

Morphometry of Articular Surfaces of Talus in Relation to Talocrural Joint and Its Clinical Implications

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Abstract

Introduction: The talus is a tarsal bone that connects the foot to the leg by forming the ankle joint. For planning the arthroplasty, knowledge of morphometry of articular surfaces of the talus has great importance for joint surgeries. The present study was done to measure the various parameters of the trochlear, lateral, and medial articular surface of dry human talus bone, compare the values of the right and left sides, and discuss its clinical significance. **Materials and Methods:** A present cross-sectional study was carried out on 66 adult dry human tali, morphometry of trochlear (superior), medial, and lateral articular surface were done with the digital Vernier caliper (0.01 mm). All the data were tabulated and expressed as mean, minimum, maximum, and standard deviation. Both right and left side parameters were compared with *t*-test, and $P < 0.05$ taken as significant. **Results:** The mean trochlear anteroposterior distance of total 66 tali were 29.42 ± 3.27 mm (medial), 30.68 ± 2.62 mm (central), and 30.74 ± 2.91 mm (lateral). The mean transverse width was 25.65 ± 2.54 mm (anterior), 24.72 ± 2.33 mm (central), and 21.38 ± 2.76 mm (posterior). The mean central height and central width of the lateral articular surface were 23.34 ± 2.14 mm and 19.43 ± 2.46 mm, respectively. The mean central height and central width of the medial articular surface were 13.08 ± 1.84 mm and 27.14 ± 2.59 mm, respectively. A significant difference was found only for the value of central height and central width of the medial articular surface of the right and left talus ($P < 0.05$). **Conclusion:** The values of the central height of the medial articular surface of the left side were higher, whereas the value of the central width of the same was higher in the right side. Hence, this study may help in ankle joint surgeries for choosing the appropriate size of Talus implant.

Keywords: Ankle joint, talus, trochlear surface

INTRODUCTION

The talus is the bone of the ankle which forms the ankle joint and joins the foot with the leg. It has three parts – head, neck, and body. The head lies distally and inferomedially. Its distal surface is convex and articulates with navicular bone. The plantar surface of the head has three articular facets. There is a deep sulcus present on the planter aspect of the neck on its medial side, known as sulcus tali, which articulates with the sulcus calcanei to forms the roof of sinus tarsi. The long axis of the neck forms an angle of 150° with that of the body. At birth, it was 130° – 140° .^[1]

The body of the talus is cuboidal in shape. Dorsally, it has a trochlear surface, which articulates with the distal end of the tibia. It is convex anteroposteriorly, gently concave

transversally, and widest anteriorly and, therefore smaller. The lateral surface is triangular, smooth, and vertically concave for articulation with the lateral malleolus. Superiorly, it continuous with the trochlear surface, and inferiorly, its apex forms a lateral process. The medial comma-shaped articular facet is deeper in front and articulates with the medial malleolus of the tibia. The small posterior surface is having rough projection known as the posterior process. It is marked by an oblique groove between two tubercles, which lodges the tendon of flexor hallucis longus. The lateral tubercle is usually larger, and the medial tubercle is less prominent and immediately behind the sustentaculum tali. The medial edge of the trochlear surface is straight, but

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its lateral edge inclines medially on its posterior part, and is often broadened into a small elongated triangular area that is in contact with the posterior tibiofibular ligament in dorsiflexion.^[1]

The trochlear surface, medial, and lateral articular surface of the talus articulate with the lower end of the tibia, medial malleolus, and lateral malleolus, respectively, to form the talocrural joint (ankle joint). Nowadays, joint reconstructive surgeries and joint replacement surgeries are more trending. Hence, in view of the ankle joints, the knowledge of morphometric parameters of the articular surface of the talus is important for reconstructive surgeries of the ankle as well as for choosing the right size of talus prosthesis. Hence, the present study aimed to measure the various parameters of the trochlear, lateral, and medial articular surface of dry human talus bones, compare the values of the right and left sides, and discuss its clinical significance. As radiological morphometric measurement may not be accurate due to soft-tissue shadow or angle of radiological exposure, so the present study was carried out on dry human talus available in the Museum of the Anatomy department.

MATERIALS AND METHODS

After taking Institutional Ethical Clearance ((IEC/IRB No. IEC/11/2020), the present cross-sectional study was carried out in the museum of the Department of Anatomy of Rohilkhand Medical College and Hospital in North India from September to December 2020. The sample size was calculated as 55 with reference to the study of Shishirkumar *et al.*^[2] with a standard deviation of 3.01, with a 95% confidence interval ($Z=1.96$), and a precision of 10%. Various parameters of the trochlear (superior), medial, and lateral articular surface of the talus were measured with the digital Vernier caliper (with the least count of 0.01 mm). Sixty-six dry human tali were measured, after excluding the damaged bones and bones with pathological changes. Each parameter was measured by two observers on different occasions, and mean values for each measurement were taken.

The following morphometric parameters of the articular surface of the talus were measured:

Trochlear surface

(A) Anteroposterior distance (mm) – measured as – trochlear medial anteroposterior distance (TM-APD), trochlear central anteroposterior diameter (TC-APD), and trochlear lateral anteroposterior distance (TL-APD) [Figure 1]. (B) Width of trochlear surface (mm) taken as – trochlear anterior width (TA-Width), trochlear central width (TC-Width), and trochlear posterior width (TP-Width) [Figure 2].^[3]

Lateral articular surface

(A) Lateral central height (LC-Height) of facet and (B) Lateral central width (LC-Width) of facet [Figure 3].^[3]

Medial articular surface

It was measured for – (A) Medial central height (MC-Height) and (B) Medial central width (MC-Width) [Figure 4].^[3]

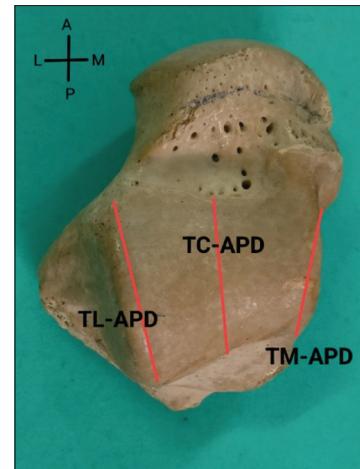


Figure 1: Left talus-superior view, morphometric parameters of trochlear surface, TM-APD: Trochlear medial Anteroposterior Distance, TC-APD: Trochlear central anteroposterior distance, TL-APD = Trochlear lateral anteroposterior distance, A: Anterior, P: Posterior, M: Medial, L: Lateral

Statistical analysis

The collected data were tabulated in Microsoft excel worksheet and analysis was performed using software SPSS version 22 (IBM Corp., Armonk, NY, USA). All data were expressed in mean, minimum, maximum values, and standard deviation. Student's *t*-test was applied to know any significant difference present between the mean morphometric values of right and left side talus and *p*-value <0.05 was taken as significant.

RESULTS

Morphometry of the trochlear, medial, and lateral articular surface of the talus was done on a total of 66 talus (33 of the right side and 33 of the left side). Mean trochlear anteroposterior length (T-APD) was measured as 29.42 ± 3.27 mm (TM-APD), 30.68 ± 2.62 mm (TC-APD), and 30.74 ± 2.91 mm (TL-APD). Mean transverse width (T-Width) was 25.65 ± 2.54 mm (TA-Width), 24.72 ± 2.33 mm (TC-Width), and 21.38 ± 2.76 mm (TP-Width). The mean central height (LC-Height) and central width (LC-Width) of the lateral articular surface for fibula were 23.34 ± 2.14 mm and 19.43 ± 2.46 mm, respectively. The mean central height (MC-Height) and central width (MC-Width) of the medial articular surface for the tibia were 13.08 ± 1.84 mm and 27.14 ± 2.59 mm, respectively [Table 1]. The value of both right and left sides was compared with *t*-test, and no significant difference was found except for the value of central height and central width of the medial articular surface of talus ($P < 0.05$) [Table 2].

DISCUSSION

Knowledge of morphometric values of articular facets of the talus is important and helpful to arthroplasty surgeries of the ankle. In the present study, there was no significant statistical difference between the value of medial, central, and lateral APD of the trochlear surface of the right and left side talus

[Table 2]. Values for trochlear APD, reported by Sakaue^[4] in Japanese talus, Lee *et al.*,^[5] in Korean, Ilgaz and Ülkir^[6] in Turkish talus, and by many Indian authors^[3,7-10] were similar to values of the present study, whereas Shishirkumar *et al.*^[2] reported higher values for trochlear APD in dry talus bone and Daud *et al.*^[11] reported higher APD values in radiological study (two-dimensional computed tomography [2D CT] scan) in the Malaysian population [Table 3].

In the present study, mean values of the anterior, central, and posterior width of the trochlear surface of the talus of the right side and left side were almost similar, and statistically, there was no significant difference [Table 2]. Values of TA-Width and TC-Width of the present study were similar to the values reported by Garg *et al.*,^[9] and smaller than the values reported by many other authors.^[2-8,10] The mean values of TP-Width of the present study were almost similar to the values reported by many studies^[2,3,6-10] [Table 3]. Radiological study

(three-dimensional-CT scan) done in America reported higher values for transverse width of trochlear surface,^[12] whereas in Malaysian radiological study (2D-CT scan),^[11] they reported smaller values for the same.

In the present study, there was no statistically significant difference between the mean values of LC-Height and LC-Width (Fibular facet) of the right and left talus [Table 2]. Many authors^[2,3,7] reported similar values for LC-Height and LC-Width as the present study, whereas Ilgaz and Ülkir^[6] reported higher values. Garg *et al.*,^[9] Naqshi *et al.*,^[10] and Koshy *et al.*^[13] reported similar values for LC-Height, but higher values for LC-Width [Table 4].

In the present study, mean values of MC-Height and MC-Width (Facet for medial malleolus) of right-side talus were 12.19 ± 1.33 mm and 27.80 ± 2.5 mm, and of left side values were 13.97 ± 1.88 mm and 26.48 ± 2.53 mm, respectively. Statistical significant difference was present between the

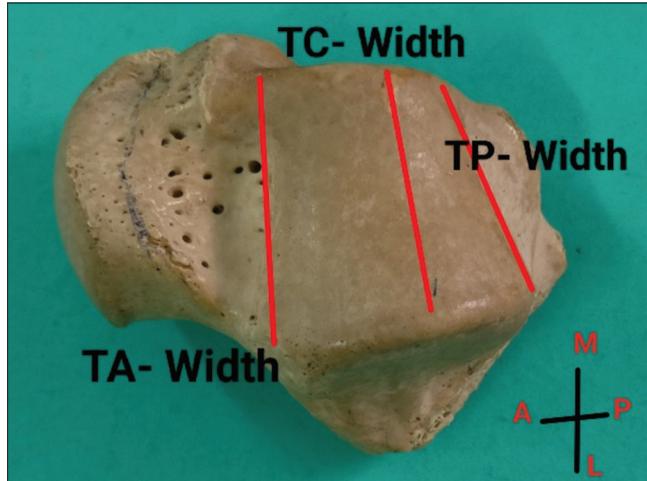


Figure 2: Left talus-superior view, morphometric parameters of trochlear surface, TA-Width: Trochlear anterior width, TC-Width: Trochlear central width and TP-Width: Trochlear posterior width, A: Anterior, P: Posterior, M: Medial, L: Lateral

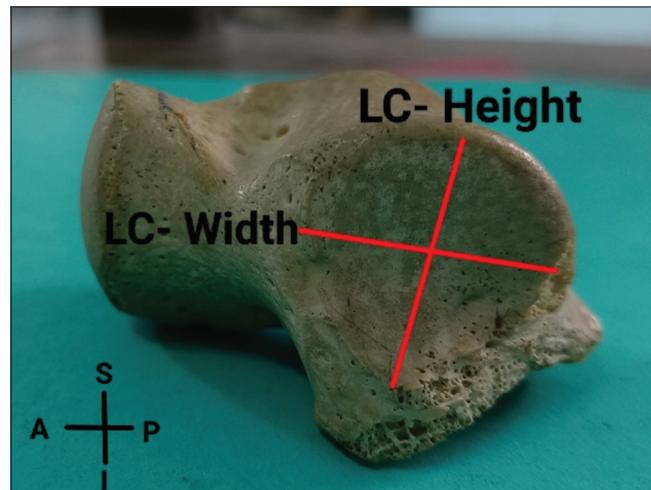


Figure 3: Left talus-lateral view: Morphometric parameters of lateral articular surface. LC-Height: Lateral central height, LC-Width: Lateral central width, A: Anterior, P: Posterior, S: Superior, I: Inferior

Table 1: Morphometric values of trochlear, lateral, and medial articular surfaces of talus

Morphometric parameters (n=66)	Minimum (mm)	Maximum (mm)	Mean \pm SD (mm)
Trochlear surface			
TM-APD	23.73	39.94	29.4214 \pm 3.27162
TC-APD	24.66	36.88	30.6765 \pm 2.62250
TL-APD	24.81	38.26	30.7400 \pm 2.91178
TA-Width	20.32	30.79	25.6459 \pm 2.54447
TC-Width	18.67	29.92	24.7183 \pm 2.33001
TP-Width	15.90	28.52	21.3789 \pm 2.76405
Lateral articular surface			
LC-Height	18.67	29.85	23.3358 \pm 2.13838
LC-Width	14.21	26.74	19.4274 \pm 2.46010
Medial articular surface			
MC-Height	9.92	17.25	13.0842 \pm 1.84389
MC-Width	20.00	35.42	27.1423 \pm 2.58854

TM: Trochlear medial, TC: Trochlear central, TL: Trochlear lateral, APD: Anteroposterior distance, LC: Lateral central, MC: Medial central, SD: Standard deviation, TA: Trochlear anterior, TP: Trochlear posterior

Table 2: Minimum, maximum, and mean value of morphometric parameters of trochlear, lateral, and medial articular surfaces of right and left talus and *t*-value and *P* value

Morphometric parameters	Right (n=33)			Left (n=33)			<i>t</i>	<i>P</i>
	Minimum (mm)	Maximum (mm)	Mean±SD (mm)	Minimum (mm)	Maximum (mm)	Mean±SD (mm)		
Trochlear surface								
TM-APD	24.62	36.03	29.02±2.96	23.73	39.94	29.83±3.55	1.073	0.291
TC-APD	26.72	36.88	30.63±2.52	24.66	36.56	30.72±2.75	0.133	0.895
TL-APD	24.90	36.22	30.11±2.71	24.81	38.26	31.38±3.01	1.653	0.108
TA-Width	21.14	30.51	25.32±2.49	20.32	30.79	25.97±2.58	0.937	0.356
TC-Width	20.52	29.92	24.58±2.34	18.67	29.42	24.85±2.35	0.430	0.670
TP-Width	16.47	26.53	20.77±2.62	15.90	28.52	21.98±2.8	1.960	0.059
Lateral articular surface								
LC-Height	18.83	29.85	23.42±2.19	18.67	27.07	23.25±2.11	0.322	0.750
LC-Width	15.09	26.74	19.19±2.63	14.21	24.44	19.66±2.28	0.805	0.427
Medial articular surface								
MC-Height	9.92	15.16	12.19±1.33	10.70	17.25	13.97±1.88	4.227	0.001
MC-Width	23.26	35.42	27.80±2.5	20.00	30.48	26.48±2.53	2.051	0.049

TM: Trochlear medial, TC: Trochlear central, TL: Trochlear lateral, APD: Anteroposterior distance, LC: Lateral central, MC: Medial central, SD: Standard deviation, TA: Trochlear anterior, TP: Trochlear posterior

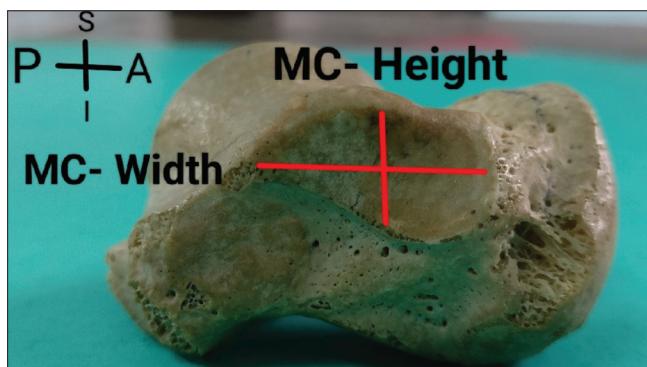


Figure 4: Left talus-medial view: Morphometric parameters of Medial articular surface. MC-Height: Medial central height, MC-Width: Medial central width, A: Anterior, P: Posterior, S: Superior, I: Inferior

values of height of the talus of both side and width of the talus of both the side (*p* value <0.05) [Table 2]. Values for the medial articular facet reported by the present study were almost similar to the values reported by many authors,^[2,3,6,7,9,10] whereas Koshy *et al.*^[13] reported higher values for MC-Height and smaller values for MC-Width [Table 4].

The difference seen in the mean of morphometric values of the present study with other studies can be due to racial, regional, cultural, environmental, genetic, or geographical differences.

Anghong *et al.*^[14] conducted a cadaveric study on talus in Thailand and concluded that morphometric parameters of opposite talus in same individual may not be used as a single reference to reconstruct or choosing the size of talar implant or customized total ankle replacement.

Conclusion

In the present study, statistically, there was no significant

difference found between the values of the right and left sides of various measured parameters of the trochlear, medial, and lateral articular surface of the talus except the central height and central width of the medial articular surface. Where the *P*<0.05. The central height of the medial articular surface was higher on the left side, and the central width was higher on the right side.

The inappropriate size of the talar implant may lead to pathological or mechanical problems to the joint. As Yurttas *et al.*^[15] in the Turkish population, conducted a study to know the relation between ankle morphology and the development of talus osteochondritis dissecans (OCD) using high-resolution magnetic resonance imaging and found that out of five selected parameters for investigation, intermalleolar width, and trochlear length were significantly higher in the OCD groups compared to healthy volunteers which were statistically significant. Hence, it shows that there is the relation between the morphometric values and the pathogenesis of the talus. The size of the prosthesis may vary in different genders, races, ethnic groups, social cultures, etc.^[16] Hence, the present study may help orthopedic surgeons to choose the correct size of the implant in ankle joint replacement surgeries in India.

Limitations

The sample size of the present study was small, such kind of studies may be supplemented with the radiological morphometry of talus.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Table 3: Mean anteroposterior distance and transverse width of trochlear surface of talus reported by different authors

Authors	Country	Side (n)	Mean \pm SD					
			Trochlear APD (mm)			Trochlear transverse width (mm)		
			TR-MAPD	TR-CAPD	TR-LAPD	TR-AW	TR-CW	TR-PW
Sakaue, 2011 ^[4]	Japan	Total (144)	-	30.6	-	-	27.2	-
Lee <i>et al.</i> , 2012 ^[5]	Korea	Total (140)	-	32.2	-	-	27.35	-
Ilgaz and Ülkir, 2022 ^[6]	Turkey	Right (36)	-	33.58 \pm 2.84	-	-	28.66 \pm 2.82	-
		Left (51)	-	32.43 \pm 3.06	-	-	27.95 \pm 3.30	-
Jatin <i>et al.</i> , 2015 ^[3]	India	Right (20)	31.02 \pm 1.83	30.39 \pm 1.63	29.63 \pm 0.65	28.87 \pm 1.73	28.16 \pm 1.60	21.59 \pm 1.42
		Left (20)	31.79 \pm 1.34	30.65 \pm 0.91	29.45 \pm 1.59	29.08 \pm 2.73	27.54 \pm 2.32	21.78 \pm 1.47
Veenatai and V. Janaki, 2017 ^[7]	India	Right (20)	28.4	29.4	28.4	28.5	26.4	21.3
		Left (22)	31	28	30	26.1	24.4	22.7
Narayanan <i>et al.</i> , 2018 ^[8]	India	Total (160)	-	29.6 \pm 2.7	-	31 \pm 2.5	28.2 \pm 2.6	21.4 \pm 2.1
Shishirkumar <i>et al.</i> , 2014 ^[2]	India	Right (15)	36 \pm 3.09	36.8 \pm 2.24	36.4 \pm 2.41	27.87 \pm 1.30	26.6 \pm 1.92	21.47 \pm 1.68
		Left (15)	36.53 \pm 3.35	37.4 \pm 2.41	36.4 \pm 3.18	28.4 \pm 1.72	26.67 \pm 1.87	22.13 \pm 1.68
Garg <i>et al.</i> , 2021 ^[9]	India	Right (26)	29.87 \pm 2.93	29.87 \pm 3.14	29.32 \pm 2.98	27.01 \pm 2.70	26.2 \pm 2.76	22.92 \pm 2.33
		Left (24)	30.18 \pm 3.37	29.97 \pm 2.11	29.60 \pm 1.91	28.16 \pm 2.76	26.77 \pm 1.94	22.98 \pm 2.46
Naqshi <i>et al.</i> , 2018 ^[10]	India	Right (40)	27	28.1	27.4	27.6	26.2	21.1
		Left (30)	29.4	27	29.1	27	24	23.1
Daud <i>et al.</i> , 2013 ^[11] (2D CT-scan)	Malaysia	Right (99)	-	27.69 \pm 2.66	-	30.47 \pm 2.93	-	11.34 \pm 2.43
		Left (99)	-	27.52 \pm 2.41	-	30.32 \pm 2.93	-	12.14 \pm 2.6
Hayes <i>et al.</i> , 2006 ^[12] (3D CT-scan)	America	Total (42)	-	-	-	29.9 \pm 2.6	27.9 \pm 3.0	25.2 \pm 3.7
Present study	India	Right (33)	29.02 \pm 2.96	30.63 \pm 2.52	30.11 \pm 2.71	25.32 \pm 2.49	24.58 \pm 2.34	20.77 \pm 2.62
		Left (33)	29.83 \pm 3.55	30.72 \pm 2.75	31.38 \pm 3.01	25.97 \pm 2.58	24.85 \pm 2.35	21.98 \pm 2.8

SD: Standard deviation, APD: Anteroposterior Distance, TR-AW: Trochlear anterior width, TR-CW: Trochlear central width, TR-PW: Trochlear posterior width, TR-MAPD: Trochlear medial APD, TR-CAPD: Trochlear central APD, TR-LAPD: Trochlear lateral APD, CT: Computed tomography

Table 4: Mean morphometric values of lateral and medial articular surfaces of talus reported by different authors

Authors	Country	Side (n)	Mean \pm SD			
			Lateral articular surface measurements (mm)		Medial articular surface measurements (mm)	
			LC-Height	LC-Width	MC-Height	MC-Width
Shishirkumar <i>et al.</i> , 2014 ^[2]	India	Right (15)	23.2 \pm 1.08	-	13.07 \pm 0.88	-
		Left (15)	23.6 \pm 1.24	-	13.07 \pm 1.03	-
Goda Jatin <i>et al.</i> , 2015 ^[3]	India	Right (20)	22.14 \pm 1.71	18.93 \pm 0.92	11.93 \pm 1.44	27.94 \pm 2.90
		Left (20)	22.63 \pm 3.24	18.99 \pm 1.59	11.29 \pm 1.17	28.29 \pm 1.79
Veenatai and V. Janaki, 2017 ^[7]	India	Right (20)	26	20.8	12.4	24
		Left (22)	22.7	16.3	10.4	18.2
Ilgaz and Ülkir, 2022 ^[6]	Turkey	Right (36)	26.55 \pm 2.25	28.4 \pm 3.22	14.51 \pm 1.51	30.49 \pm 3.15
		Left (51)	25.1 \pm 2.64	27.05 \pm 3.37	12.83 \pm 1.34	29.01 \pm 3.42
Garg <i>et al.</i> , 2021 ^[9]	India	Right (26)	23.25 \pm 3.72	24.84 \pm 4.08	12.81 \pm 3.66	27.21 \pm 2.56
		Left (24)	24.08 \pm 1.99	25.05 \pm 4.3	12.08 \pm 1.58	26.43 \pm 2.75
Naqshi <i>et al.</i> , 2018 ^[10]	India	Right (40)	26.2	21.9	13.6	25.9
		Left (30)	23	16.8	10.8	17.9
Koshy <i>et al.</i> , 2002 ^[13]	India	Total (70)	23.3 \pm 2.4	27.2 \pm 2.9	26.4 \pm 3.6	11.8 \pm 2.3
Present study	India	Right (33)	23.42 \pm 2.19	19.19 \pm 2.63	12.19 \pm 1.33	27.80 \pm 2.5
		Left (33)	23.25 \pm 2.11	19.66 \pm 2.28	13.97 \pm 1.88	26.48 \pm 2.53

SD: Standard deviation, LC: Lateral central, MC: Medial central

REFERENCES

1. Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 40th ed. UK: Elsevier Health Sciences; 2008. p. 1434-6.
2. Shishirkumar DS, Arunachalam K, Girish VP. Morphometric analysis of superior articulating surface of talus. *Int J Sci Res IJSR* 2014;3:2387-91.
3. Goda Jatin B, Patel Shailesh M, Parmar Ajay M, Agarwal GC. Morphometry of the articular facets on the superior, medial and lateral surfaces of the body of talus and its clinical relevance. *Int J Med Res Health Sci* 2015;4:531-4.
4. Sakaue K. Sex assessment from the talus and calcaneus of Japanese. *Bull Natl Mus Sci* 2011;37:35-48.
5. Lee UY, Han SH, Park DK, Kim YS, Kim DI, Chung IH, *et al.* Sex determination from the talus of Koreans by discriminant function analysis. *J Forensic Sci* 2012;57:166-71.
6. Ilgaz H, Ülkir M. Evaluation of some morphological and morphometric properties of talus. *Sag Bil Derg* 2022;8:134-8.

7. Veenatai J, V. Janaki. Morphometry of articular facets of the body of talus. *IOSR J Dent Med Sci* 2017;16:19-21.
8. Narayanan S, Phalgunan V, Shankar N. Morphometry of talar trochlear surface and its correlation. *Natl J Clin Anat* 2018;7:123-7.
9. Garg S, Verma MU, Suri A, Aulakh KK. A morphometric study on the articulating facets of talus in North Indian population. *Asian J Med Sci* 2021;12:161-3.
10. Naqshi BF, Shah AB, Gupta S. Morphometry of articular facets of talus and anatomical variations of the trochlear surface in North Indian population. *Int J Sci Res* 2018;7:39-40.
11. Daud R, Abdul Kadir MR, Izman S, Md Saad AP, Lee MH, Che Ahmad A. Three-dimensional morphometric study of the trapezium shape of the trochlea Tali. *J Foot Ankle Surg* 2013;52:426-31.
12. Hayes A, Tochigi Y, Saltzman CL. Ankle morphometry on 3D-CT images. *Iowa Orthop J* 2006;26:1-4.
13. Koshy S, Vettivel S, Selvaraj KG. Estimation of length of calcaneum and talus from their bony markers. *Forensic Sci Int* 2002;129:200-4.
14. Angthong C, Rajbhandari P, Veljkovic A, Piyaphanee A, Stufkens SA, Wibowo R. Morphometric geometric differences between right and left human tali: A cadaveric study of fluctuating asymmetry via systematic measurement and three-dimensional scanning. *PLoS One* 2020;15:e0232012.
15. Yurttas Y, Kilic C, Akpancar S, Celikkanat S, Hanifi Gemci M, Hamcan S, *et al.* The relation between ankle morphology and osteochondritis dissecans of talus. *Acta Orthop Belg* 2018;84:229-34.
16. Gundapaneni D, Tsatalis JT, Laughlin RT, Goswami T. Anthropomorphic characterization of ankle joint. *Bioengineering (Basel)* 2023;10:1212.