may have to be coupled with a notch plasty to make the entire reconstruction much more stable. In

our study to define this anatomy, the most common type in males and females is the C-type sigmoid notch. Again, "C-type" is the most common type among all individuals. Similarly, Bhat et al. identified the 'C-type' as the most common sigmoid notch type in their study and emphasized that it is the most stable configuration due to its increased curvature [1]. In contrast, Tolat et al. reported the "Flat face type" as the most prevalent [12]. Meanwhile, Shivadas et al., in their study involving 102 wrists, found the "S-type" to be the most common [13]. In this paper, the most commonly seen was the C-type sigmoid notch, followed by F-type sigmoid notch, S-type sigmoid notch, and Ski-type sigmoid notch in females, whereas, the most prevalence sigmoid notch was the C-type, followed by S-type sigmoid notch, F-type sigmoid notch, and Ski-type sigmoid notch in males, respectively.

Another issue concerning the morphology of the wrist region is the lunate type. The lunate is the wrist cornerstone and an essential part of the carpus central column. It is frequently subjected to significant axial and torsional loads from the mid-carpal bones and the surrounding proximal carpal interosseous ligaments, respectively. The predisposition to asymmetric loading results from variations in lunate morphology (LM). Under such conditions, microtrauma and a predisposition to avascular necrosis become inevitable. Furthermore, it has been reported this bone morphology affects carpal kinematics (CK), which may be involved in the formation of certain carpal instability (CI). A variation in the bone in consideration is caused by the absence (Type I, L_{T1}) or presence (Type II, L_{T2}) of the medial facet on the distal articular surface of the lunate corresponding to the proximal part of the hamate. This additional hamatolunate articulation may affect load transmission through the radiocarpal joint (RCJ) and influence carpal kinematics (CK). A type 2 lunate (LT2) may have a protective effect on carpal instability (CI) patterns. The CI is related to scaphoid non-unions, scapholunate dissociations, and carpal collapse advancement, which leads to Kienböck disease[14].

Galley et al. evaluated the effect of lunate type on scaphoid kinematics by examining 100 healthy wrists (18 L_{T1}, 19 middle lunate, and 63 L_{T2}. It was reported that no statistically significant difference was found between lunate type, age, or hand dominance. In the same study, it was reported that the proportion of females with L_{T1} was significantly higher. The authors also emphasized that L_{T1} wrists demonstrated significantly greater scaphoid translation with radial deviation, whereas L_{T2} wrists showed significantly greater scaphoid flexion with radial deviation [15]. Rhee et al. conducted a study covering the years 2002 to 2010 to investigate whether individuals with Kienböck's disease had the L_{T1} and L_{T2} morphology. A total of 106 wrists were examined. Also, 75 were classified as L_{T1}, and 31 as L_{T2}. The study reported that subjects with LT1 tended to present with more advanced disease, suggesting that LM made facilitate the progression or increase the severity of Kienböck's disease [16]. In the study conducted by Viegas, 61 cadaver wrists were dissected to evaluate the medial lunate facet frequency and the associated pathological changes in the mediocarpal joint. 39.3% type 1 and 60.7% Type 2 lunate were found [17]. Galley et al. stated that the results obtained from these studies are ultimately important for surgeons to predict which type of surgical reconstruction may be ideally suited for each type of wrist [15]. Nuttal et al. stated that the determination of lunate types may be important in the selection of the surgery to be performed and in the application of the appropriate procedure to the individual [18]. In our study, among 88 female individuals, 45 had type 1 lunate and 43 had type 2 lunate. Among 164 male individuals, 70 had type 1 lunate and 94 had type 2 lunate. No statistically significant difference was found between genders. Among all individuals, the number of individuals with type 2 lunate was higher.

Ulnar variance is a clinical measurement used to determine the relative length difference between the radius and ulna on hand radiographs. In particular, it provides important information for predicting the healing outcome of distal forearm fractures, treatment planning, and the type of surgical intervention to be performed. It also helps to diagnose some wrist degeneration, which manifests as excessive stress on the lunate and triquetrum, wrist pain, and instability. When the relative length of the ulna differs from that of the radius by less than 1 mm, the terms neutral ulnar variance or ulna plus, which refers to the ulna deviating from the neutral position and extending more distally than the radius, are used. One of the issues concerning the anatomy of the wrist region is ulnar variance [19]. Daneshvar et al. examined 100 cadaver forearms and found the mean ulnar variance to be -0.9 ± 1.8 mm [20]. In a study performed by Claessens et al. to assess the variability of ulnar variance in elite female gymnasts, 156 skeletally immature women, aged between 13.1 and

20.6 years, were included. The ulnar variance was found to vary between -10.5 mm and +5.9 mm [21]. In the study conducted by Nakamura et al., ulnar variance was measured in 325 normal wrists and 41 wrists with Kienböck's disease. A positive correlation between ulnar variance and age was confirmed in normal wrists and was found to be lower in men than in women. It was concluded that the probability of ulnar variance being an important predisposing factor in Kienböck's disease is very low 22. In our study, N-type variance was present in 72 subjects, and P-type variance was present in 4 male subjects. The ulnar variance was not found in 176 subjects. No significant difference was found between the genders. Apart from all these evaluations, no anatomically and morphologically significant results were obtained in our study regarding the C-type sigmoid depth, lunate type evaluations according to sigmoid type.

This study has several limitations. Firstly, as the study was conducted at a single institution, the sample size may not fully represent the broader population. Secondly, due to the retrospective nature of the study, data on certain variables, such as body weight and height, may be incomplete or unavailable. As a result, we believe that evaluations related to the wrist region will guide scientists interested in this region from an anatomical and morphological perspective regarding the problems and treatments in this region. Moreover, this data can be a guide when considering reconstructive procedures or dealing with complex fractures involving the DRUJ. Additionally, the findings of this study not only address significant gaps in the existing literature but also provide crucial directions for future research. Subsequent studies should involve larger, more diverse sample populations, and the generalizability of the data should be tested by incorporating various age groups and geographical regions. In light of the limitations inherent in retrospective studies, it is recommended that prospective and longitudinal studies be conducted to obtain more robust and reliable data.

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