ANATOMIC VARIATIONS

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Morphological features of the bifurcated ligament

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Abstract

Introduction Damage to the bifurcate ligament is one of the most difficult injuries to diagnose from imaging techniques. A probable reason for this is that the morphological characteristics of this structure have yet to be sufficiently elucidated. We, therefore, endeavored to elucidate the morphological characteristics of the bifurcate ligament through a large-scale study involving numerous specimens.

Materials and Methods This study included 100 feet from 52 formalin-fixed cadavers. The bifurcate ligament was classified into three types: presence of both calcaneonavicular ligament and calcaneocuboid ligament (Type I); absence of calcaneocuboid ligament (Type II); and absence of calcaneonavicular ligament (Type III). Morphological characteristics of the bifurcate ligament were determined by measuring fiber bundle length, width, and thickness at the center of each ligament.

Results This classification resulted in 68 Type I feet (68%), 32 Type II feet (32%), and 0 Type III feet (0%). The calcaneonavicular ligament was 20.8 ± 2.9 mm long, 4.9 ± 1.2 mm wide, and 3.8 ± 1.1 mm thick. The calcaneocuboid ligament was approximately 10.5 ± 2.7 mm long, 4.7 ± 2.4 mm wide, and 1.5 ± 0.6 mm thick. The bifurcate ligament was located deep under the extensor hallucis brevis and extensor digitorum brevis muscles in all specimens. The calcaneal origin of the calcaneonavicular ligament was situated deep under the interosseous talocalcaneal ligament in all specimens. Two sides were identified in which the calcaneocuboid ligament was located deep under the dorsal calcaneocuboid ligament.

Conclusion Such variations and positional relationships were suggested to be factors complicating the diagnostic imaging of bifurcate ligament injuries. The present study results will likely form useful basic data for diagnostic imaging.

Keywords Calcaneocuboid ligament · Calcaneonavicular ligament · Gross anatomy

Introduction

Damage to the bifurcate ligament is one of the most difficult injuries to diagnose from imaging modalities [3]. One of the likely reasons for this is that the morphological characteristics of the bifurcate ligament have yet to be sufficiently clarified. Hovelacque and Sourdin (1933) [1] reported that the bifurcate ligament comprised the calcaneonavicular ligament and the calcaneocuboid ligament, with lengths of ~2–2.5 and 1 cm, respectively, and widths of ~1 and 0.5 cm, respectively. Kokturk et al. (1957) [2] investigated 40 feet, finding that 57.5% of specimens presented both calcaneonavicular and calcaneocuboid ligaments, while 40% lacked a calcaneocuboid ligament and 2.5% lacked a calcaneonavicular ligament. To the best of our knowledge, those are the only two reports to provide morphological data on the bifurcate ligament. We, therefore, believe that a large-scale, detailed morphological investigation using numerous specimens is essential to facilitate definitive diagnosis and to establish effective treatments for bifurcate ligament injuries.

This study endeavored to elucidate the morphological characteristics of the bifurcate ligament through a large-scale study of cadaveric specimens.

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Materials and methods

Cadavers

This investigation examined 100 legs from 52 Japanese cadavers (mean age at death, 79 ± 13 years; 55 sides from men, 45 from women; 51 right sides, 49 left sides) that had been switched to alcohol after placement in 10% formalin. None showed signs of previous major surgery around the foot or ankle or any relevant deformities. And, there was no prominent degeneration in all specimens. This study was approved by the Ethics Committee at our institution.

Methods

The dissection procedure for the bifurcate ligament is described below. One author (first author) dissected the bifurcated ligament alone. First, isolated specimens of the leg were created by transection 10 cm above the ankle. Skin, subcutaneous tissue, muscle/tendon, and leg fascia were subsequently removed, and the bifurcate ligament was carefully exposed. Based on a previous study, the bifurcate ligament was classified as follows: Type I, presenting both calcaneonavicular and calcaneocuboid ligaments; Type II, lacking a calcaneocuboid ligament; and Type III, lacking a lateral calcaneonavicular ligament. To assess the morphological characteristics of the bifurcate ligament, the length, width, and thickness of the fiber bundle were measured. Measurements were made at the center of the lateral calcaneonavicular

ligament and medial calcaneocuboid ligament using digital calipers (Shinwa Rules, Niigata, Japan). All measurements were performed by the same examiner.

Statistical analysis

A Chi-squared test was used to compare differences according to sex, laterality, and presence of the dorsal calcaneocuboid ligament between each type. Unpaired t testing was used to compare length, width, and thickness of the fiber bundle between and within each type. The level of significance was 5%.

Results

Classification of bifurcate ligament

Type I was seen in 68 feet (68%), Type II in 32 feet (32%), and Type III in 0 feet (0%) (Fig. 1). In the comparison between men and women, the type in men was Type I in 38 legs (69.1%), Type II in 17 legs (30.9%), and Type III in 0 legs (0%), and the type in women was Type I in 30 legs (66.7%), Type II in 15 legs (33.3%), and Type III in 0 legs (0%). No significant differences were seen between men and women. In determining differences between left and right legs, we were able to measure both legs from 48 cadavers (54 legs from 27 male cadavers, 42 legs from 21 female cadavers). In comparisons between left and right legs, the right leg was Type I in 32 legs (66.7%), Type II in 16 legs
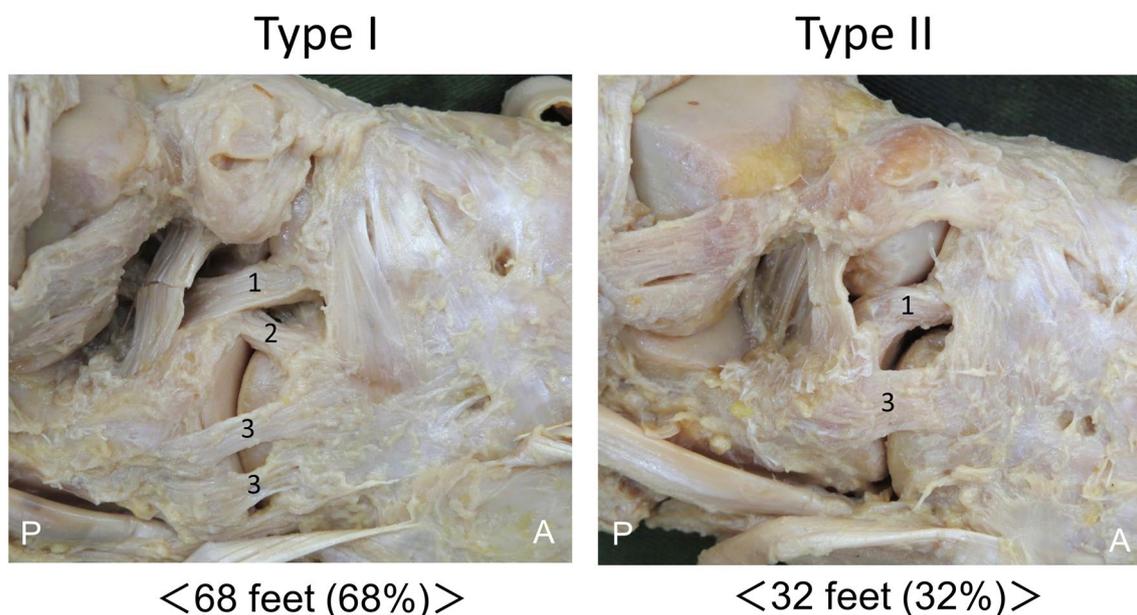

Fig. 1 Classification of bifurcate ligament. Type I: presence of both calcaneonavicular and calcaneocuboid ligaments. Type II: absence of calcaneocuboid ligament. (1) Calcaneonavicular ligament; (2) calcaneocuboid ligament; (3) dorsal calcaneocuboid ligament; *P* posterior; *A* anterior

Table 1 Measurements of the bifurcated ligament

	Length (mm)		Width (mm)		Depth (mm)	
	Calcaneona-vicular ligament	Calcaneo-cuboideum ligament	Calcaneona-vicular ligament	Calcaneo-cuboideum ligament	Calcaneona-vicular ligament	Calcaneo-cuboideum ligament
Type I	21.2 ± 2.9	10.5 ± 2.7[a]	4.9 ± 1.1	4.7 ± 2.4	3.8 ± 1.1	1.5 ± 0.6[a]
Type II	20.1 ± 2.7	–	5.0 ± 1.3	–	3.9 ± 1.0	–
Type III	–	–	–	–	–	–
Average	20.8 ± 2.9	10.5 ± 2.7	4.9 ± 1.2	4.7 ± 2.4	3.8 ± 1.1	1.5 ± 0.6

Values represent mean ± SD

[a] $P < 0.01$, vs. the calcaneonavicular ligament

(33.3%), and Type III in 0 legs (0%). The left leg was Type I in 32 legs (66.9%), Type II in 16 legs (33.3%), and Type III in 0 legs (0%). No significant differences were seen between the right and left legs. A dorsal calcaneocuboid ligament was present in 8 Type I feet (11.7%) and in 3 Type II feet (9.4%). No significant difference in frequency of a dorsal ligament was seen between Types I and II.

Morphological characteristics of the bifurcate ligament (Table 1)

The calcaneonavicular ligament was 20.8 ± 2.9 mm long, 4.9 ± 1.2 mm wide, and 3.8 ± 1.1 mm thick (mean values). The calcaneocuboid ligament was approximately 10.5 ± 2.7 mm long, 4.7 ± 2.4 mm wide, and 1.5 ± 0.6 mm thick (mean values). No significant differences between types were seen in measurements of the calcaneonavicular ligament. In addition, fiber bundle length and thickness were significantly greater for the calcaneonavicular ligament compared to the calcaneocuboid ligament in Type I feet.

Positional relationship of the bifurcate ligament (Fig. 2)

The bifurcate ligament was located deep under the extensor hallucis brevis and extensor digitorum brevis muscles in all specimens. The origin of calcaneonavicular ligament on the calcaneus was located deep under the interosseous talocalcaneal ligament in all specimens. Two sides were identified in which the calcaneocuboid ligament was situated deep under the dorsal calcaneocuboid ligament.

Discussion

In our study, 68 feet were classified as Type I (68%), 32 as Type II (32%), and 0 as Type III (0%). Although our study did not include any Type III feet (i.e., without a calcaneonavicular ligament), results for Types I and II were similar to previously reported findings [2].

Regarding morphological characteristics, no significant differences were seen between types in terms of measurements for the calcaneonavicular ligament. Moreover, although we hypothesized that the frequency of a dorsal calcaneocuboid ligament would be greater in Type II without the calcaneocuboid ligament than in Type I, we did not find any significant difference between types.

In our study, not all bifurcate ligaments presented two ligaments and 32% of examined specimens were classified as Type II, without a calcaneocuboid ligament. Moreover, the bifurcate ligament was located deep under the extensor hallucis brevis and extensor digitorum brevis muscles in all specimens. Furthermore, the origin of the calcaneonavicular ligament on the calcaneus was situated deep under the interosseous talocalcaneal ligament in all specimens and the calcaneocuboid ligament was located deep under the dorsal calcaneocuboid ligament in some specimens. Such positional relationships of the bifurcate ligament were considered as one factor complicating diagnostic imaging.

The results from this study will provide useful basic data for diagnostic imaging. In the future, in vivo studies based on the present study data will be necessary.
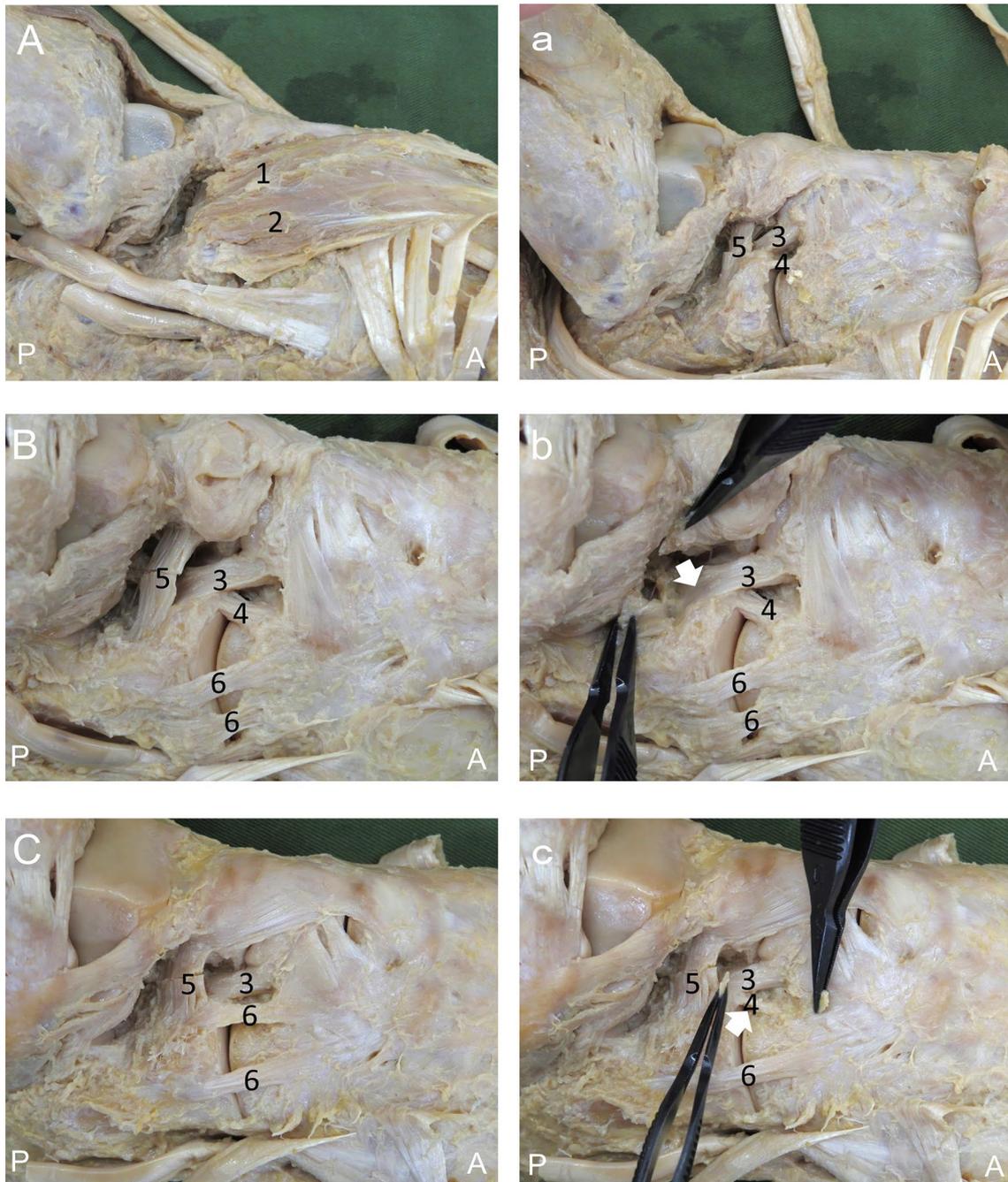
Fig. 2 Positional relationship of the bifurcate ligament. **A, a** Extensor digitorum brevis and extensor hallucis brevis muscles are inverted, and the calcaneonavicular ligament and calcaneocuboid ligament are revealed. **B, b** The cervical talocalcaneal ligament is transected and inverted bilaterally, and the origin of the calcaneonavicular ligament (white arrow) is revealed. **C, c** The dorsal calcaneocuboid ligament is transected and inverted, and the calcaneocuboid ligament (white arrow) is revealed. (1) extensor hallucis brevis muscle; (2) extensor digitorum brevis muscle; (3) calcaneonavicular ligament; (4) calcaneocuboid ligament; (5) cervical ligament; (6) dorsal calcaneocuboid ligament; *P* posterior; *A* anterior

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethics approval The methods were carried out in accordance with the 1964 Helsinki declaration and the cadavers were legally donated for the research by the Nippon Dental University of Life Dentistry at Niigata in Japan.

Informed consent Informed consent was obtained from the families of all subjects.

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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