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The peroneus brevis tendon at its insertion site on fifth metatarsal bone

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ABSTRACT

Background: The differences at the attachment site of peroneus brevis (PB) to the fifth metatarsal bone is important in terms of the forces exerted on the bone and hence the mechanism of fractures involving this structure. In this study, we investigated the anatomical properties of PB at the insertion site to the base of fifth metatarsal bone, its possible intertendinous connections with peroneus tertius (PT) and their possible effects on the fracture occurrence at the bony attachment site.
Methods: The length and the width of PB tendons at their mid- and end-points were measured and classified according to the insertion types. Besides, the length and the width of the base of fifth metatarsal bone were assessed. The slips extending from the PB tendons and their relationship with PT were also evaluated. The data was compared statistically with each other and between the right and left sides.
Results: The length of PB tendon was measured 79.57 ± 15.40 mm on the right side; 81.48 ± 14.31 mm on the left. The width of PB tendon at the mid-point was 4.46 ± 0.80 mm on the right side; 4.42 ± 0.94 mm on the left. The width of the tendon at its insertion point was measured 14.85 ± 3.40 mm and 15.16 ± 3.42 mm on the right and left sides respectively. PB was divided into three types according to its attachment to base of fifth metatarsal bone (5thMB). Type I, Type II and Type III were observed at the rates of 59.5%, 28.6% and 11.5% respectively. It was observed that the slips to the bone were extending more commonly from PB than from PT and that the large majority of them were single having their insertions on the base of the proximal phalanx of the fifth toe.
Conclusions: Knowing the width and insertional types of PB aids in understanding the mechanism of fractures at the site of bony attachment. The existence of slips may help the surgeon in the procedures involving PB or the lateral side of the forefoot.

1. Introduction

The anatomy of the PB tendon at its insertion site on the base of fifth metatarsal bone (MB) is important in terms of surgeries involving lateral side of the foot [1,2]. Peroneal (fibular) muscles are the ones running in the evertion motion of the foot. Peroneus brevis (PB) has its insertion on the base of the fifth MB. It is known that intensive contractions of the muscles and sudden and severe motions of the extremities may lead to avulsion fractures at the attachment sites of tendons. Avulsion fractures of the base of fifth MB are among the frequently encountered fractures in orthopedic practice.

Here, we aimed to study the detailed anatomy of the PB tendon at its insertion area on the base of fifth MB in cadavers and we aimed to discuss its clinical importance for to determine the possible etiological factors of avulsion fracture. The PB tendon has also been analyzed on MR imaging in a limited number of patients with fractures located at the base of fifth MB to evaluate which the tendon type is more likely to be associated with these fractures.

2. Materials and methods

2.1. Anatomy

A total of 45 lower extremities of the cadavers fixed by 10% formalin were included in the study. Both sides of lower extremities of 17 cadavers (male 15, female 2; years of 64–78;

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Table 1
The measurements attributed to the PB tendon in whole embalmed cadavers.

Case number	Gender	Right			Left			Case number	Gender	Right			Left		
		Width at insertion	Length	Width of tendon proper	Width at insertion	Length	Width of tendon proper			Width at insertion	Length	Width of tendon proper	Width at insertion	Length	Width of tendon proper
1	M	14.58	109.66	3.91	18.09	106.17	3.44	10	M	16.66	94.48	5.02	15.94	91.75	3.71
2	M	14.22	106.41	5.53	15.12	97.85	4.66	11	M	16.79	80.34	3.93	15.99	76.47	4.26
3	M	22.18	96.26	4.71	23.22	96.82	4.82	12	M	16.18	83.30	3.69	20.69	79.80	5.17
4	F	13.95	62.68	5.75	13.10	55.01	5.43	13	M	19.19	84.80	5.13	18.40	79.32	4.78
5	M	12.54	81.62	4.08	16.36	93.83	6.14	14	M	12.63	67.97	5.28	12	57.47	3.76
6	M	13.09	78.02	4.64	13.88	84.03	4.70	15	F	8.40	73.39	3.29	10.03	80.46	2.93
7	M	15.81	57.94	6.19	12.42	62.22	4.98	16	M	13.04	90.23	4.12	15.37	96.00	5.12
8	M	23.01	84.18	4.81	19.20	88.92	4.74	17	M	15.71	77.84	4.93	[a]	[a]	[a]
9	M	13.55	89.66	4.83	13.31	90.80	5.96								

[a] The sides which could not be measured.

mean age 67) and 11 isolated lower extremities of with an unknown age and sex were included in the study.

There was no recorded history of trauma at the time of the death of the cadavers. No structural impairment or pathology related to the bones or soft tissues were observed. An incision was made from the level of the lateral malleolus of the cadavers toward the level of the fifth metatarsophalangeal joints. Dissection was advanced following the tendons and ended on reaching the attachment of the PB on the bone. Owing to the importance of the slips in the orthopedic practice, we also made the morphometric analysis of these structures.

The measurements were made from the following points:

1) The widest part of the tendon of PB (PBiw) at its insertion: the distance between the tip of the base of fifth MB and the most medial attachment side of the tendon.
2) The tendon length from musculotendinous junction to the insertion site (PBtl) [3].
3) The width of the PB tendon at its mid-point (PBtw).

3. Imaging

For five patients (three males, two females; years of 32–55; mean age 45) of whom the base of fifth MB fractures was identified on their radiographies, magnetic resonance (MR) imaging (1,5 T, Siemens, Sonata) was planned. The images were obtained with T2-weighted (TR/TE = 3573/70) fast spin-echo and T1-weighted (TR/TE = 500/17) fast spin-echo sequences for to evaluate the integration of the PB tendons and their structure at the attachment site on the bone.

Table 2
The measurements attributed to the PB tendon in isolated limbs.

Case number	Gender	Side	Width at insertion	Length	Width of tendon proper
1	M	Right	9.87	97.19	4.09
2	[a]	Right	14.09	64.29	3.29
3	[a]	Right	11.21	78.18	4.01
4	M	Right	11.84	52.01	4.94
5	M	Right	16.18	79.69	3.75
6	[a]	Right	13.56	63.92	3.27
7	[a]	Right	17.40	55.74	3.90
8	M	Left	13.30	76.74	3.14
9	[a]	Left	13.70	82.48	2.86
10	F	Left	9.79	63.22	4.07
11	[a]	Left	13.14	70.28	3.81

[a] Cases with gender unknown to the department.

4. Results

The measurements related to the PB which were taken on the cadavers were shown in Tables 1 and 2. The mean values of the measurements, the classification related to the attachment of the tendon and the cases with slips were displayed in Tables 3–5.

We have classified the tendon insertion characteristics of the PB as shown in Table 4a (Figs. 1 and 2).

In 13 of 45 lower extremities (8 right, 5 left) a single slip and in five of 45 lower extremities (2 right, 3 left) a double slip was observed. According to this evaluation, the average widths and

Table 3
The highest, the lowest, means and standard deviation results of the measurements performed.

Parameters	Side	The highest value (mm)	The lowest value (mm)	Mean value (mm)	Standard deviation
PBiw	Right	23.01	8.40	14.85	3.40
	Left	23.22	9.79	15.16	3.42
PBtl	Right	109.66	52.01	79.57	15.40
	Left	106.17	55.01	81.48	14.31
PBtw	Right	6.19	3.27	4.46	0.80
	Left	6.14	2.86	4.42	0.94

Note: PBiw: the widest part of the tendon of PB; PBtl: the tendon length from musculotendinous junction to the insertion; PBtw: the width of the PB tendon at its mid-point.

Table 4
(A) The classification for the tendon of the PB. (B) Summary of the classification of the tendon of the PB according to the insertional properties.

(A)

TYPE		Right	Left	Total
I	Ia	10 (23.8%)	10 (23.8%)	20 (47.6%)
	Ib	3 (7.1%)	2 (4.8%)	5 (11.9%)
II	IIa	4 (9.5%)	3 (7.1%)	7 (16.7%)
	IIb	3 (7.1%)	2 (4.8%)	5 (11.9%)
III	IIIa	–	2 (4.8%)	2 (4.8%)
	IIIb	2 (4.8%)	1 (2.4%)	3 (7.1%)
				42 (100%)

(B)

Type	Right	Total	Left
Tip I	13	12	25 (59.5%)
Tip II	7	5	12 (28.6%)
Tip III	2	3	5 (11.9%)
			42 (100%)

Table 5
The measurements related to the slip tendons emanating the PB tendon.

Peroneus brevis						
Single slip			Two slips			
Side	Length (mm)	Width (mm)		Side	Length (mm)	Width (mm)
Left	76.94	2.35	1. slip	Right	64.52	1.93
Right	35.80	1.90	2. slip		96.61	1.57
Left	35.08	1.90	1. slip	Left	50.36	2.43
Right	93.64	0.87	2. slip		89.54	1.66
Left	96.95	2.54	1. slip	Right	37.28	1.83
Left	67.39	1.69	2. slip		63.30	1.90
Right	16.08	1.54	1. slip	Left	[a]	[a]
Right	72.49	1.95	2. slip		67.39	1.27
Left	75.88	2.35	1. slip	Left	21.90	1.90
Right	[a]	[a]	2. slip		74.89	1.23
Right	40.29	1.90				
Right	97.45	1.50				
Right	77.69	2.06				

[a] The cases which slip tendons could not be followed at the distal aspect.

lengths of the single slips on the right feet were 1.67 mm and 61.92 mm respectively. Same measurements on the left side were as 2.16 mm and 70.44 mm respectively.

The mean widths and lengths of the double slips on the right feet were 1.80 mm and 65.43 mm respectively while same parameters on the left feet were measured as 1.70 mm and 60.81 mm respectively.

In seven of the total 45 lower extremity (2 right, 5 left) intertendinous connection between PB and PT tendons was observed (Fig. 3).

On radiographs, the measured distances between the insertion points of PB and PT tendons on the metatarsocuboidal joints are shown in Table 6. The mean distances were measured as 8.53 ± 3.11 mm for the PB tendon and 11.09 ± 2.97 mm for the PT tendon (Fig. 4).

In all of the MR images (Fig. 4) the fractures were observed as a high intensity line on FS T2-weighted sequences and as a low intensity line on T1-weighted sequences. The PB tendons were seen as a single tendon with the normal hypointensity and continuity in all of the images. No slips could be identified as was defined in the cadavers.

5. Discussion

In previous studies it was reported that the length of the PB tendon was important in tendon transplantations and the rotational grafts needed in orthopedic surgical procedures [1,2]. In our study, the mean tendon length of the PB tendon was found to be 79.57 ± 15.40 mm on the right and 81.48 ± 14.31 mm on the left side.

Teng et al. [4] measured the width of the PB tendon as 2.8–6 mm (mean 4 ± 0.9 mm). In our study, the mean values for the width of the PB tendon was found to be 4.46 ± 0.80 mm on the right side and

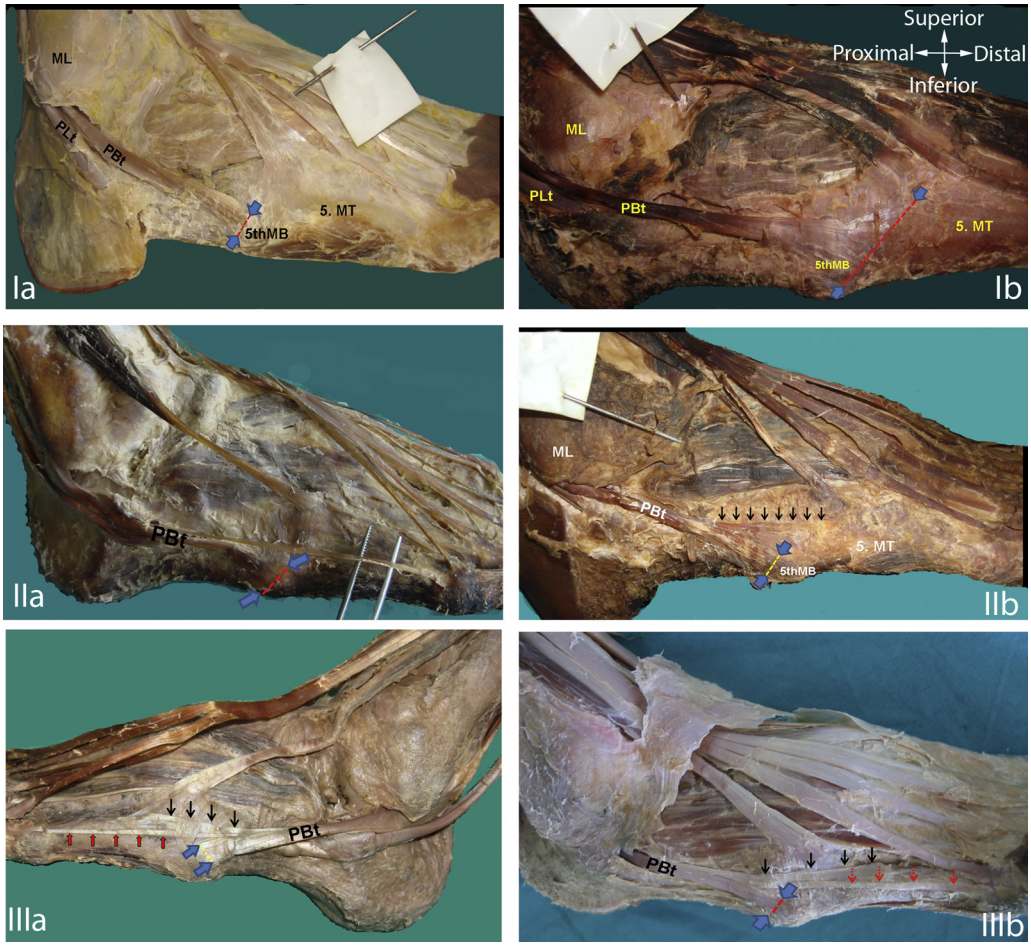

Fig. 1. The classification of the tendon insertion characteristics of the PB (peroneus brevis); Types Ia–IIIb; the interrupted lines among the ends of the blue arrows show the location where PB terminated; black arrows show the course of the slip tendon and its insertion to the fifth finger; red arrows show the course of slip tendon and its insertion to the basis of the fifth finger; 5. MT: fifth metatarsal bone; PBt: tendon of peroneus brevis; PLt: tendon of peroneus longus; ML: lateral malleol. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

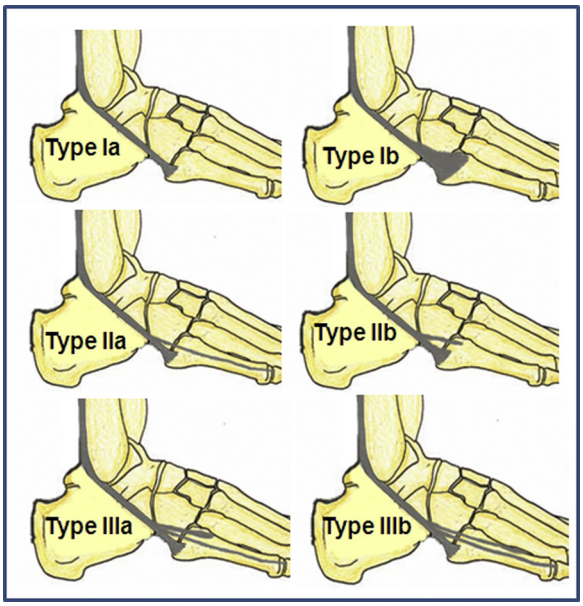

Fig. 2. Schematic drawing of the classification of the tendon insertion characteristics of the PB (peroneus brevis); Types 1a–IIIb.

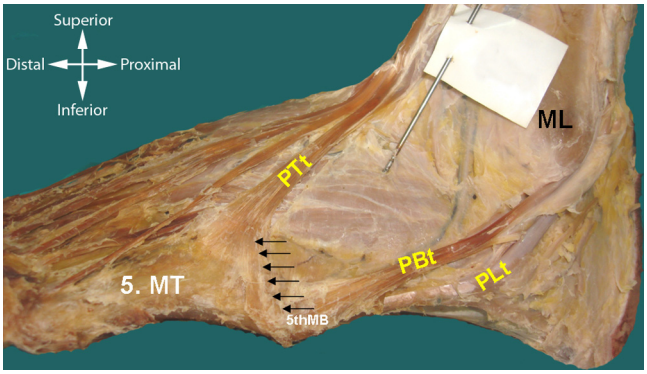

Fig. 3. Intertendinous connection between peroneus brevis and peroneus tertius tendons (black arrows); 5. MT: fifth metatarsal bone; PBt: tendon of peroneus brevis; PLt: tendon of peroneus longus; PTt: tendon of peroneus tertius; ML: lateral malleol.

Table 6
The distances between the insertion points of the ending tendons of the PB and PT tendons and the metatarsocuboidal joint.

Number of cadaver	Peroneus brevis (mm)	Peroneus tertius (mm)
1	8.74	10.68
2	8.91	16.63
3	11.79	11.82
4	3.90	9.25
5	12.26	6.30
6	4.13	11.70
7	8.56	12.50
8	9.95	9.87

4.42 ± 0.94 mm on the left side which were slightly higher than the ones Teng et al. [4] reported.

Theodorou et al. [5] expressed that the PB tendon was inserting to a wider area at the dorsolateral aspect of the base of fifth MB which was fourfold compared the diameter of the tendon proper. In our study, the mean width of the PB tendon at its insertion site was measured 14.85 ± 3.40 mm on the right side and 15.16 ± 3.42 mm on the left side. The ratio of the widths of the tendons at the

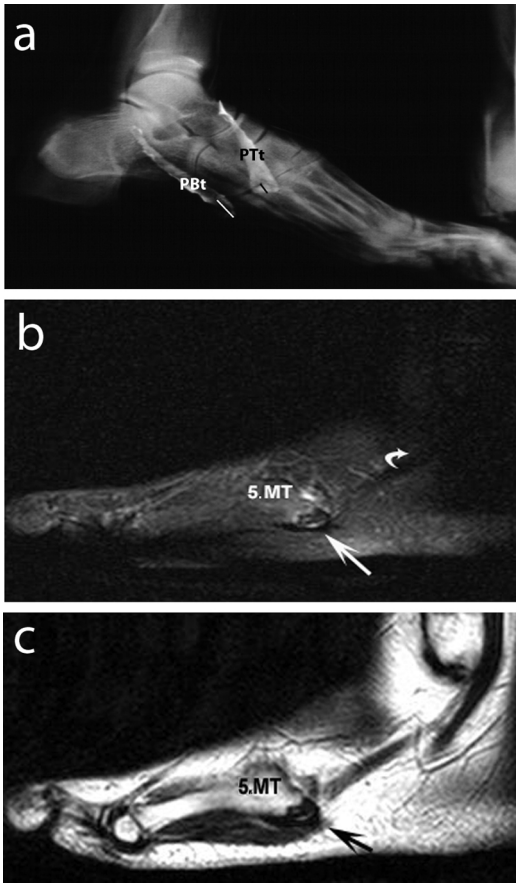

Fig. 4. (a) Oblique view X-ray graphy of right foot of the cadaver. Tendons of peroneus brevis and peroneus tertius stained by barium sulphate are well seen with their radioopacity. The lines drawn are the distances of the tendons measured at their mid points at the attachment site to the metatarsocuboid joint; 5.MT: the fifth metatarsal bone; PBt: tendon of peroneus brevis; PTt: tendon of peroneus tertius. (b, c) The left foot of a 45-years-old male patient on FST2-weighted image (b) and T1-weighted image (c). The tendon of peroneus brevis (curved arrow) is seen with its normal hypointensity on both sequences with the avulsive bony part (arrow). 5. MT: the fifth metatarsal bone.

insertion site to the tendon proper was found to be threefold, same ratio with what Theodorou et al. [5] has reported.

Raheja et al. [6] proposed that the slips might have a mechanical advantage enhancing the effectiveness of the muscles existing on the same route as the slips [6]. The existence of these slips was reported previously [7]. In our study, we observed one single slip from the PB tendons of 13 feet and two slips in five. Though the existence of these slips was reported previously, morphometrical analysis directed to this muscle tendon has not been studied in detail. In half of the cases of our study group, we observed slip tendons arising from the PB tendons. It was expressed that the slips terminating on the fifth toe not only helped in abduction and extension movements of the fifth toe but also played a role in transferring the evertion movement in subtalar joint toward the anterior part of the foot.

In his study, Testut [8] has classified the variations of the PB tendon as incomplete and complete. He reported that in incomplete type, the extra tendon was attaching to the metatarsal or tarsal bones and in complete type extending up to the phalanx. Here we studied the ending tendon of the PB in more detail. A classification was made based on the number of branches of the tendon at the insertion site. In our study; Type I, Type II and Type III cases were observed in the proportions of 59.5%, 28.6% and 11.5% respectively.

The bases of the metatarsal bones were supplied by arteries running toward the bases on the plantar and dorsal side with one to three branches in accordance to a previous study [8]. Interestingly, the nutrient artery seems to be dispensable for the head of the metatarsal bone, since despite its loss during these surgeries [9], the head seems rarely to develop avascular necrosis with other study. The fractures involving the base of fifth MB which is encountered frequently in daily routine of orthopedic practice may occur during foot injuries [5].

The avulsion fractures of base of fifth MB which generally occurs as a result of the compulsory inversion of the foot [10] is the most common type observed. Owing to the stretching of the tendon of the PB attaching to base of fifth MB, a bony part is separated [5]. In some of our cases we observed that, one part of the tendon of the PT was extending to base of fifth metatarsal bone and had intertendinous connection with the tendon of the PB. In these types of cases, we believe that in addition to PB tendon, the PT tendon may also have an additional effect to these kinds of fractures. In some of their cases with avulsion fracture, Theodorou et al. [5] observed the existence of the PT tendon fibers on those separated bones. This finding may also support that the PT tendon may also play a role in the mechanism of the separation fractures. It may be suggested that the narrow inserted tendons may apply more stress on the insertion site since the internal force applied on per unit area will increase when compared with a wider insertion area. Of course, the biological tissues may act in a different way and true validation of this general assumption on biological tissues needs further biomechanical study. The major limitation of our study is the material we used. Since our cadavers were fixed with formaldehyde, it was impossible to carry out a biomechanical study. But we believe that future biomechanical studies biomechanics may enlighten this issue.

According to Pao et al. [11] avulsion fractures do occur owing to the wide insertion of the PB tendon on the base of fifth MB. However, in our patient group, on MR images we observed that the PB tendons end in a narrow fashion on the base of fifth MB. This may lead the PB tendon to apply a strong pushing force on the base of fifth metatarsal bone during its contraction resulting in separation fractures. Further MR studies should be carried out and the number of the patients should be increased for further validation. We hope that our data can help for to plan a further study on this topic.

6. Conclusion

Our study is the detailed study to establish the detailed distal anatomy of the PB at its insertion site. Knowing the differences at the attachment site of the PB tendon on the base of fifth metatarsal bone is important in surgical procedures when this tendon is needed in transplantation or rotational grafting. We suggest that a narrowly inserted tendon may apply more stress since the internal force applied on per unit area will increase when compared with a wider insertion area. Increased stress may eventually lead a higher tension and may result in an increased risk of fracture.

Conflict of interest

The authors declare that they have no conflict of interest.

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