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Original Article

Morphology of the incisura fibularis in the Turkish population

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Abstract

Aim: Morphology of the distal tibiofibular syndesmosis plays an important role in the pattern of ankle fracture and reduction strategy. This study aimed to describe the normal morphology of the distal tibiofibular syndesmosis in a Turkish population.

Materials and Methods: All analyzes were based on 349 computed tomography images, contributed by 265 male and 84 female patients. The following features were measured on axial images: the depth of the incisura fibularis, anterior tibiofibular depth, posterior tibiofibular depth, anterior-posterior length of the fibula, mediolateral width of the fibula, version of the incisura fibularis, anterior tubercle length, posterior tubercle length, and tibiofibular engagement. All measure ts were performed by an orthopedic surgeon and an experienced musculoskeletal radiologist, repeated at a 2-week interval.

Results: The most common morphology of the incisura fibularis was concave (C-shape, depth >4 mm, 66.5%), followed by a shallow morphology (I-shape, depth <4 mm, 18.3%), and r-shape (15.2%). Significant between-sex differences were identified for depth of the incisura fibularis, posterior tibiofibular depth, anterior-posterior length of fibula, mediolateral width of the fibula, anterior tubercle length, posterior tubercle length, tibiofibular engagement, and incisura fibularis height. Across the three morphologies (C-, I- and r-shape), there was a significant difference in the anterior tibiofibular depth, anterior-posterior length of the fibula, degree of retroversion of the incisura fibularis, and extent of tibiofibular engagement (p<0.001).

Conclusions: Knowledge of the variability in the morphology and measurements of the features of the incisura fibularis can be useful in the diagnosis of syndesmosis injury and lowering the risk of malreduction during surgery of ankle fractures among Turkish individuals.

Keywords: Incisura fibularis; malreduction; morphology; shape; syndesmosis

INTRODUCTION

The distal tibiofibular syndesmosis is a complex structure that includes both osseous and ligamentous structures (1). The distal tibiofibular syndesmosis provides stability to the ankle mortise by maintaining the position of the distal fibula in the incisura fibularis (1). In 13% of ankle fractures, the distal tibiofibular syndesmosis is injured (2) and, consequently, anatomical reduction is difficult to achieve, with a rate of malreduction as high as 50% having been reported, despite the use of open reduction and internal fixation (3). Variability in the anatomy of the incisura fibularis anatomy affects the reduction fractures of the distal tibiofibular syndesmosis (4). Specifically, incongruity of the distal tibiofibular syndesmosis markedly affects contact stresses at the ankle joint (5), with a 1-mm widening of the ankle mortise decreasing the tibiofibular contact area by 42% (6). The resulting instability can lead to functional loss and ankle joint arthrosis (7).

Computed tomography (CT) is a widely accepted imaging method in the evaluation of ankle fractures and syndesmosis injury, due to the difficulty in diagnosing ankle injuries using direct radiographic criteria (8), particularly as the image quality of plain radiographs is highly dependent on ankle position (9). Variability in the anatomical morphology of the distal tibiofibular syndesmosis has previously been described (10-13), with certain morphologies of the tibial incisura increasing the risk of specific syndesmotic malreduction patterns (14). To the best of our knowledge, a comprehensive assessment of the morphology of the incisura fibularis in a Turkish population has not previously been performed. Therefore, the aim of our study was to assess the morphological

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features of the distal tibiofibular syndesmosis in a Turkish population. Our hypothesis was that the concave morphology is more common in Turkish population, contrary to those mentioned earlier. This information could improve the diagnosis and treatment strategies for distal syndesmosis injuries and ankle fractures in this population.

MATERIALS and METHODS

The study protocol was approved by the Ordu University Clinical Investigations Research Ethics Board (Approval date and number: 13.12.2018/2018-253). A retrospective analysis was performed in patients who underwent CT examination for an ankle injury, between 2015 and 2018. Patients with clinically and radiologically confirmed ankle fracture or syndesmosis injury, a history of foot and ankle surgery, congenital or acquired foot and ankle deformity, or inflammatory arthritis, as those whose CT images were of poor quality, were excluded. The exclusion of pathology at the level of the ankle and distal syndesmosis was confirmed by an experienced musculoskeletal radiologist. After screening, 349 sets of CT images, contributed by 265 male and 84 female, were included in our analysis. The mean age of patients was 34.9 ± 14.0 years (32.6 ± 12.9 years for males, and 42.1 ± 14.8 years for females). The analysis set included 186 (53.3%) images of the right ankle and 163 (46.7%) of the left.

Coronal, sagittal and axial 2D-CT images were obtained in the supine position, using a GE Medical Systems Optima CT540 CT scanner (GE Healthcare, Chicago, IL), with 2-mm slices. All image-based measurements were performed using Infinitt PACS system (Infinitt Healthcare Co, Seoul, South Korea). The following measures were obtained on axial CT images, using previously described methods (8,14,16) (Table 1): depth of the incisura fibularis; anterior tibiofibular depth; posterior tibiofibular depth; anterior-posterior (AP) length of the fibula; mediolateral width of the fibula; version of the incisura fibularis; anterior tubercle length; posterior tubercle length; and tibiofibular engagement (Figure 1). The height of the incisura fibularis was measured on coronal plane CT images (Table 1). All measurements were performed 10 mm proximal to the tibial plafond (8,15). The morphology of the incisura fibularis was divided into 3 main categories, as follows: reference depth of 4 mm (r-shape), concave (depth >4 mm, C-shape), and shallow (depth <4 mm, I-shape) (Figure 2) (16). All measurements were performed by an orthopedic surgeon and an experienced musculoskeletal radiologist, repeated at a 2-week interval.

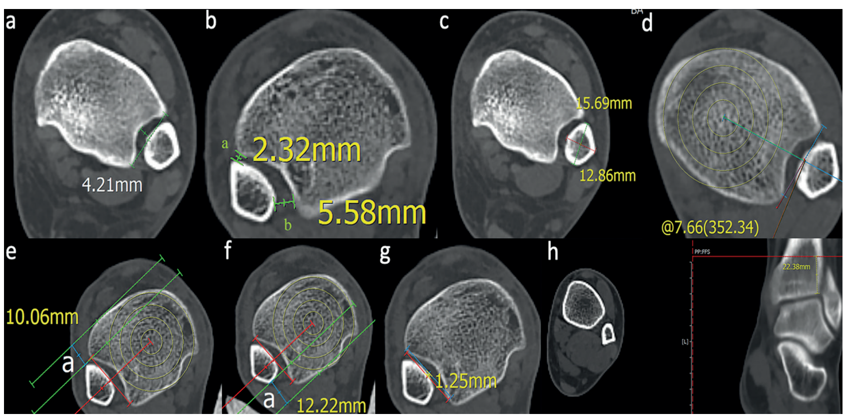

Figure 1. Measurement parameters. A, depth of incisura fibularis. B, anterior and posterior tibiofibular depth. C, AP and ML width of the fibula. D, anteversion/retroversion of the incisura fibularis. E, anterior tubercle length. F, posterior tubercle length. G, tibiofibular engagement. H, height of the incisura fibularis

Table 1. Definition of measurement parameters

Measurement parameter	Measurement definition
Incisura fibularis depth (mm)	The distance between the line connecting the tip of the anterior and posterior tibial tubercles and the deepest point of the incisura fibularis
Anterior tibiofibular depth (mm)	The distance between the two points drawn to the anterior border of the fibula and the nearest perpendicular point to the first point on the anterior tibial tubercle
Posterior tibiofibular depth (mm)	The distance between the two points drawn to the medial border of the fibula and the lateral border of the posterior tibial tubercle
AP length and ML width of the fibula (mm)	The distance between the most anterior and the most posterior points of the fibula
ML width of the fibula (mm)	The distance between the most medial and the most lateral points of the fibula

Version of the incisura fibularis (°)	First, the center of the tibia is defined using a ROI circle fitted to the anterior, posterior and the medial border of the tibia. Second, the center of the incisura is defined with a line dividing it two equal part. Third, a separate orthogonal line to the line connecting the first and second lines is drawn. The angle between the second and third lines is measured. Negative values indicate anteversion
Anterior tubercle length (mm)	Two lines are drawn parallel to the line dividing the incisura to two equal part. The distance between the lines that are tangent to the most anterior point of the fibula and tibia
Posterior tubercle length (mm)	Two lines drawn parallel to the line dividing the incisura to two equal part. The distance between the lines that are tangent to the most posterior point of the fibula and the highest point of the posterior tubercle
Tibiofibular engagement (mm)	The distance between the inter-tubercular line and the medial border of the fibula
Height of the incisura fibularis (mm)	The distance between the most proximal and the most distal points of the incisura fibularis determined in the axial cuts. The distance between the two cuts was measured on the coronal image using cross-link function

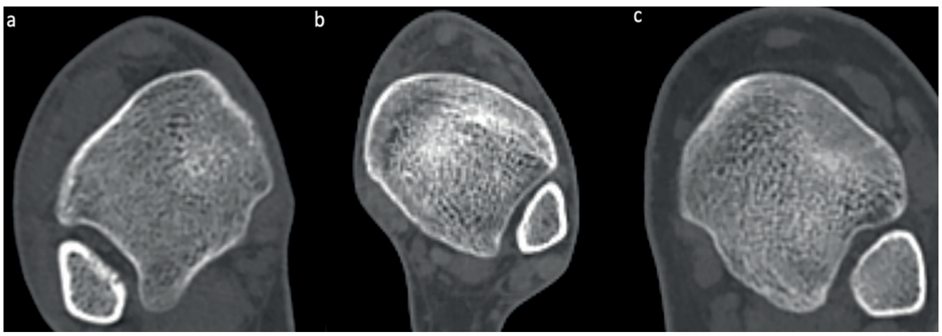

Figure 2. Incisura fibularis shapes. a, C type. b, I type. C, r type

Statistical analysis

The morphology and measured features of the incisura fibularis were described using the mean, standard deviation, median, lowest, highest, frequency and ratio values, as appropriate. The normality of the distribution of measures for each variable was evaluated using the Kolmogorov-Simirnov test. Continuous quantitative data were evaluated using the Mann-Whitney U test, with categorical data assessed using the chi-squared test. The association between measured parameters was evaluated using a Spearman's correlation analysis. Intra-class correlation coefficient and Kappa correlation coefficient were used to determine the intra- and inter-observer reliability of ordinal and continuous measurement parameters. IBM SPSS V23 (IBM corporation, Armonk, NY) was used for all data analyses.

RESULTS

The most common morphology of the incisura fibularis was C-shape (concave), observed in 232 of 349 patients (66.5%), and followed by the I-shape (shallow, 64 of 349 patients, 18.3%) and r-shape (reference depth, 53 of 349 patients, 15.2%) morphologies. The mean anterior tibiofibular distance was significantly smaller than the mean posterior tibiofibular distance (2.5 ± 0.8 mm and 3.8 ± 1.0 mm, p<0.001; Table 2).

Table 2. Comparative measurement parameters and syndesmosis shape results

	Overall (Mean ± SD)	Female (Mean ± SD)	Male (Mean ± SD)	p
Incisura fibularis depth	3.3 ± 0.9	3.0 ± 0.9	3.3 ± 0.9	**0.001***
Anterior tibiofibular depth	2.5 ± 0.8	2.4 ± 0.9	2.5 ± 0.8	0.221*
Posterior tibiofibular depth	3.8 ± 1.0	3.5 ± 0.9	3.8 ± 1.0	**0.044***
AP length of fibula	16.7 ± 2.0	15.4 ± 1.9	17.0 ± 1.9	**<0.001***
ML width of fibula	12.9 ± 1.8	12.4 ± 1.5	13.1± 1.8	**<0.001***
Incisura fibularis retroversion	28.0 ± 5.1	28.7 ± 5.1	27.8 ± 5.1	0.359*
Anterior tubercle length	11.2 ± 2.6	9.7 ± 3.0	11.9 ± 2.1	**<0.001***

Posterior tubercle length		15.9 ± 2.0	12.9 ± 2.2	16.7 ± 1.3	**<0.001***
Tibiofibular engagement		1.3 ± 0.3	1.8 ± 0.8	1.2 ± 0.6	**0.001***
Incisura fibularis height		27.2 ± 2.9	25.4 ± 2.3	27.8 ± 2.9	**<0.001***
Incisura fibularis morphology (n [%])	C	232 (66.4%)	54 (64.2%)	178 (67.1%)	
	I	64 (18.4%)	13 (15.4%)	51 (19.2%)	0.296**
	R	53 (15.2%)	17 (21.4%)	36 (13.7%)	

* Mann-Whitney U test, ** Chi-square test

There was also a significant difference between the mean AP length and mediolateral width of the fibula (16.7 ± 2.0 mm and 12.9 ± 1.8 mm, p=0.001). There were no differences in measured features between the right and left ankle (p>0.05). However, we did observe significant difference between male and female patients regarding the depth of the incisura fibularis, posterior tibiofibular depth, AP length of the fibula, mediolateral width of fibula, anterior tubercle length, posterior tubercle length, tibiofibular engagement, and incisura fibularis height.

The measured features of the incisura fibularis for the three different morphologies are reported in Table 3, with a significant difference in the anterior tibiofibular depth, AP length of fibula, degree of incisura fibularis retroversion, and tibiofibular engagement identified (p<0.001). There was no significant correlation between measured features of the incisura fibularis (p>0.05).

The intra- and inter-observer agreement in classification of the morphology and measured features of the incisura fibularis was excellent (Table 4 and 5).

Table 3. Comparative values of measurement parameters according to syndesmosis shapes

	C type (Mean ± SD)	I type (Mean ± SD)	R type (Mean ± SD)	p
Incisura fibularis depth	3.3 ± 0.9	3.2 ± 1.0	3.3 ± 0.9	0.654*
Anterior tibiofibular depth	2.4 ± 0.8	2.5 ± 0.9	2.2 ± 0.9	**<0.001***
Posterior tibiofibular depth	3.8 ± 1.0	3.7 ± 0.9	3.7 ± 1.0	0.789*
AP length of fibula	16.7 ± 2.0	15.4 ± 1.8	17.0 ± 1.9	**<0.001***
ML width of fibula	12.9 ± 1.8	12.7 ± 1.5	13.0± 1.9	0.096*
Incisura fibularis retroversion	28.0 ± 5.1	24.7 ± 6.3	26.8 ± 5.5	**<0.001***
Anterior tubercle length	11.4 ± 1.9	11.4 ± 1.6	11.1 ± 2.0	0.096*
Posterior tubercle length	15.5 ± 2.3	15.8 ± 1.7	16.0 ± 2.0	0.063*
Tibiofibular engagement	1.2 ± 0.3	0.5 ± 0.2	1.1 ± 0.7	**<0.001***
Incisura fibularis height	27.2 ± 2.9	27.0 ± 2.3	27.0 ± 2.9	0.494*

* Mann-Whitney U test

Table 4. Intra- and interobserver reliability table for measurement parameters

	Mean ± SD	ICC	95% CI	p
Incisura fibularis depth				
Observer A 1.	3.3 ± 0.9			
Observer A 2.	3.3 ± 0.9	0.995	0.992 - 0.998	**<0.001**
Observer B	3.3 ± 0.9	0.999	0.998 - 0.999	**0.025**
Anterior tibiofibular depth				
Observer A 1.	2.5 ± 0.8			
Observer A 2.	2.4 ± 0.8	0.988	0.982 - 0.994	**<0.001**
Observer B	2.5± 0.8	0.996	0.995 - 0.997	**<0.001**
Posterior tibiofibular depth				
Observer A 1.	3.8 ± 1.0			
Observer A 2.	3.8 ± 1.1	0.992	0.987 - 0.997	**<0.001**
Observer B	3.7± 1.0	0.989	0.987 - 0.991	**<0.001**

AP length of the fibula				
Observer A 1.	16.7 ± 2.0			
Observer A 2.	16.7 ± 2.0	0.994	0.992 - 0.996	**<0.001**
Observer B	16.6 ± 2.1	0.965	0.957 - 0.962	**<0.001**
ML width of the fibula				
Observer A 1.	12.9 ± 1.8			
Observer A 2.	12.9 ± 1.8	0.999	0.998 - 1.000	**<0.001**
Observer B	13.0 ± 1.8	0.995	0.994 - 0.996	**<0.001**
Incisura fibularis retroversion				
Observer A 1.	28.0 ± 5.1			
Observer A 2.	28.1 ± 5.0	0.976	0.972 - 0.982	**<0.001**
Observer B	28.0 ± 4.8	0.958	0.948 - 0.966	**0.001**
Anterior tubercle length				
Observer A 1.	11.2 ± 2.6			
Observer A 2.	11.0 ± 2.6	0.910	0.905 - 0.915	**0.001**
Observer B	10.9 ± 2.0	0.922	0.920 - 0.924	**0.001**
Posterior tubercle length				
Observer A 1.	15.9 ± 2.0			
Observer A 2.	15.9 ± 2.1	0.986	0.984 - 0.990	**<0.001**
Observer B	16.1 ± 1.8	0.965	0.960 - 0.970	**<0.001**
Tibiofibular engagement				
Observer A 1.	1.3 ± 0.3			
Observer A 2.	1.3 ± 0.3	0.998	0.996 - 1.000	**<0.001**
Observer B	1.4 ± 0.3	0.986	0.982 - 0.990	**<0.001**
Incisura fibularis height				
Observer A 1.	27.2 ± 2.9			
Observer A 2.	27.4 ± 2.7	0.924	0.920 - 0.928	**<0.001**
Observer B	27.6 ± 2.7	0.946	0.933 - 0.956	**<0.001**

ICC: Intraclass Correlation Coefficient, CI: Confidence interval

Table 5. Intra- and interobserver reliability table for incisura fibularis morphologic types

	Incisura fibularis morphology			k	95% CI	p
	C type	I type	R type			
Observer A 1.	232 (66.4%)	64 (18.4%)	53 (15.2%)			
Observer A 2.	230 (65.9%)	64 (18.4%)	55 (15.7%)	0.998	0.996 - 1.000	**<0.001**
Observer B	226 (64.7%)	63 (18%)	60 (17.3%)	0.996	0.994 - 0.998	**<0.001**

k: Kappa correlation coefficient, CI: Confidence Interval

DISCUSSION

Most commonly, the incisura fibularis was concave (C-shape), identified in 66.5% of cases in our study group. There was no significant difference in morphology and measured features of the incisura fibularis between the right and left ankles. However, there were significant differences in specific parameters between male and female patients: depth of the incisura fibularis, posterior tibiofibular depth, the AP length of the fibula, the mediolateral width of fibula, the anterior tubercle length, the posterior tubercle length, the extent of tibiofibular engagement, and height of the incisura fibularis. Also, a 'r' shaped incisura fibularis was described in Turkish population.

We identified two previous studies regarding the shape of the tibiofibular syndesmosis in a Turkish population, published by Taser et al. (16) and Mavi et al. (17). Both studies reported a predominance of a shallow (I-shape) morphology. This is in contrast to a predominance of a concave (C-shape) morphology reported in other populations (8,10,18-20). In our study, the concave (C-shape) morphology was the most common, observed in 66.5% of our cases, compared to 18.3% for the shallow (I-shape) morphology. We also observed an r-shape morphology of the incisura fibularis in 15.2% of our cases, which has not previously been described in Turkish patients. All measured features were greater in male than female patients.

A previous study reported a larger posterior tibiofibular distance (TFD) than anterior TFD, resulting in a more prominent anterior tubercle (8). Our findings in Turkish population were consistent with this previous report, but different from another study that reported a ratio of the posterior-to-anterior TFD of 1 (21). The ratio of the posterior-to-anterior TFD is clinically relevant, with a difference of 2 mm being indicative of a malreduction of an ankle fracture (3). Of note, however, there are the findings from studies that have reported a ratio of <1 and a difference >2 mm in normal ankle joints (8,10,13,20,22). In our study, the mean difference between the anterior and posterior TFD was 1.3 mm, with a ratio of 0.66. Elgafy et al. and Tonogai et al. (8,10) reported that the posterior TFD was slightly greater in males than females, with no between-sex difference in the anterior TFD.

Individual variability in the anatomy of the distal syndesmosis has previously been reported (14), with this variability contributing to malreduction (23), including when using the clamp method of ankle fracture reduction (14). Similarly, we identified variability in the morphology and measures of the anatomical features of the incisura fibularis among our study group of Turkish patients; as such, surgeons should consider this variability when evaluating reduction of the syndesmosis.

Boszcyzk et al. (14) reported a higher rate of over-compression of the incisura among patients with a deep incisura, likely due to the presence of a thick soft tissue layer between the distal tibia and fibula which decreases the contact at the joint. In contrast, a biomechanical study indicated that excessive compression of the syndesmosis may be associated with clamp pressure (24). Our results are consistent with those of Boszcyzk et al. (14), indicating that surgeons should be cautious to avoid excessive compression of the syndesmosis during fracture reduction, particularly in male Turkish patients.

Anteversion and retroversion of the incisura fibularis were associated with a tendency to anterior and posterior fibular displacement associated with the use of a standard axial clamp position (14). Therefore, an anterior positioning of the clamp on the distal fibular is recommended for an anteverted incisura and a posterior clamp for a retroverted incisura (14). It is important to note the conflicting results regarding the relationship between the shape of the syndesmosis shape and the direction of displacement of the distal fibula (14,25). In our study, we identified a high variability in the version angle of the incisura fibularis. Consequently, clamp positioning should be planned using measurement of version based on pre-operative CT images.

The limitations and strengths of our study should be acknowledged in the interpretation of the results. The main limitation was that the measurements were performed 10 mm proximal to the tibial plafond. Although this location for measurement is consistent with previous research, it may not be suitable for patients with different body and lower limb heights. Also, the angle of version of the incisura fibularis was measured on CT images obtained with the foot and ankle placed in a neutral position, although standardization of this position was not enforced, which may have contributed to the variability in the measured features of the incisura fibularis. The major strength of our study was our large sample size, providing comprehensive information regarding the anatomy of the distal tibiofibular syndesmosis in a Turkish population.

CONCLUSION

In conclusion, knowledge of the high variability in the angle of version of the incisura fibularis and the morphology of the syndesmosis, as well as between-sex differences in the depth of the incisura fibularis, posterior tibiofibular depth, AP length of fibula, mediolateral width of fibula, anterior tubercle length, and posterior tubercle length, may assist surgeons towards accurate fracture reduction; thus, lowering the rate of malreduction in a Turkish population.

Competing interests: The authors declare that they have no competing interest.

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Ethical approval: The study protocol was approved by Ordu University Clinical investigations research ethics committee (Approval date and number: 13/12/2018-2018/253.

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