Anatomical Characteristics of the Flexor Digitorum Accessorius Longus Muscle and Their Relevance to Tarsal Tunnel Syndrome

A Systematic Review

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Background: Clinical and cadaver studies have reported that supernumerary muscles could be the etiology of a variety of pathologic disorders, such as posterior impingement syndrome, tarsal tunnel syndrome (TTS), and flexor hallucis longus tenosynovitis. We describe a unique variant of the flexor digitorum accessorius longus (FDAL) muscle as an apparent cause of TTS, functioning as an independent flexor of the second toe, which has not been described in the literature. In addition to this case report, a systematic review was performed of TTS caused by the FDAL muscle.

Methods: A targeted search of PubMed, the Cochrane Library, the Cumulative Index to Nursing and Allied Health Literature, and Web of Science identified full-text papers that fulfilled the inclusion and exclusion criteria.

Results: Twenty-nine papers were identified for inclusion in the systematic review: 12 clinical papers of TTS caused by the FDAL muscle and 17 cadaver-based papers.

Conclusions: Clinicians often do not include the FDAL muscle in the differential diagnosis of TTS. This literature review suggests that the FDAL is an important muscle in terms of its functional and clinical significance. Knowledge of this muscle, its anatomical location and variations, and its magnetic resonance imaging characteristics may help clinicians make an accurate differential diagnosis. (J Am Podiatr Med Assoc 105(4): 344-355, 2015)

The existence of supernumerary or accessory muscles of the posteromedial compartment of the leg is well documented in the literature.[1-3] The most common accessory muscles in this region, such as the soleus accessorius, the low-lying flexor hallucis longus (FHL) muscle belly, the flexor digitorum accessorius longus (FDAL), the peroneus calcaneus internus, and the tibiocalcaneus internus, were described in the 19th century by many anatomists, including Meckel,[4] Wood,[2] and Testut.[3] These anatomists emphasized that clinicians were not always aware of or familiar with their existence despite their high incidence, which varies from 1% to 13%.[1,5]

Clinical and cadaveric studies have reported that these supernumerary muscles could be the etiology of a variety of pathologic disorders, such as posterior impingement syndrome, FHL tenosynovitis, and tarsal tunnel syndrome (TTS).[2-4,6] With the development of better imaging techniques and the subspecialization of orthopedic surgeons for foot and ankle pathologic disorders, an increase in the

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reported observation of foot and ankle accessory muscles has been noted in the literature.

The FDAL muscle is the most common accessory muscle reported in the medial aspect of the foot and ankle region.[7] It can originate from the medial margin of the tibia and the fascia of the deep posterior compartment, from the lateral margin of the distal part of the fibula and the origin of the FHL muscle, or from any structure of the deep posterior compartment, including adjacent muscles. This accessory muscle runs posteriorly and superficially to the tibial nerve and continues beneath the flexor retinaculum through the tarsal tunnel. This tunnel is an area of anatomical narrowing caused by tight ligamentous structures. It is a fibro-osseous tunnel bordered superficially by the flexor retinaculum, which passes obliquely from proximal to distal to anterior. The flexor retinaculum forms the roof of the tarsal tunnel, as well as the superior and inferior margins. The floor of the tunnel is formed by the medial wall of the talus and calcaneus and the distal medial wall of the tibia.[8,9]

In view of the fact that the FDAL muscle has a close relationship with the neurovascular bundle in the tarsal tunnel, it is not surprising that the presence of the FDAL is associated with TTS, defined in the literature as an entrapment neuropathy of the posterior tibial nerve or one of its branches in the tarsal tunnel.[9,10] In this systematic review, the etiology of TTS associated with the presence of the FDAL muscle is described, with emphasis on clinical testing methods, diagnostic imaging, and nonsurgical and surgical management.

Methods

Inclusion and Exclusion Criteria

Studies about TTS caused by the FDAL muscle published in English as full papers or case reports were considered in this systematic review. Cadaver studies were included to provide an accurate description of the anatomy of the FDAL muscle.

The following criteria were used to eliminate papers from this review: papers written in non-English languages, letters/personal opinions, and papers that did not report the anatomical characteristics of the FDAL muscle.

Search Strategy

The databases searched were MEDLINE via PubMed, the Cumulative Index to Nursing and Allied Health Literature, the Cochrane Library, and Web of Science (January 1990 to February 2013). Key words, selected from Medical Subject Headings terminology, were *foot* and *anatomy*. The search was narrowed by combining these terms with the following search strings: *tarsal tunnel syndrome*, *flexor digitorum accessorius longus*, *long accessory flexor muscle*, *accessory flexor digitorum longus*, *long accessory of the quadratus plantae*, *accessorius of the accessorius of Turner*, and *second accessorius of Humphrey*.

Two reviewers (T.L. and P.-A.D.) performed the online searches. References and abstracts of studies were stored alphabetically on separate worksheets. Examination of the reference list of each paper identified additional relevant papers.

Review Process

Duplicate references sourced from different electronic databases were removed. Two independent reviewers (B.D.B. and V.G.) undertook the inclusion and exclusion process based on the title and abstracts of the retrieved articles. A full-text evaluation was undertaken if the title and abstract did not provide adequate information. Finally, to affirm the inclusion of all eligible studies, one reviewer (P.-A.D.) manually screened the reference lists of the included studies.

Results

The initial search yielded 1,431 papers. After the exclusion of duplicate references, 29 published papers were included based on the abstract. Manual screening of the reference lists provided two additional papers. A total of 29 published papers were identified for inclusion in the systematic review[5,7,10-37]: 11 clinical papers of TTS caused by the FDAL muscle, 1 clinical study describing the anatomy of the FDAL muscle based on MRI scans, 1 clinical case in Appendix 1, and 17 cadaver-based papers. Tables 1 and 2 summarize the findings of these papers.

Incidence and Anatomical Descriptions of the FDAL Muscle

The FDAL muscle is an accessory muscle in the lower leg, the prevalence of which was reported as varying from 1.6% to 12.2%[20,32] based on cadaver lower-limb dissections. Kinoshita et al[16] surgically treated 41 patients (49 feet) with TTS. In six of these feet (12.2%), an FDAL muscle was identified as the cause of the TTS.[16]

Table 1. Summary of the Findings Regarding the Anatomical Descriptions of the FDAL Muscle in Association with TTS

Study	Year	Patients (No.)	Sex	Origin
Sammarco and Stephens[11]	1990	1	F	Medial aspect of the belly of the FHL
Buschman et al[12]	1991	1	NR	Various portions Tibia/fibula/interosseous membrane
Ho et al[13]	1993	1	M	Peroneus brevis near the cranial aspect of the tarsal tunnel
Sammarco and Conti[14]	1994	6	4 F/2 M	4 Tibia and deep fascia of the leg 2 Fibula and deep fascia of the leg
Burks and DeHeer[15]	2001	1	F	Posterior surface of the FDL tendon 3–5 cm superior to the distal tip of the medial malleolus
Kinoshita et al[16]	2003	6	3 F/3 M	3 Intermuscular fascia septum 2 Fascia of the FDL 1 Fascia of the FHL
Best et al[17]	2005	1	NR	Gastrocnemius-soleus complex
Wittmayer and Freed[7]	2007	1	F	Unknown
Duran-Stanton and Bui-Mansfield[5]	2010	2	M	Flexor retinaculum
Saar and Bell[18]	2011	1	F	Flexor retinaculum
Samaras[19]	2011	1	M	NR
The present case	2011	1	F	Soleus

Abbreviations: EMG, electromyography; FDAL, flexor digitorum accessorius longus; FDL, flexor digitorum longus; FHL, flexor hallucis longus; MRI, magnetic resonance imaging; NA, not applicable; NR, not reported; QP, quadratus plantae; TTS, tarsal tunnel syndrome.

The FDAL muscle can originate 1) from the upper third of the leg, inferior to the popliteal fossa, near the origins of the long digital flexors, or 2) in the lower third of the leg, close to the ankle joint.[20-27,30-37] In one cadaver study, the FDAL muscle was found to originate from the fascia overlying the popliteus muscle.[28] The origin of the FDAL muscle can be fleshy, tendinous, or aponeurotic. It can have a single-headed[22-25,27,28,31,32,34-37] or a double-headed[20,21,23,26,30,33] configuration.

The most common configuration of the FDAL muscle is a single head that originates from the tibia or the fibula bone, from the deep fascia of the leg, or a combination of both.[22-25,27,28,31,32,34-37] The most frequent site of origin in the reported studies seems to be the fibula (Table 2).

The double-headed FDAL muscle is composed of a long head originating in the upper third of the leg and a short head originating in the lower third of the leg. The long head has a similar configuration as the single-headed FDAL muscle and originates from either the tibial or fibular side, near the origins of the long digital flexor muscles. In all of the cadaver studies, the short head originated from the fibular side, a few centimeters above the lateral malleolus, except in the study by Holzmann et al,[30] in which the short head originated from the medial surface of the calcaneus.

In the tarsal tunnel, single- and double-headed FDAL tendons usually course posterior to the tendon of the FHL (Table 2). However, a few cadaver studies reported that the FDAL tendon passes anteriorly to the FHL tendon in the tarsal tunnel, between the flexor digitorum longus (FDL) and FHL tendons (Table 2). In some cases, the FDAL muscle enters the tarsal tunnel as a muscle belly, leaving as a tendinous slip,[20,24,29,31,36] which can cause TTS.

The FDAL has a muscular or tendinous insertion into the quadratus plantae or the FDL tendon before it divides into the four digital slips (Table 2). The

Table 1. extended

Tarsal Tunnel	Insertion	EMG	MRI	Tinel's Sign	Postoperative Results	Follow-up (mo)
NR	NR	Yes	No	Yes	Slight pain	36
NR	FDL muscle at various levels	NR	Yes	NR	NA	NR
	QP muscle	No	Yes	NR	Yes	NR
Enter tarsal tunnel as muscle belly Exit as tendinous slip	2 QP muscle 2 Common tendon of the FDL muscle	Yes Yes	No No	Yes Yes	4 Yes 2 No Less pain	47
Enter tarsal tunnel as muscle belly Exit as tendinous slip	1 QP muscle 1 Common tendon of the FDL muscle	Yes Yes	No No	Yes Yes		
Muscle belly within the tarsal tunnel	Unknown	Yes	No	Yes	Yes	40
Enter tarsal tunnel as muscle belly Exit as tendinous slip	Unknown (test clinically) FDL muscle before it divides into its four tendinous slips? QP muscle	Yes	Yes	Yes Yes Yes	Yes	36
Enter tarsal tunnel as muscle belly	QP muscle	NR	Yes	NR	Yes	12
Tendon	Unknown (test clinically) FDL muscle before it divides into its four tendinous slips? + QP muscle	Yes	Yes	Yes	Yes	4
NR	NR	NR	Yes	NR	NR	NR
Enter tarsal tunnel as muscle belly Exit as tendinous slip	Unknown	No	Yes	Yes	Yes	3
Muscle belly in the tarsal tunnel	NR	NR	Yes	Yes	Yes	18
Enter tarsal tunnel as muscle belly Exit as tendinous slip	FDL muscle of second toe (test clinically)	Yes	Yes	Yes	Yes	12

innervation of the FDAL muscle was described in only a few cases,[27,28,32,34,35] which suggest innervation from a small branch of the tibial nerve.

Different shapes of the muscle bellies of double-headed FDAL muscles were reported. The shape was primarily influenced by the size disparity of the short and long heads, which could resemble either a V-shape[26] or an L-shape.[24,30] One cadaver study described the blood supply of the FDAL muscle as originating from the posterior tibial artery.[32]

Although function was not studied in the cadaver studies, it is assumed that the FDAL muscle acts synergistically with the FDL muscle. Based on its origin and insertions, it was concluded that the FDAL muscle is a weak inverter of the foot and a weak toe flexor.

Clinical Significance of the FDAL Muscle in TTS

A total of 23 clinical cases were identified in the literature reporting a TTS caused by the FDAL muscle,[5,7,11-19] including our clinical case reported in Appendix 1, herein.

Diagnostic Tests. Clinically, all of the patients had a positive pseudo–Tinel's sign and local tenderness behind the medial malleolus. Electroneurodiagnostic studies were performed in most cases, unless the patient refused (Tables 1 and 3). Five of the 10 studies reporting TTS caused by the FDAL muscle used electrographic studies,[7,11,14,16] including our clinical case (Appendix 1). The types of electrographic studies and their findings are summarized in Table 3. The results of the nerve conduction velocities were not always conclusive. In the presence of abnormal electroneurodiagnostic study findings, the authors generally proceeded with magnetic resonance imaging (MRI) to rule out the presence of space-occupying lesions or other pathologic abnormalities in the tarsal tunnel (Fig. 1). The FDAL muscle can be optimally identified on axial MRIs, which demonstrate the muscle in the tarsal tunnel, typically superficial to the neurovascular bundle.[37] Attachment to the FDL or quadratus

Table 2. Summary of the Findings in Studies Describing the Characteristics of the FDAL Muscle

Study	Year	Patients (No.)	Origin
Nathan et al[20]	1975	12	2 Heads Long head: proximal part of the leg Short head: distal part of the leg 1 Head: deep structures of the posterior compartment of the leg Specific origins of each FDAL muscle were not reported
Pac and Malinovsky[21]	1985	1	Dorsal aspect of the middle third of the tibia Crural fascia
Yüksel et al[22]	1993	1	Deep transverse fascia of the leg Additional fibers originating from the FDL, FHL, and TP muscles
Peterson et al[23]	1995	11	5 Tibia + fascia of deep compartment of the leg 6 Fibula just distal to the FHL muscle + additional short head in 2 cases
VanCourt and Seisel[24]	1996	1	Posterior surface of fibula 3.5 cm above the summit of the lateral malleolus
Canter and Siesel[25]	1997	2	1 Fascia covering the neuromuscular bundle 1 Medial border of the tibia near the origin of the soleus muscle Crural fascia
Cheung et al[37]	1999	20	8 FHL and lower leg muscles 6 Flexor retinaculum 6 Undetermined
Gümüsalan and Kalaycioglü[26]	2000	2	1 Medial head Deep fascia of the leg 7 cm proximal to the medial malleolus Medial margin of the tibia Lateral head Deep fascia of the leg 4.5 cm proximal to the lateral malleolus Posterior intramuscular septum 1 Medial head Deep fascia of the leg 7.6 cm proximal to medial malleolus Medial margin of the tibia Lateral head Deep fascia of the leg 5 cm proximal to the lateral malleolus Posterior intramuscular septum Margin of the fibula
Kurtoglu et al[27]	2001	1	FDL muscle
Jaijesh et al[28]	2006	2	Fascia covering the popliteus muscle
Deroy et al[29]	2002	1	Not known, cadaveric specimen had been transected 8 cm above the medial malleolus

Table 2. extended

Proximal to Tarsal Tunnel	Tarsal Tunnel	Insertion
FDAL tendon anterior to the FHL muscle FDAL tendon between the FDL and FHL tendons	Muscle belly in the tarsal tunnel	Into the FDL muscle in the plantar
	FDAL muscle has its own tendon sheath and fibro-osseous canal	Tendinous insertion in the FDL muscle of toes 2, 3, and 4 FHL tendon
NR	NR	Tendon of the FDL before separation into 4 digital tendons
Intimate with the posterior tibial artery and nerve From lateral to medial deep to the neurovascular bundle From posterior to anterior in relation to the neurovascular bundle, following along the FHL muscle	FDAL tendon anterior to the FHL muscle FDAL tendon between the FDL and FHL tendons	5 QP muscle 2 QP muscle + additional insertions on the FDL muscle 3 QP muscle 3 QP + FDL muscles
NR	Muscle belly in the tarsal tunnel Posterior to the FHL tendon	Lateral aspect of the FDL and insertion before the separation into 4 digital tendons
Body of the muscle ended at the proximal end of the tarsal tunnel Posterior to the neurovascular bundle	1 Posterior position to the tibial nerve 1 Between the FDL and TP muscles	Medial head of the QP muscle Medial edge of the QP muscle + knot of Henry
18 Posteromedial to the FHL and posterior to neurovascular bundle 2 Wrapped around the posterior tibial neurovascular bundle	FDAL muscle entered the tarsal tunnel as distinct muscle fascicle FDAL muscle is anteromedially located to the neurovascular bundle	QP muscle Undivided portion of the FDL muscle or lateral head of the QP muscle
Inferolaterally and superficially to the tibial nerve Inferomedially	Blended together posterolateral to the tibial nerve 2 cm proximal to the intermalleolar line 1 Single tendon through tarsal tunnel	Superomedial aspect of the tendon of QP Second + third tendons of FDL
Inferolaterally and superficially to the tibial nerve Inferomedially	Blended together posterolateral to the tibial nerve 1 cm proximal to the intermalleolar line	Superomedial aspect of the tendon of QP Second + third tendons of FDL
NR	Became tendinous just above the flexor retinaculum and passed into the tarsal tunnel	Joined the tendon of FDL in the distal part of the tunnel
Between the flexor digitorum longus and TP muscles	Laterally positioned to the flexor retinaculum	Deep surface of the FDL muscle at its division into 4 digital slips
Between the FHL and FDL muscles	Inferior and lateral to the FHL as it enters the tarsal tunnel Fleshy fibers of the muscle entered the tarsal tunnel	FDL tendon before the latter split into 4 digital slips

Table 2. continued

Study	Year	Patients (No.)	Origin
Holzmann et al[30]	2009	1	Deep surface of the flexor retinaculum (proximal muscle body) Deep fascia + medial surface of the calcaneus (distal muscle body)
Bowers et al[31]	2009	1	Posterior crural fascia Proximal portion of the FDL muscle One-third proximal deep posterior compartment of the leg
Georgiev et al[32]	2009	1	Lower third of the posterior crural intermuscular septum Between the FHL and PB muscles 5 cm above the lateral malleolus
Hwang and Hill[33]	2009	2	Medial head Tibia (9.5–15 cm superior to the inferior margin of the medial malleolus) Proximal part of the medial head is aponeurotic Lateral head 5 mm superior to the lateral head originated from the posterior intermuscular septum Fibula (6–9.5 cm superior to the inferior margin of the lateral malleolus) Posterior portion of the belly of the fibular brevis
Singh and Shamal[34]	2010	2	Posterior aspect of the medial border of the tibia, just at its junction to the soleal line deep to the soleus muscle
Upasna et al[35]	2011	1	FDL tendon Fascia covering the FDL and TP muscles
Athavale et al[36]	2012	2	1 Fascia covering the FHL muscle in the lower part of the flexor compartment of the leg 1 Superficial surface of the FDL tendon just before it gives off the digital slips

Abbreviations: CAL, calcaneus; FDAL, flexor digitorum accessorius longus; FDL, flexor digitorum longus; FHL, flexor hallucis longus; NA, not applicable; NR, not reported; PB, peroneus brevis; QP, quadratus plantae; TP, tibialis posterior.

plantae muscle allows differentiation from other accessory muscles in the tarsal tunnel, which insert onto the calcaneus. The FDAL muscle is a known potential etiology of TTS that, despite MRI, may be overlooked when tarsal tunnel symptoms are present.[7] Magnetic resonance imaging was not performed in all of the patients (Table 1). Although not identified preoperatively, the presence of the accessory muscle was readily identified after incising the flexor retinaculum, and appropriate treatment was undertaken to remove the anomalous muscle.

Conservative Treatment. Ten of the 23 patients were treated conservatively.[5,7,13,14] This treatment consisted of a soft shoe profile, activity modification, custom orthoses, supportive taping, nonsteroidal anti-inflammatory drug administration, and physical therapy.[5,7,13,14] Success by conservative treatment was achieved in only 30% of the patients.[5,13]

Surgical Treatment. As a result of failure to alleviate symptoms by conservative management, surgical intervention was performed in 20 of the 23 patients.

The insertion of the FDAL muscle was identified surgically only in the study by Sammarco and Conti,[14] who reported it as being the quadratus plantae and the common tendon of the FDL. Six studies, including our clinical case, could not definitively locate the origin or the insertion of the anomalous muscle without more extensive dissection, and given the visible entrapment of the nerve by the FDAL tendon, no further dissection was performed (Appendix 1).[7,11,14,16,18] In some patients, the tendon was wrapped around the neurovascular bundle before entering the tarsal tunnel (Figs. 2 and 3). The dynamic compression of the nerve could potentially be caused by the contraction of the accessory muscle.[14] Interoperatively, three studies pulled the accessory muscle proximally to deter-

Table 2. extended, continued

Proximal to Tarsal Tunnel	Tarsal Tunnel	Insertion
NR	FDAL tendon posterior to the FHL tendon	FDL tendon deep surface FHL lateral and plantar surface
NR	Large bulky muscle in the tarsal tunnel FDAL tendon posterior to the FHL tendon	FDL tendon as it gave rise to the 4 tendinous slips to the digits Distal to master knot
Downward and medially	FDAL tendon posterior to the FHL tendon	Second toe FDL muscle QP muscle + additional portion of FHL muscle to the second toe
Inferolaterally Inferomedially	None of the fleshy fibers of the muscle entered the tarsal tunnel FDAL tendon posterior to the FHL tendon	Distal third of the QP muscle Inferior surface of the FDL muscle FDL muscle of the second toe
Posterior to the FHL tendon	FDAL tendon posterior to the FHL tendon	1 FHL tendon and the FDL muscle to final insertion at the second toe + the QP muscle 1 CAL and send fibrous insertions to the QP muscle, the tendon of the FDL as well as the FHL muscle
NR	Between the FHL and TP muscles	FDL muscle of the second toe TP muscle
NR	Fleshy belly passed through the tarsal tunnel NA	Tendon of FDL before the separation into 4 digital tendons Merged with the FDL tendon for the fifth toe

mine the possible function. Kinoshita and colleagues[16] reported plantarflexion of the lesser digits 2 to 4 in four of six operated feet. Wittmayer and Freed[7] also reported plantarflexion of the lesser digits 2 to 5. In our clinical case (Appendix 1), only plantarflexion of the second toe was observed, which has not previously been reported in the literature.

Surgical decompression via excision of the accessory muscle was not always reported as being highly successful in the literature. Evaluation of the surgical treatment was undertaken in only two papers with two different validated rating scales: the Maryland Foot Score and the Takakura rating scale.[14,16] The Takakura rating scale is based on a 10-point scale to measure pain (spontaneous or on movement), burning pain, Tinel's sign, sensory disturbance, and muscle atrophy or weakness. Each item is graded as definite (0 points), some (1 point), or absent (2 points).[6] The mean preoperative Takakura score was 3.1.[16]

The Maryland Foot Score is based on a 100-point scale measuring pain (45 points), function in terms of gait (22 points), functional activities (18 points), appearance (10 points), and motion (5 points). The mean Maryland Foot Score was 69.6 preoperatively and 81.0 postoperatively.[14] Sammarco and Conti[14] reported that surgical decompression was not always successful, as previously reported in the literature.

Discussion

Numerous conditions (space-occupying lesions, systemic diseases, direct trauma, and malalignment of the hindfoot and the ankle) have been reported to cause or to have a causal relationship with TTS.[10] It can be difficult to diagnose the cause of TTS, and diagnostic imaging (MRI) and electroneurodiagnostic tests are commonly used to aid diagnosis. Sammarco and Stephens[11] were the first to describe TTS caused by the FDAL muscle, and given the reported frequency of 2% to 13% of the FDAL muscle, and its position in the tarsal tunnel, it is perhaps surprising that its presence has not been reported more often.[1,20,38] However, with the development of better imaging techniques, such as ultrasonography, computer tomography, and MRI,

Table 3. Findings of the Electroneurodiagnostic Studies and Reported Scores of the Maryland Foot Score and the Takakura Rating Scale

Study	Year	Patients (No.)	EMG	Nerve Conduction Studies	Findings	Maryland Score	Takakura Score
Sammarco and Stephens[11]	1990	1	Yes	Yes	No evidence of radiculopathy Prolonged nerve conduction velocities in the medial and lateral nerves	No	No
Buschman et al[12]	1991	1	NR	NR	NR	NR	NR
Ho et al[13]	1993	1	NR	NR	NR	NR	NR
Sammarco and Conti[14]	1994	6	Yes	Yes	Prolonged distal motor latency Fibrillation of the abductus hallucis	Yes	No
Burks and DeHeer[15]	2001	1	NR	NR	NR	NR	NR
Kinoshita et al[16]	2003	6	Yes	Yes	Prolonged motor latency of medial plantar nerve 3 Reduced sensory nerve conduction velocity between the medial malleolus and the great toe 3 Absence of the action potentials of the tibial sensory nerve	NR	Yes
Best et al[17]	2005	1	NR	NR	NR	NR	NR
Wittmayer and Freed[7]	2007	1	Yes	Yes	Absence of sensory nerve action potentials in the medial plantar nerve	NR	NR
Duran-Stanton and Bui-Mansfield[5]	2010	2	NR	NR	NR	NR	NR
Saar and Bell[18]	2011	1	NR	NR	NR	NR	NR
Samaras[19]	2011	1	NR	NR	NR	NR	NR
Our case	2011	1	Yes	Yes	No anomalies	NR	NR

Abbreviations: EMG, electromyography; NR, not reported.

during the past decade, the FDAL muscle in association with TTS is now more regularly identified and reported in the literature.

Although this accessory muscle is not rare, only a few reports have implicated it in TTS. This suggests that specific conditions must be present before the accessory muscle becomes the cause of TTS. Kinoshita et al[16] suggested that the trigger of the onset of TTS could be either a previous injury or strenuous exercise. After trauma or strenuous exercise, the FDAL muscle could become edematous or hypertrophied, compressing the tibial nerve in the tarsal tunnel. The varied origin, insertion, and size of the muscle could also explain why the FDAL muscle causes TTS in only some patients. The FDAL muscle has also been associated with other pathologic conditions, such as tenosynovitis of the FHL tendon[39,40] and familial idiopathic clubfoot.[41] Most clinicians who reported TTS caused by the FDAL muscle strongly believed that the FDAL muscle should be resected to ensure that the neurovascular bundle was no longer irritated or compressed. Overall, outcomes of TTS surgery in the presence of accessory muscles are known to be associated with lesser improvement compared with those in the presence of other etiologies.[7] This lesser improvement could be explained by the fact that the long-standing nature of the entrapment neuropathy was related to the presence of the FDAL accessory muscle, which is a congenital anomaly.

Conclusions

The FDAL muscle has frequently been reported in lower-extremity cadaver and imaging studies. However, clinicians often do not include this accessory muscle in the differential diagnosis of TTS. This literature review suggests that the FDAL muscle is important in terms of its functional and clinical significance. Knowledge of this muscle, its anatomical location, and its variations, as well as its MRI characteristics, may help clinicians make an accurate differential diagnosis.

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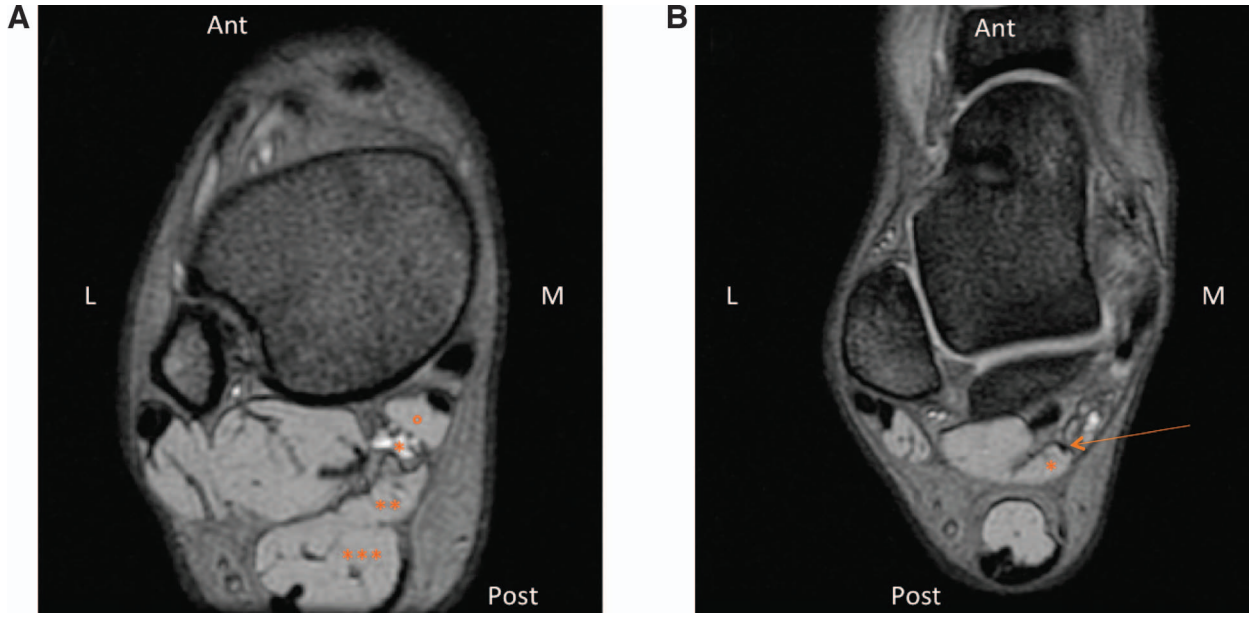


Figure 1. A, Axial magnetic resonance image (MRI) above the ankle joint showing how the neurovascular bundle can be compressed between the flexor digitorum accessorius longus (FDAL) and flexor digitorum longus (FDL) muscles. ° indicates FDL; *, neurovascular bundle; **, FDAL intricated into the muscle fibers of the soleus muscle; ***, soleus muscle. B, Axial MRI at the level of the ankle joint. * indicates the individualization of the FDAL; arrow, the beginning of the tendinous part of the FDAL muscle. Ant, anterior; L, lateral; M, medial; post, posterior.

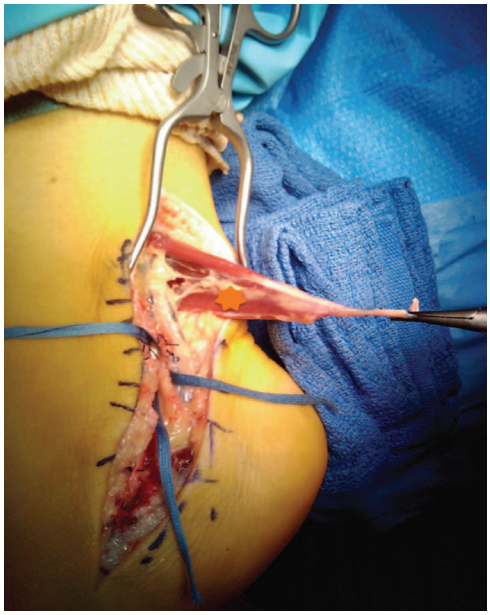


Figure 2. Interoperative view showing release of the neurovascular bundle after performing a tenotomy of the flexor digitorum accessorius longus tendon (*).

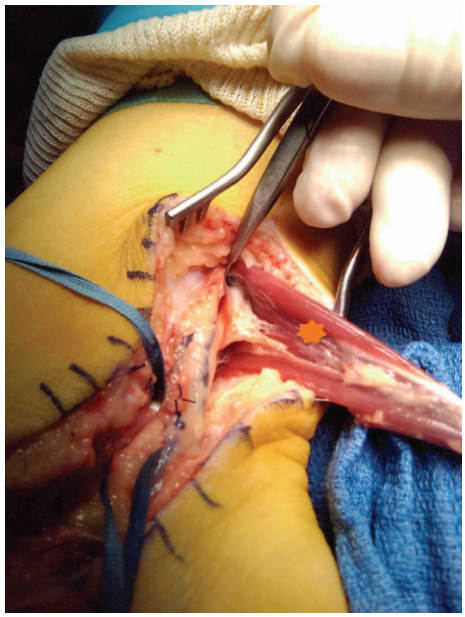


Figure 3. Interoperative view. After releasing the flexor digitorum accessorius longus tendon (*), one can observe underneath the scissors the dynamic compression of the accessory muscle on the neurovascular bundle.

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Appendix 1

Case Description of the New-Variant FDAL Muscle Causing TTS

A 17-year-old woman presented to the Parc Leopold Clinic (Brussels) with a long-standing history of right medial ankle pain and swelling of approximately 1 year in duration. She also presented a claw toe of the interphalangeal joint of her right hallux, clinically reducible. An MRI showed an arthrosynovial cyst in front of the tarsal tunnel. Results of computed tomography and electroneurodiagnostic testing were normal.

On the preoperative MRI, a cystic lesion was found that was believed to be the etiology of the TTS. The existence of an accessory muscle was not known preoperatively but was confirmed on surgery.

The incision was made posterior to the medial malleolus along the course of the tibial nerve. After opening the proximal part of the tarsal tunnel, a progressive release with exposition of the tibial nerve was performed. Several venous vessels surrounding the nerve were ligated. The cystic lesion, arising from the sheath of the FDL muscle, was removed. Release of the medial tibial nerve was then performed after sectioning of the deep fascia of the abductor hallucis muscle. At the tarsal tunnel itself, an abnormal structure was identified, possibly an accessory muscle going into the sheath of the flexors. Preoperatively, traction of the proximal part of the accessory muscle tendon resulted in plantarflexion of the second toe. The tendon was wrapped around the neurovascular bundle before entering the tarsal tunnel, as reported by Sammarco and Conti[14] in their early report of TTS caused by the FDAL muscle. The proximal insertion of the accessory muscle was identified as being the muscle fibers of the soleus muscle (Fig. 2). Figures 2 and 3 of the procedure document the accessory muscle and clearly show the dynamic compression of the nerve caused by contraction of the accessory muscle. It was believed that the presence of a clawing of the interphalangeal joint of the hallux was the result of this compression of the plantar nerve, leading to insufficiency of the intrinsic muscles. Another potential etiology of the hallux contracture may have been antalgic guarding, with the FHL muscle firing preemptively in gait before the hallux was adequately loaded to the sagittal plane, providing sagittal plane stabilization. There is good evidence to suggest that often an accessory slip from the FHL muscle inserts along the FDL muscle slip to the second toe. If such were the case here, firing of the FHL muscle would reduce tension on the FDAL muscle, thus reducing irritation to the tibial nerve in the tarsal tunnel. This accessory muscle was excised proximally from its proximal insertion in the soleus muscle and distally at the level of the sustentaculum tali.