The computed tomography-based anatomy of the ossa cuneiformia

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Abstract

There is a lack of basic anatomic information regarding the ossa cuneiformia. The aim of the present descriptive study was the detailed evaluation of the anatomy of the ossa cuneiformia. We analyzed 100 computer tomography scans of feet without deformities or previous trauma. The length, height and width of each cuneiforme and their articular surfaces were assessed. We itemized the data to gender differences and to foot length. The medial cuneiforme os had a length of 24.0 mm ± 2.4 (mean ± standard deviation), a width of 17.3 mm ± 2.8 and a height of 28.0 mm ± 3.4. The respective values for the intermediate cuneiforme were 18.2 mm ± 2.1, 15.8 mm ± 2.1 and 22.5 ± 2.2 and for the lateral cuneiforme 26.4 mm ± 2.7, 17.2 mm ± 2.9 and 22.8 mm ± 2.9. We found statistical relevant differences regarding gender and foot length subgroups whereas not for all parameters. The present study illustrates basic anatomic data regarding the ossa cuneiformia. This information might be helpful for implant design and placement during midfoot surgery.

Introduction

A thorough anatomical knowledge is crucial for designing surgical implants and planning surgical procedures. The relevance of this information increased within the last years as the implant producers were prompted to enhance and engross the verification of the quality of their implants via clinical and biomechanical testing (Regulation of the European Union 2017/745, 04/05/17).

The cuneiforms present the proximal part of the first to third tarsometatarsal joint (TMT) or medial Lisfranc joint. The adjacent joints are physiologically constraint with a range of motion below 4 degrees for dorsal extension and plantar flexion.[1-4] A high number of forefoot surgery is performed due to hallux valgus deformity.[5,6] One of the most frequently used procedure for hallux valgus correction is the Lapidus arthrodesis or arthrodesis of the first TMT.[1,7,8] Additionally in severe cases of osteoarthritis of the TMT I-III, intercuneiforme joints or naviculocuneiforme joints an arthrodesis of the respective joints including the cuneiforms is performed.[9] The Cotton osteotomy, an osteotomy of the medial cuneiform, is a reliable option to treat plat foot deformity.[10] Nonetheless ligamental injuries, luxations or fractures can occur requiring surgical intervention after relevant trauma.[11-13] That highlights the relevance of a detailed knowledge of the anatomy of the cuneiforms.

The present study aimed to illustrate the computer tomography- (CT-) based anatomy of the ossa cuneiformia.

Materials and Methods

Patients and computer tomography scans

The local ethical committee had no concerns regarding this study. We analyzed 100 consecutive CT scans of the foot and ankle that were performed within 11/16 and 06/17. Exclusion criteria were incomplete datasets, incomplete illustration of the foot, degenerative changes, previous trauma or operation and insufficient scan segmentation. CT scans were segmented orientated on the recommendations of the International society of biomechanics. The frontal plane was orientated tip of the medial and lateral malleolus and the tibial anatomical axis. The sagittal plane was perpendicular to the frontal plane and orientated on the axis of the second metatarsal. The axial plane was perpendicular to the frontal and sagittal planes.[14] CT scans were performed in supine position using the Siemens Emotion 16 (2007), with an x-ray tube current of 126 mA, KVP 130 kV. The slice thickness was 1.5 mm (Figure 1).

The evaluation included the determination of length, height and width of the cuneiforms. The values were defined to be the distance of the central points of the opposing articular surfaces or for the width of the medial cuneiform the line connecting the center of the lateral articular surface and the center of the medial cortical surface. The assessment of the height of the intermediate and lateral cuneiform respected the physiologic transverse arch of the foot. Likewise, the articular surfaces were determined in their respective central parts. Thereby we gained information about the height and width of the proximal and distal articular surfaces of each cuneiform as well as the length and height of the two intercuneiform joints. Additionally, we assessed the joint between lateral cuneiform and cuboid.

We determined differences between male and female patients. Furthermore, orientated on a publication of Ryan *et al.,* we divided the patients into three subgroups depending on the foot length and evaluated differences between these groups.[15]

Statistical analysis

Data collection and analysis were performed with GraphPad Prism 5 (GraphPad Software, Inc., La Jolla, CA 92037). Values are expressed as mean and standard deviation (SD). The statistical analysis was performed using an unpaired two-sided Student's t-test. Statistical significance was defined as a P-value <0.05. A power analysis was performed based on the data of Ryan *et al*. for the depth of the first TMT joint resulting in a required total sample size of 48 for a significance level of 0.05 and a power of 0.95.[15,16]

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Results

The age of the patients averaged 44.8±16.1 years, 28 legs were from female patients and 72 from male patients. In 46 cases the right foot and in 54 cases the left foot was assessed. The results of the evaluation of anatomic parameters of the cuneiforms are illustrated in Table 1 for gender subgroups and in Table 2 for foot length subgroups. We found statistical relevant intersexual differences and differences depending on foot length, whereas not for every parameter. Tables 1 and 2 provide a detailed illustration. The mean foot length was 25.8 mm ± 2.1. To divide the patients into three subgroups we used the 33.3 and 66.6 percentiles of 24.6 mm and 27.0 mm. All patients with a foot length of 24.6 mm or lower were ranked as Small, all patients with a foot length of 24.7 mm to 27.0 mm were ranked as Medium and all patients with a foot length of 27.1 mm or higher were ranked as Large.

Discussion

The quality of surgical implants in foot and ankle enhanced within the last years. However especially for the ossa cuneiformia basic anatomic parameters remained undefined so far. The present study provides a CT based description of the anatomy of the ossa cuneiformia.

Several previous studies including anatomic evaluations used CT scans as they give detailed information about bony anatomy and assures measurement in a physiologic orientation.[17] Homogenous and thin cartilage layer of medial TMT joints supports the use of CT scans.[18] CT scans are not as susceptible as plain radiographs to foot position and rotation.[19,20] Additionally, in comparison to magnet resonance imaging CT scans are preferable as they are cheaper and easier to evaluate due to higher resolution. Our coordinate system was based on ISB recommendations providing a standardized and validated system as used by several previous studies.[14,21-24]

Most previous studies regarding the TMT joint line analyzed different fixation techniques in biomechanical or clinical studies.[1,2,7,8,25-32] Anatomic studies evaluated primarily the ligamentous anatomy regarding comparative data for Lisfranc luxation injuries.[3,11,12,33] To our knowledge the present study is the first study that provides a standardized evaluation of the cuneiforms. Only partially comparable data was described by Ryan et al who described a depth for TMT I of 32.2 mm, for TMT II of 26.9 mm and 23.6 mm for TMT III. They itemized their information to different foot lengths and found a correlation of foot length and depths of the respective TMT joints.[15] Our respective values for these values (height in the present study) were smaller. The reason for the difference might be the different measurement technique. However, in accordance to Ryan *et al.* we found for most anatomic parameters a correlation to the foot length.

The present study is of clinical relevance as despite recent improvements of implants and techniques in foot and ankle surgery our data might help to optimize implants for surgical procedures including the cuneiforms. Especially for new plate systems the provision of different plate sizes should be discussed. The differences of the subgroups were within three Millimeters what seem to be little. Still as the usage of precontoured plates raises our data queries whether one plate size really fits all feet. Additionally, our study highlighted the fact that the intercuneifom joints are located in the dorsal aspect of the respective bones. The height of the articular surfaces is lower compared the height of the cuneiforms itself. That should be consid-

Table 1. Anatomy of the ossa cuneiformia including their articular surfaces of gender subgroups. The results of the evaluation of basic anatomic parameters of the cuneiforms and their articular surfaces are illustrated. Additionally, we itemized this information for female and male patients.

		All (n=100)	Male (n=72)	Female (n=28)	P-value
Medial cuneiform	Lentgh	23.8±2.4	24.3±2.3	22.3±2.2	*<0.0001*
	Width	15.9±2.7	16.4±2.8	14.8±2.2	*0.0002*
	Height	26.9±3.6	27.6±3.5	24.9±3.1	*<0.0001*
	Proximal articular surface width	16.0±3.0	16.4±3.0	14.7±2.7	*0.0006*
	Proximal articular surface height	16.7±3.2	17.3±3.1	14.8±2.5	*<0.0001*
	Distal articular surface width	19.0±5.9	19.0±6.1	18.7±5.5	0.7498
	Distal articular surface height	22.6±6.4	23.4±6.3	20.3±6.1	*0.0028*
	Intercuneiform I/II articular surface lentgh	19.0±5.9	19.5±3.7	19.0±3.3	0.3908
	Intercuneiform I/II articular surface height	22.6±6.4	17.7±5.2	17.0±4.7	0.3969
Intermedium cuneiform	Lentgh	17.7±1.9	18.1±1.8	16.8±1.8	*<0.0001*
	Width	12.4±3.1	12.8±3.0	11.5±3.2	*0.0127*
	Height	20.8±2.9	21.2±2.8	20.0±3.0	*0.0028*
	Proximal articular surface width	12.8±2.9	13.4±4.4	11.3±4.5	*0.0044*
	Proximal articular surface height	12.9±4.5	14.4±5.5	13.1±4.1	0.1462
	Distal articular surface width	14.0±5.3	13.8±3.9	13.2±4.1	0.3613
	Distal articular surface height	13.7±4.0	16.1±4.3	15.1±4.0	0.1401
	Intercuneiform II/III articular surface lentgh	15.7±4.2	17.2±4.3	16.2±3.7	0.0817
	Intercuneiform II/III articular surface height	16.9±4.1	16.6±4.4	15.4±3.8	0.0864
Lateral cuneiform	Lentgh	16.3±4.3	24.7±2.9	23.1±2.3	*0.0004*
	Width	24.3±2.9	15.1±3.1	14.3±2.3	0.0632
	Height	17.3±4.3	17.9±4.3	15.9±3.9	*0.0032*
	Proximal articular surface width	11.4±2.5	11.7±2.6	10.6±1.8	*0.0074*
	Proximal articular surface height	12.2±2.9	13.0±2.7	10.1±2.3	*<0.0001*
	Distal articular surface width	12.9±3.0	13.2±3.2	12.1±2.1	*0.0228*
	Distal articular surface height	12.5±3.5	12.8±2.5	11.9±2.3	*0.0387*
	Cuneiformcuboidal articular surface lentgh	16.0±3.3	16.3±3.5	15.3±3.0	0.0674
	Cuneiformcuboidal articular surface height	15.6±3.4	16.2±3.3	14.0±2.3	*<0.0001*

Results are illustrated as mean±SD. Statistically relevant differences are in italics.

ered especially when placing an intercuneiform lag screw. Furthermore, the triangular shape of the intermedium and lateral cuneiform might be noteworthy. For the TMT II+III joints a relatively small articular surface should be noted. This fact might rather support the use of one lag screw with plate fixation compared to a two-screw technique.

Our study has limitations worth considering. We used CT scans in our study. A cadaver-based analyses might have different results especially for our interpretation of the intercuneiform joints. Additionally, we are not able to provide information about the anatomy of the surrounding soft tissue.

Conclusions

We firstly describe the CT based anatomy of the ossa cuneiformia with adjacent joints in correlation to sex and foot length. This might assist surgeons in performing surgical procedures including the cuneiforms via a better understanding of the

Table 2. Anatomy of the ossa cuneiformia including their articular surfaces of foot length subgroups. We found statistically relevant differences especially for the comparisons of the subgroup with larger feet.

		All (n=100)	Small (n=34)	Medium (n=33)	Large (n=33)	P-value S *vs.* M	P-value S *vs.* L	P-value M *vs.* L
Medial cuneiform	Lentgh	23.8±2.4	22.9±2.3	23.7±2.5	24.9±2.1	0.0584	*<0.0001*	*0.0051*
	Width	15.9±2.7	15.3±2.9	15.5±2.1	16.9±3.0	0.6448	*0.0021*	*0.0032*
	Height	26.9±3.6	26.3±3.3	25.9±3.4	28.6±3.6	0.5417	*0.0001*	*<0.0001*
	Proximal articular surface width	16.0±3.0	15.1±3.0	16.0±2.8	16.7±3.1	0.0750	*0.0049*	0.2320
	Proximal articular surface height	16.7±3.2	16.3±3.1	16.1±2.6	17.7±3.6	0.8124	*0.0200*	*0.0078*
	Distal articular surface width	19.0±5.9	17.3±5.8	20.0±5.5	19.7±6.1	*0.0092*	*0.0256*	0.7707
	Distal articular surface height	22.6±6.4	22.0±6.5	21.1±6.0	24.8±6.3	0.4565	*0.0151*	*0.0012*
	Intercuneiform I/II articular surface lentgh	19.0±5.9	18.8±3.4	18.8±3.2	20.5±3.9	0.9700	*0.0154*	0.0141
	Intercuneiform I/II articular surface height	22.6±6.4	17.0±5.0	17.0±5.5	18.7±4.6	0.9260	*0.0433*	*0.0757*
Intermedium cuneiform	Lentgh	17.7±1.9	17.0±1.9	17.8±2.0	18.4±1.6	*0.0182*	*<0.0001*	0.1088
	Width	12.4±3.1	11.6±2.6	12.6±3.4	13.1±2.9	*0.0494*	*0.0019*	0.3883
	Height	20.8±2.9	20.5±2.4	19.9±2.7	22.0±3.2	0.1797	*0.0019*	*<0.0001*
	Proximal articular surface width	12.8±2.9	11.8±4.5	13.1±4.2	13.6±4.7	0.0872	*0.0259*	0.5331
	Proximal articular surface height	12.9±4.5	14.4±5.0	12.9±4.9	14.9±5.5	0.0919	0.5361	0.0298
	Distal articular surface width	14.0±5.3	13.5±4.2	14.3±3.8	13.3±3.9	*0.2766*	0.8090	*0.1656*
	Distal articular surface height	13.7±4.0	15.5±4.0	15.4±4.3	16.7±4.3	0.9434	0.0978	0.0964
	Intercuneiform II/III articular surface lentgh	15.7±4.2	17.2±4.4	15.8±3.6	17.6±4.2	0.0576	0.5843	*0.0113*
	Intercuneiform II/III articular surface height	16.9±4.1	15.6±4.0	15.1±4.4	18.3±3.9	0.5229	*0.0002*	*<0.0001*
Lateral cuneiform	Lentgh	16.3±4.3	23.4±2.1	24.0±3.3	25.4±2.7	0.2289	*<0.0001*	*0.0081*
	Width	24.3±2.9	14.0±2.9	15.5±2.7	15.2±2.9	*0.0025*	*0.0159*	0.5881
	Height	17.3±4.3	16.8±3.5	17.0±4.8	18.1±4.4	0.8335	0.0747	0.1775
	Proximal articular surface width	11.4±2.5	10.9±2.9	11.5±2.1	11.8±2.4	0.2392	0.0768	0.4451
	Proximal articular surface height	12.2±2.9	11.5±3.0	12.5±3.5	12.7±3.1	0.0834	*0.0137*	0.6578
	Distal articular surface width	12.9±3.0	12.1±2.6	12.7±2.8	13.9±3.3	0.2185	*0.0007*	*0.0274*
	Distal articular surface height	12.5±3.5	12.3±2.4	11.9±2.5	13.5±2.4	0.3115	*0.0052*	*0.0002*
	Cuneiformcuboidal articular surface lentgh	16.0±3.3	16.1±3.6	15.1±2.7	16.9±3.5	0.0748	0.2293	*0.0017*
	Cuneiformcuboidal articular surface height	15.6±3.4	14.8±3.4	15.3±3.2	16.7±3.3	0.4510	*0.0014*	*0.0122*

Results are illustrated as mean ± SD. Statistically relevant differences in italics.

Figure 1. Exemplary illustration of the evaluation in three standardized planes. In this case the axial plane in a) serves as an orientation for the measurement of the height and length of the medial cuneiform in the sagittal plane (b). c) Illustrates the measurement of the intercuneiform I/II joint in coronar plane.

anatomy and support the improvement of implants for midfoot foot surgery.

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