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Orgınal Article

Investigation of Anatomic and Orthopedic Properties of First Metatarsal Bone

Os Metatarsale'nin Anatomik ve Ortopedik Özelliklerinin Araştirilmasi

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Abstract

Background: Structure most affected by the clinical deformities associated with lower extremity is the first metatarsal bone which may cause orthopedic problems and chronic pain on foot, because approximately 80% of the load from the talus and calcaneus is transmitted to the ground via medial arch. **Materials and Methods:** Our study was performed on lower extremities of 32 adult patients without any foot deformity, which were amputated due to circulation failure in the Department of Orthopaedics and Traumatology. Firstly, tibia length, foot length and foot width were measured. Subsequently, the dimensions and length of first metatarsus as well as proximal and distal articular surface dimensions of the first metatarsus were measured.**Results:** The average values were as follows: tibia length: 35.9 cm, foot length:22.7cm, foot width: 8 cm, length of first metatarsus: 5.8 cm. Statistical significance was found among the dimensions of proximal end, dimensions of distal head and the thinnest site of the bone ($p \leq 0.01$). **Conclusions:** Various external deforming forces cause variations in the medial longitudinal arch and lead foot pain. The length, shape of the head as well as the dimensions of the proximal and distal joint surfaces of the first metatarsal bone are important factors in the development of foot deformities. Since peroneus longus and tibialis anterior muscles insert onto the first metatarsal bone, the forces exerted by their tendons affect morphology of the bone. Therefore, dimensions of these muscles and their tendons in relation with the dimensions of first metatarsal bone are essential in the prevention and treatment of foot deformities.

Key Words: First metatarsal bone, Lower Extremity, Morphology, Anatomy, Orthopedics

ÖZ

Amaç: Alt ekstremite ile ilişkili klinik deformitelerden en çok etkilenen yapı, ortopedik problemlere ve ayakta kronik ağrıya neden olabilen birinci metatarsal kemiktir, çünkü talus ve calcaneus'tan gelen yükün yaklaşık %80'i arcus longitudinalis medialis pedis yoluyla yere iletilir. **Materyal ve Metod:** Çalışmamız Ortopedi ve Travmatoloji Anabilim Dalı'nda dolaşım yetmezliği nedeniyle ampute edilen ayak deformitesi olmayan 32 erişkin hastanın alt ekstremiteleri üzerinde yapıldı. İlk olarak tibia uzunluğu, ayak uzunluğu ve ayak genişliği ölçüldü. Daha sonra os metatarsale I uzunluğu ile proksimal ve distal eklem yüzey boyutları ölçüldü. **Bulgular:** Ortalama değerler; tibia uzunluğu: 35,9 cm, ayak uzunluğu: 22,7 cm, ayak genişliği: 8 cm, os metatarsale I uzunluğu: 5,8 cm olarak hesaplandı. Proksimal uç boy, distal baş ve kemiğin en ince yerinin boyutu kıyaslandığında birbirleriyle arasında istatistiksel anlamlılık bulundu ($p \leq 0,01$). Çeşitli dış deforme edici kuvvetler, arcus longitudinalis medialis pedis'te değişikliklere neden olur ve ayak ağrısına yol açar. Başın uzunluğu, şekli ve os metatarsale I'in proksimal ve distal eklem yüzeylerinin boyutları ayak deformitelerinin gelişiminde önemli faktörlerdir. **Sonuç:** Musculus peroneus longus ve musculus tibialis anterior, os metatarsale I üzerine tutunduğundan, tendonlarının uyguladığı kuvvetler kemiğin morfolojisini etkiler. Bu nedenle, ayak deformitelerinin önlenmesi ve tedavisinde bu kasların ve tendonlarının, os metatarsale I boyutlarına göre boyutları önemlidir.

Anahtar Kelimeler: Os metatarsale I, Alt ekstremite, Morfoloji, Anatomi, Ortopedi

Highlights

- First metatarsal bone are important factors in the development of foot deformities.
- To detect feet at risk in terms of deformities such as hallux valgus, hallux varus, hallux rigidus in the early period and take precautions.

Introduction

Compared to other metatarsals, the first metatarsal bone has a unique anatomical configuration and two main articular surfaces at its proximal and distal ends, whose angles have an important clinical impact in the management of hallux deformities. In addition, an articulation occurs between the base of the first metatarsal and the second metatarsal laterally, and this complex structure makes the first metatarsal bone an indispensable element in the preservation of the foot arch and dynamics (1).

Clinically; deformities such as hallux valgus, hallux varus, hallux rigidus and metatarsus adductus constitute the majority of foot deformities. It is thought that these deformities are directly or indirectly caused by the first metatarsal bone being longer or shorter than normal (2). While the reaction force in the metatarsophalangeal joint (MTPJ) is approximately 80% of the body weight in the pushing phase of gait, the load on the big toe in the heel rise phase corresponds to twice that of the other toes (3). This situation reveals that, first metatarsal bone is more prominent orthopedically and clinically in force transmission of the foot. Because morphometric factors such as the length and width of the first metatarsal bone, the width of the proximal and distal articular surfaces and the shape of the metatarsal head may disrupt the normal orthopedics of the foot as a deformity factor (4-6). As a result, it does not only cause deformities in the foot, but also causes many health problems by disrupting the holistic structure of the foot.

It is known that the diameters of the proximal and distal joint surfaces are important in the pronation of the metatarsal, and they also play an active role in the deformities that may occur with the effect of the muscles (7). In particular, the angulation of the proximal joint diameter with respect to the first metatarsal shaft and the role of this angle in the pathology of the first metatarsal are not clearly defined. The shape of the distal articular surface of the first metatarsal bone, which varies from flat or round to chevron, is believed to be a contributing factor to the hallux valgus deformity. Theoretically, the round head is considered the least stable, while the flat and zigzag head is more resistant to lateral displacement of the proximal phalanx over the metatarsal head (8).

Extremely long or short first metatarsal bone compared to second metatarsal bone has also been associated with these deformities, especially hallux valgus (9,10). In the literature, it is thought that the joints and muscles to which first metatarsal bone is attached, rather than its pure bone structure, are important in foot clinic (11). However, there are biomechanical studies state that the causes of deformities are not due to the excessive length or shortness of the first metatarsal bone alone, but to the shape of the metatarsal head, morphological features of the inserting muscles, or their medial protrusion (12,13).

With this viewpoint; we think that proximal and distal head of first metatarsal bone, distal head shape, also the tibialis anterior and the peroneus longus muscles which attach to its proximal part, also play role in the foot clinic by affecting the metatarsal. The aim of this study was to determine the length, width and articular surfaces of the first metatarsal bone in the anatomical position; to reveal the attachment sites and distances of peroneus tertius and tibialis anterior tendons attached to the metatarsal and to determine the relationships between them, also to examine the relationship between head shape and other morphometric features of first metatarsal bone.

Material and Method

Study place and design

This research was carried out as a result of the colloborative work of the Anatomy and Orthopedics Departments at Kahramanmaraş Sütçü İmam University.

Ethic approval

Permission was obtained from Kahramanmaraş Sütçü İmam University Ethics Committee for Non-Pharmaceutical Practices. (2013/12-5).

Dissection

This study was performed on 32 (12 female-20 male; age range 40-65 years) lower extremities which were amputated for ischemic reasons and had no congenital structural anomalies. After measuring the length and width of the foot, fine dissection was performed starting from the anterior and posterior of the leg, without damaging the tendons of tibialis anterior and peroneus longus muscles, to expose the dorsal and plantar aspects of the foot **(Figure 1).** All samples were sealed in airtight plastic bags and stored in a frost-free freezer (-20 °C). The samples were thawed at room temperature (+20 °C) 1 day before the process. After the skin was lifted, dissection of the peroneus longus and tibialis anterior was performed and the attachment sites to the first metatarsal bone were exposed. After the necessary measurements were made in the neutral position, deep dissection of the first metatarsal bone and measurements of the bone were made.

Data collection

Firstly, the lengths of tibialis anterior and peroneus longus tendons up to the point of insertion, the distal extension of the muscle fibers, their distance from the lateral and medial malleolus levels, and the dimensions of the tendons at the thinnest part and at the insertion were measured. Then; the first metatarsal bone was dissected and removed from the foot skeleton. Major parameters measured after dissection was completed:

- Foot size (Length-Width)
- Tibia size
- First metatarsal bone size (Length-Width)
- First metatarsal bone head type
- Proximal tip size (Height Width)
- The length of the metatarsal
- Distal head size (Height Width)
- Thinnest part size (Height Width)
- Diameter of the proximal articular surface
- Diameter of the distal articular surface
- Peroneus longus (PL) and Tibialis anterior (TA) tendon length
- Diameter of PL and TA tendon in origo, insertio and level of Tibiotalar Joint (TTJ)
- Distance of muscle fibers to insertion

Statistical analysis

After all measurements were made, statistical analyzes were performed in SPSS 15.0 for windows. Descriptive statistics were given as arithmetic mean ± standard deviation. Parametric tests were applied due to normal distribution (Independent t test). For the correlation analysis, Pearson correlation was performed and the significance levels were evaluated. Significance level was accepted as $p<0.05$.

RESULTS

Study groups were divided according to their gender and right-left distinction. Subsequently, foot lengths, foot widths, tibia and first metatarsal bone lengths were measured. Mean values obtained were as follows; tibia length 34.3 cm, foot length 21 cm, foot width 8 cm and first metatarsal bone length 5.6 cm for women, and tibia length 37.5 cm, foot length 24.5 cm, foot width 8.7 cm, and first metatarsal bone length 6 cm for men **(Figure 2).** It was observed that the right side was statistically larger than the left side in both genders, and there was a positive correlation between the length of the first metatarsal bone and tibia length (medium correlation), foot length and foot width (high correlation) ($p<0.05$). No correlation was found between the right and left sides, also between tibia length and foot length ($p>0.05$).

Morphometric results of first metatarsal bone

The results of the measurements obtained from the first metatarsal bone are shown in **Table 2**. In both genders, the proximal end size was larger than the distal head size, and the proximal articular surface size was larger than the distal articular surface size. Metaphyseal dimensions were taken from 1.5 cm distal to the proximal end, and distal metaphyseal dimensions were taken from 1.5 cm proximal to the distal end. While no difference was found between the proximal and distal metaphyses in women, it was observed that the distal metaphysis size was larger than the proximal in men. It was measured that the PL tendon was attached to an average of 9.1 mm proximal in women and 10.5 mm proximal in men, while the TA tendon descended from 12.7 mm proximal to distal in women and 13 mm proximal to distal in men **(Table 2).** Metatarsal length and foot width were found to be correlated. According to the correlation results between first metatarsal bone and related parameters **(table 2)**, there were correlation;

- Between metatarsal length and foot length (r=.426, $p<0.05$),
- Between proximal head height and foot length (r=.375, $p<0.05$),
- Between the thinnest ground width and metatarsal length (r=.391, $p<0.05$) and proximal head width (r=.544, $p<0.01$),
- Between the thinnest ground height and metatarsal length (r=.369) and proximal head height (r=.509),
- Between distal head height and foot length (r=.579, $p<0.01$), foot width (r=.463, $p<0.05$), metatarsal length (r=.403, $p<0.05$), and the thinnest ground height (r=,416, $p<0.05$),

- Between proximal joint surface diameter and foot length (r=.470, *p<0.05*), metatarsal length (r=.563, *p<0.01*), proximal head width (r=.419, *p<0.05*), proximal head height (r=.559, p<0.05),
- Between distal articular surface diameter (r=.396, *p<0.05*), foot length (r=.576, *p<0.01*), metatarsal length (r=.570, *p<0.01*) and distal head height (r=.468, *p<0.01*),
- Between head shape and tibia length (r=.39, *p<0.05*), metatarsal length (r=-0.19, *p<0.05*), thinnest ground elevation (r=.363, *p<0.05*)

Head shape results of first metatarsal bone

First metatarsal bone was found to be round-headed in 40.6% (13 individuals; 7 males 6 females), dome-shaped in 28.1% (9 individuals; 6 males 3 females) and had a flat head in 32% (10 individuals; 7 males 3 females) of the legs (Figure 3). As a result of the statistical analysis, using the Pearson correlation test, it was observed that there was a statistically negative level correlation between head shape and metatarsal length *(p<0.05*). One of the most striking statistical results regarding the head shape of the first metatarsal bone was that it showed a tight relationship with the dimensions of the PL tendon at the insertion point. In other words, the dimensions of the PL tendon are also effective in shaping the head of the metatarsal bone (*p<0.05*).

Relationship of PL and TA tendon Findings with First Metatarsal bone

In order to reveal the relationship of the PL and TA muscles with the first metatarsal bone; the tendon lengths of the muscles and tendons, the distance of the muscle fibers to the insertion, and the dimensions of the tendons at the insertion and TTJ level were measured, as shown in **Table 1**. The mean tendon length of PL was found to be 30.4 cm in women, 32 cm in men, and the mean tendon length of TA was found to be 20.3 cm in women and 20.6 cm in men. The mean size of the PL tendon at insertion was 10.2x4.4 mm in women, 9.2x4.5 mm in men, and the mean size of the TA tendon at insertion was 10.7x3.8 mm in women and 12.3x5.1 mm in men **(Table 3).**

It was observed that the dimensions of the PL muscle, the tendon at the insertion site, and the dimensions of the tendon at the TTJ level were larger on the left side in women, but there was no significant difference between the right and left sides in men. In the statistical analysis, no difference was found between male-female or right-left sides (*p>0.05*).

Although the PL and TA muscles were located in different parts of the leg, tendon lengths and sizes were related to each other. At the insertion points, both the place of attachment on the first metatarsal bone and their distance from the proximal end of the first metatarsal bone were related to each other.

It was observed that there was a significant correlation between the tendon lengths of PL and TA (r=0.48, *p<0.01*). In addition, a negative correlation was found between the lengths of the PL and TA tendons and their width at the TTJ level (r=-0.34, *p<0.05*). In other words, as the length of the tendon increased, the width at the level of the tibiotalar joint decreased. There was also a close correlation between the width at the insertion points and the width at the TTJ level (r=0.40, *p<0.01*). There was a negative correlation (r=-0.469, *p<0.05*) between foot width and PL tendon **(Table 4)**.

Table1. Results of informative parameters (proximal and distal head) from first metatarsal bone, Length of PL and TA tendon

Gender	Side	P 3D (mm)	Dimension of thin place (mm)	D head dimension (mm)	P metaphysical dimension (mm)	D metaphysical dimension (mm)	P articular surface dimension (mm)	D articular surface dimension (mm)	PL tendon distance (mm)	TA tendon distance (mm)
Female	**right**	26x22	14x15	22x21	20x18	20x19	27x15	19x20	9.3	13.5
	left	25x19	14x13	21x20	19x17	19x18	25x14	18x17	9	12
mean		25.5x 20.5	14x14	21.5x20.5	19.5x17.5	19.5x 18.5	26x14.5	18.5x 18.5	9.1	12.7
P		0.98	0.12	0.23	0.54	0.09	**0.04**	0.10	0.91	0.08
Male	**right**	30x22	15x15	24x25	23x20	25x23	29x16	23x20	13	14
	left	30x22	15x15	23x25	18x17	24x23	31x16	25x18	8	12
mean		30x22	15x15	23.5x25	20.5x 18.5	24.5x23	30x16	24x19	10.5	13
P		0.23	0.67	0.09	0.03	0.14	0.07	0.03	0.04	0.09

Test: Independent t test, p<0.05 P: Proximal, D: Distal, PL: Peroneus longus, TA: Tibialis anterior

Table 2. Correlation between informative parameters of First metatarsal bone

	FL	FW	TL	MTL	PTW	PTH	Th PW	Th PH	DH W	DHH	TA TL	DP AS	PAS H	DD AS	DA SH
FL	1.00														
FW	.33	1.00													
TL	.04	-.19	1.000												
MTL	.13	.42*	.026	1.00											
PTW	.22	.08	.129	.19	1.00										
PTH	.37*	.28	-.072	.28	.16	1.00									
ThPW	.25	-.00	.238	.39*	.54**	.28	1.00								
ThPH	.19	.19	.107	.36*	.34	.50**	.38*	1.00							
DHW	-.02	-.21	.177	.25	.59**	.25	.49**	.22	1.00						
DHH	.57**	.46**	.211	.40*	.26	.34	.26	.41*	.06	1.00					
TATL	.00	.04	.399	-.19	-.12	-.05	.07	-.12	.16	.32	1.00				
DPAS	.30*	.47**	-.125	.56**	.49*	.47**	.35*	.55**	.16	.53**	-.39	1.00			
PASH	.235	.32	-.42*	.19	.00	.40*	.24	.04	.17	.11	-.40	.46**	1.00		
DDAS	.39*	.57*	-.081	.57**	.21	.28	.13	.27	-.09	.46**	-.33	.75**	.36*	1.00	
DASH	.08	.01	.317	.226	.41*	.11	.39*	.28	.40*	.20	-.18	.19	.21	.19	1.00
HT	.39*	.18	.39*	-.19*	.20	.22	.28	.36*	.22	.32	.04	.31	.01	.14	.23

Aberrations: *$p<0.05$ P: Proximal, D: Distal, PL: Peroneus longus, TA: Tibialis anterior, FL:* Foot length, FW: foot width, TL:Tibia length, MTL: Metatars length, PTW: Proximal tip Width, PTH: Proximal tip height,ThPW: Thinnest part Width, ThPH: Thinnest part height, DHW: Distal head Width, DHH: Distal head height, TATL: TA tendon length, DPAS: Diameter of proximal articular surface, PASH: P articular surface height,DDAS: Diameter of the distal articular surface, DASH: D articular surface height, HT: Head type

Table 3. Averages of the data obtained from the measurements made in PL and TA tendon, according to sex

Gender	Side	Length of tendon (cm)		Distance of muscle fibers to insertion (cm)		Size of tendon at insertion (mm)		Tendon size at TTJ level (mm)	
		PL	TA	PL	TA	PL	TA	PL	TA
Female	**right**	27±5	19.7±3	20.4±3	13.3±2	9.3x4.3	11.1x 3.3	9.1x 3.7	9.1x3.6
	left	33.5±2	21±0.8	23.8±0.2	13.8±0.2	12.6x4.6	9.3x5.3	12.3x 4.3	7.6x3.8
Total mean		30.4±7	20.3±5	22.1±5	13.5±0.2	10.2x4.4	10.7x3.8	9.9x3.8	8.8x3.7
p		0.13	0.76	0.61	0.22	0.10	0.09	0.12	0.09
Male	**right**	32±5	20.2±4	19.9±3	11.75±1	9.5±1 x 4.4±0.9	12.6x4.7	9.2x3.9	8.6x3.7
	left	32±2	21.1±2	22.2±3.6	13.0±2	9x4.6	12x5.6	9.3x3.6	8.5x4
Total mean		32±6	20.6±4	21.5±3.6	12.3±1.8	9.2x4.5	12.6x5	9.2x3.7	8.5x3.6
p		0.15	0.56	0.77	0.31	0.20	0.11	0.09	0.13

Aberrations: *Test: Independent t test, $p<0.05$* TA: Tibialis anterior, PL: Peroneus longus, TTJ: Tibiotalar joint AO±SD

Table 4. Relationship between the PL and TA tendons properties and metatarsale I bone morphology

	FL	FW	TL	MTL	DPAS	DD AS	HT	TADT ATO	PLTD TTJL	TATD TTJL	DPLTİ	DTATİ	LP LT
MTL	.154	.439*	-.095	1									
DPAS	.400*	.522**	-.292	.580**	1								
DDAS	399*	.581**	-.290	.554**	.670**	1							
HT	.382*	.210	.258	.199	.341	.154	1						
DTATO	-.183	-.069	-.345	.239	.115	-.067	-.193	1					
PLTDTTJL	-.127	-.387*	-.035	.119	-.201	-.161	-.164	.482**	1				
TATDTTJL	.103	.030	-.151	-.026	.128	.193	-.104	-.269	-.099	1			
DPLTİ	.533**	-.504**	-.123	.009	-.297	.231	.176	-.391*	-.221	.002	1		
DTATİ	.105	.203	.226	-.007	.400*	-.163	.086	-.180	.341	.187	-.137*	1	
LPLT	.020	.110	-.46	.081	-.022	.134	.677	.102	-.34*	.309	.099	.056	1
LTAT	.125	.172	-.26	.314	.256	.678	.812	.400*	.211	-.34*	.122	.78	.48*

Aberrations:*$p<0.05$ P: Proximal, D: Distal, PL: Peroneus longus, TA: Tibialis anterior FL:* Foot length, FW: foot width, TL:Tibia length, MTL: Metatars length, DPAS: Diameter of proximal articular surface, DDAS: Diameter of the distal articular surface, HT: Head type, DTATO: Diameter of TA tendon in origo, PLTDTTJL: PL Tendon diameter at TTJ level, TATDTTJL:TA Tendon diameter at TTJ level, DPLTİ: Diameter of PL tendon in insertion, DTATİ: Diameter of TA tendon in insertion, LPLT: Length of PL tendon, LTAT: Length of TA tendon

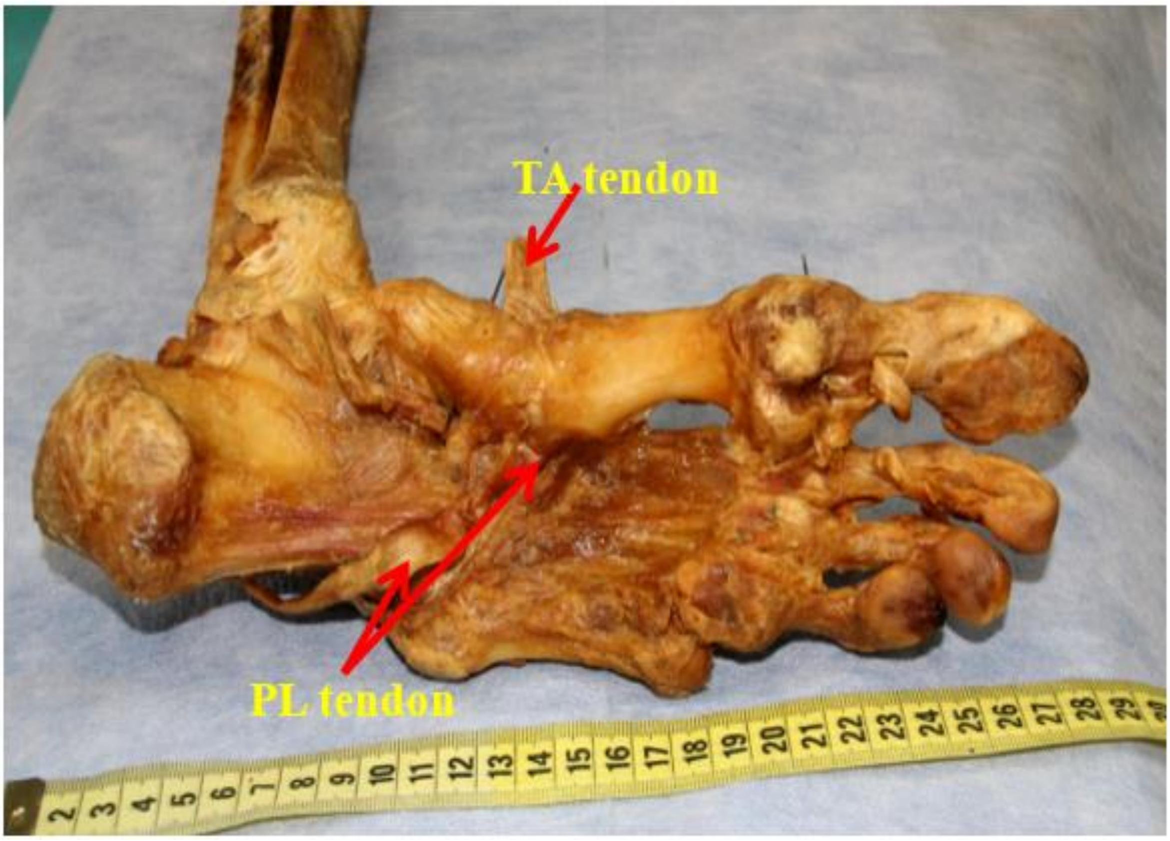

Figure 1: Deep plan view of the foot from the plantar face. The PL tendon was exposed by lifting the muscle and fascia on the plantar aspect of the foot. (TA: Tibialis anterior PL: Peroneus longus)

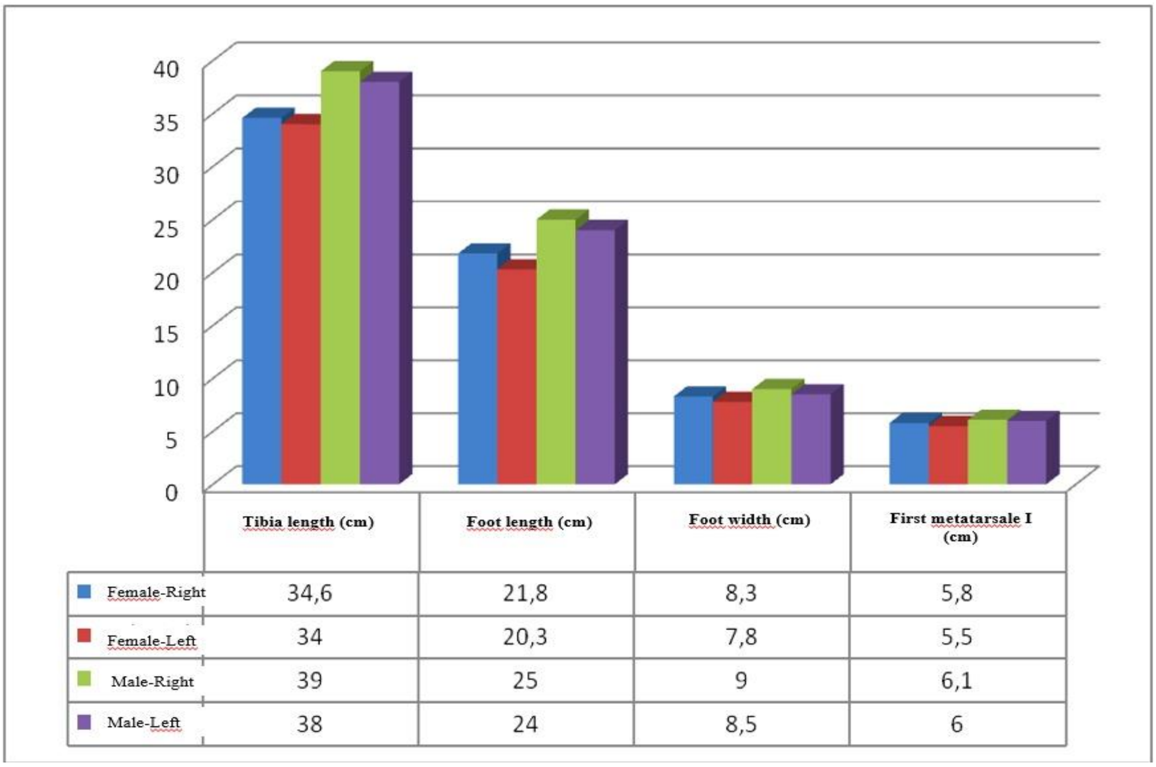

Figure 2. Comparison of Tibia, Foot length, Foot width and First metatarsal bone

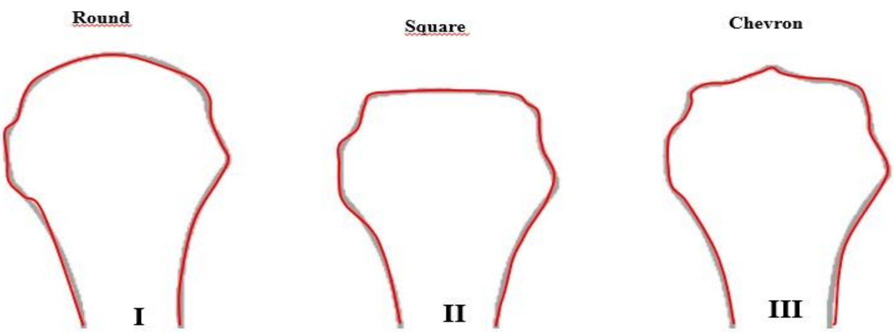

Figure 3: First metatarsal bone head shapes

Disscussion

Our first parameter of clinical significance of first metatarsal bone was its longitudinal length. Because in various studies, it has been stated that the first metatarsal bone being shorter or longer than normal plays a role in the etiology of hallux valgus (14). In studies on metatarsal shortness, it has been reported that the short metatarsal may cause difficulty in standing and walking due to the insufficiency of the metatarsal arch. Recent advances in orthopedic surgery have already shown that any defect in the feet, especially shortness, can be corrected with improved surgical techniques. Some investigators have reported that the pain and cosmetic problem caused by brachymetatarsia can be relieved by lengthening the short metatarsal and thus satisfactory results can be obtained (15,16). In our study, the length of the first metatarsal bone was determined with the help of the line drawn perpendicular to its longitudinal axis passing through the most extreme point of the proximal and distal ends and the diaphysis/metaphyseal intersection (17). Beeson et al. (2009) reported the mean length of the first metatarsal bone as 6.0 cm in their study in which they performed the radiological evaluation of hallux rigidus on 180 individuals aged between 18 and 70 (18). In a similar study; Coughlin et al. (1999) measured the mean length of the first metatarsal bone as 6.3 cm (19). In the study of Doğan et al. (8.89±0.79 mm in men and 7.83±0.72 mm in women) the first metatarsal was found to be the shortest (13). Abdel et al. reported the mean length of this bone as 5.11 cm in women and 6.4 cm in men (20). In our study, the mean length of the first metatarsal bone was found to be 5.6 cm in women and 6 cm in men. Our results were found to be similar to the literature.

According to many researchers, long metatarsals cause metatarsus primus adductus and hallux rigidus as it will increase the pressure on the joint. Especially if it is longer than the second metatarsal, it is an important factor in the etiopathogenesis of hallux rigidus (21). Bryant et al. (2000) stated that there is a relationship between long metatarsal and tibia length (22). Mancuso et al. (2003) reported that a long first metatarsal would prevent the dorsiflexor ability of the first metatarsophalangeal joint since it is prevented from falling under the second metatarsal, and this may lead to functional metatarsus primus elevatus and subluxation of the first metatarsophalangeal joint over time (23). As a result of our statistical analysis based on these statements, we could not find any significant relationship between metatarsal length and tibia length, but we found a positive correlation between foot width and metatarsal length. As a result, it will be more vital to have data on metatarsal lengths, which will be more important for any surgical intervention. In addition, in procedures that require surgical shortening of the metatarsal, the amount of shortening is thought to depend on the length of the metatarsal and the articular surfaces (24).

While the proximal articular surface plays a decisive role for the metatarsophalangeal joint angle, the distal joint angle plays an active role in the transmission of power to the phalanxes (25). Brenner et al. (2003) examined the dimensions of the proximal and distal heads of the first metatarsal bone and found the mean proximal head size of the first metatarsal bone as 22x30 mm (26). They stated that there is no correlation between metatarsal heads and metatarsal or foot lengths in adults (26). We found the mean proximal tip size as 22x20 mm in women and 30x22 mm in men. However, in our results, there was a close relationship between proximal head articular surface and metatarsal length. The increase in the metatarsophalangeal angle, which is called the proximal metatarsal joint angle, causes an increase in the degree of hallux valgus.

Proximal and distal head size is associated with the proximal and distal articular surfaces, and it is known that the articular surface is the main factor that plays a role in the activity of the metatarsal. Because the size of the articular surface is effective on the pronation of the metatarsal, and the smaller the articular surface, the more restricted the movement of the metatarsal (27). El Said et al (2006) studied 478 metatarsal bones to examine the anatomical variations of first metatarsal bone. They examined the length and width of the bone, the middle region of the shaft, the proximal and distal joint angles. They stated that these angles were related to the proximal and distal head size (8). On the other hand, Coughlin (1999) reported that the proximal articular surface was correlated with the proximal head diameter, and also emphasized that as the area of the articular surface in the proximal and distal head increases, the metatarsal length may increase. Similarly, we determined that there is a positive correlation between proximal articular surface diameter and proximal head width, foot length and metatarsal length. We could not find a study in the literature that gives the relationship between head width and articular surfaces of first metatarsal bone with metatarsal and foot length.

Metatarsal shortening surgery is related to both metatarsal length and joint surfaces, and it has been reported that osteotomy of more than 6 mm will cause disproportionate load distribution in the joints (24). Therefore, we think that knowing the size and diameter of the joint surfaces is important in osteotomy surgery.

All the articles we identified state that the first metatarsal head has three types, and all authors associate each head type with the diagnosis of a foot pathology such as hallux valgus or hallux rigidus (28,29). Among the first metatarsal heads, the most common ones are round and then square ones (30). van Deventer et al. (2020) reported that the round shape was the most common (60.6%) and the chevron shape was the rarest (7.1%); They argued that reference values should be established in order to confirm the morphological typing of the head of first metatarsal bone and to defend its clinical use (29). In our study, first metatarsal bone was found to be round-headed in 40.6% (13 individuals; 7 men, 6 women), chevron in 28.1% (9 individuals; 6 men, 3 women), and had a flat (square) head in 32% (10 individuals; 7 men, 3 women). According to our results, there was a negative correlation between head shape of first metatarsal bone and metatarsal length. In other words, shortening of the metatarsal length was observed due to the change of the head of the first metatarsal bone from round to square. In a similar study, it was stated that as the metatarsal length increases, damage occurs in the MTPJ angle and the head shape becomes flat (18). In other words, it is believed that the round head of the first metatarsal bone is associated with the long metatarsal and predisposes to the development of hallux valgus deformity, whereas a square-shaped head resists deforming forces (10). In summary, long metatarsal and round metatarsal head shapes are risk factors for hallux valgus formation.

While explaining the etiology of hallux valgus, Mann and Coughlin argued that the flat or square metatarsal head is more resistant to the deforming forces caused by the use of shoes, while the round metatarsal head is more prone to the development of hallux valgus (19). In addition, one of the most striking results statistically regarding the head shape of first metatarsal bone in our study was that it showed a close relationship with the dimensions of the insertion point of the PL tendon. In other words, besides the angle of the metatarsophalangeal joint, the dimensions of the PL tendon are also effective in shaping the head of the metatarsal bone (31).

As a result of our study, we found that the length of the PL tendon also affects the metatarsal length, and that the distance of attachment of the PL tendon to the first metatarsal bone and the size of the place where it is attached can affect both the length of the metatarsal and the diameter of the proximal articular surface directly. The size of the TA tendon at insertion increased in direct proportion to the diameter of the distal articular surface. We also believe that it is necessary to know how many cm the PL and TA tendons extend to the distal of the first metatarsal bone and their diameters at the insertion. Because, the larger the PL insertion tendon is and the more distally it extends, also the smaller the TA tendon and the more proximal it is, the greater the predisposition to metatarsus adductus and hallux valgus. In summary, TA pulls the metatarsal base medially and PL pulls laterally to balance each other.

Conclusion

In conclusion, we think that the length, proximal and distal articular surfaces and dimensions, also head shape of the first metatarsal bone are important factors in the development of foot deformities. Although various external deforming forces disrupt the medial arch and cause pain and deformities in the foot, we think that many foot deformities can be corrected if the dimensions of the PL and TA tendons at the insertion point and their relationship with the first metatarsal bone are precisely determined. Thus, it will be possible to detect feet at risk in terms of deformities such as hallux valgus, hallux varus, hallux rigidus in the early period and take precautions. When PL and TA muscles are evaluated biomechanically in selected clinical cases, we think that the results will confirm the anatomical data of our study.

Study Limitation

The small number of samples in the study and the inability to confirm the results biomechanically constitute the most important limitation of the study.

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