Foot and Ankle Surgery 27 (2021) 291–295

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

The anatomy of the anterior inferior tibiofibular ligament and its relationship with the Wagstaffe fracture

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ARTICLE INFO

Article history:
Received 14 November 2020
Received in revised form 28 December 2020
Accepted 4 January 2021

Keywords:
Ankle fracture
Wagstaffe fracture
ATFL
AITFL
Lateral ankle ligaments

ABSTRACT

Background: Our aim in this study was to identify the fibular footprint of the Anterior Inferior Tibiofibular Ligament (AITFL) and its relation to Wagstaffe fracture fragment size.
Methods: We examined 25 cadaveric lower limbs which were carefully dissected to identify the lateral ankle ligaments. The AITFL anatomy was compared to 40 Wagstaffe fractures identified from our ankle fracture database.
Results: The AITFL origin was from the anterior fibular tubercle with an average length of 21.61 mm (95% CI 20.22, 22.99). The average distance of the distal aspect of the AITFL footprint to the distal fibula margin was 11.60 mm (95% CI 10.49, 12.71). In the ankle fractures analyzed, the average length of the Wagstaffe fragment was 17.88 mm (95% CI 16.21, 19.54). The average distance from the distal tip of the fibula to the Wagstaffe fracture fragment was 21.40 mm (95% CI 19.78, 23.01).
In total there were 22 syndesmosis injuries. There was no statistical difference in Wagstaffe fragment size between stable and unstable groups.
Conclusion: The AITFL fibular origin was both larger and more distal than the Wagstaffe fracture fragments seen in our institution. Therefore, this suggests that a ligamentous failure will also have to occur to result in syndesmotic instability. The size of fracture fragment also did not confer to syndesmotic instability on testing.
Level of Evidence - 3

1. Introduction

In 1875, Wagstaffe described avulsed fragments of the distal fibula associated with fractures to the ankle [1]. Subsequently, in 1886, LeFort described the same vertical fracture of the anteromedial portion of the fibula (Wagstaffe tubercle) suggesting it was at the site of the anterior inferior tibiofibular ligament (AITFL) insertion [2]. Authors have reported the incidence of Wagstaffe fractures in ankle fractures to range from 1.5 to 25.8% [3,4]. Park et al. described four types of Wagstaffe fractures; type 1 being a solitary fracture of the anterior fibular tubercle; type 2 being a fracture of the anterior fibular tubercle combined with a fibular fracture; type 3 being a fibular fracture and a fracture of the anterior incisura of the tibia; and a type 4 being a fracture of the anterior fibular tubercle combined with a fibular fracture and a fracture of the anterior incisura of the tibia [3]. Although the assumption that the Wagstaffe fracture is an avulsion of the AITFL, not all Wagstaffe fractures have reported anterior syndesmotic instability.

The distal tibiofibular syndesmosis is comprised of three groups of ligaments; AITFL, PITFL and interosseous ligament. The AITFL prevents lateral translation of the fibular and confers rotational stability, preventing approximately 24% of external rotation at the ankle joint [5,6]. Malhotra et al., reported the normal mechanics of the tibiofibular motion indicating that on weight-bearing CT imaging the fibula translated laterally and posteriorly, and rotated externally with respect to the incisura. The fibula pivots on the posterior inferior tibiofibular ligament, with more rotational movement anteriorly [7]. This is down to the shallower posterior

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https://doi.org/10.1016/j.fas.2021.01.003
1268-7731/

tibial tubercle permitting a degree of posterior escape. In contrast, the more prominent anterior tubercle prevents any anterior translation of the lateral malleolus.

There remains a lack of consensus to the most appropriate surgical treatment of the syndesmosis, although most authors agree that malreduction of the syndesmosis leads to poor clinical outcomes [8]. In regards to the Wagstaffe fracture, there is minimal evidence of optimal treatment or anatomical validation of the fracture anatomy and association with instability. The aim of this study is to analyse the AITFL anatomy and compare it to the Wagstaffe fracture fragment morphology.

2. Methods

The study was completed in two sections. Anatomy dissection was completed at the Human Anatomy and Resource laboratory at the University of Liverpool, on cadavers bequeathed to the department under auspices of the Human Tissue Authority, UK. Ethical approval was granted by the University of Liverpool (No. 4233). We selected 25 cadaveric foot and ankle specimens, 13 right and 12 left, preserved for dissection in a solution of formaldehyde. Each specimen was morphologically normal, with no signs of previous surgical intervention.

The second aspect of the study was undertaken at the Liverpool University Hospitals NHS Foundation Trust, using our prospectively collected database of ankle fractures to identify ankle fractures that had a Wagstaffe fragment present. All ankles which had undergone CT imaging were included for analysis in the study. It was recorded if the ankle fractures had unstable syndesmosis on testing during surgical intervention by live screening internal and external rotation tests under general anaesthetic [9].

3. Dissection

All 25 specimens were dissected in the same sequence. Initially the skin along with the subcutaneous fat was removed as one layer. The anterior and lateral compartments of the lower limb were then removed en bloc, starting distally and progressing proximally. This included the excision of the superficial peroneal nerve, deep peroneal nerve, anterior tibial artery and perforating peroneal artery. All remaining fat was excised. The lateral ankle ligament complex, and anterior inferior tibiofibular ligament complex, were identified and preserved for analysis.

Digital images were taken in accordance with the human tissue authority license held by the Human Anatomy and Resource Centre. The measurement of all structures was completed using a digital calliper (calibrated to 0.1 mm). All 25 specimens were measured in identical sequence, measuring the distance of the origin of the AITFL to the distal margin of the fibular and the breadth of the AITFL insertion on the fibular (as seen in Fig. 1).

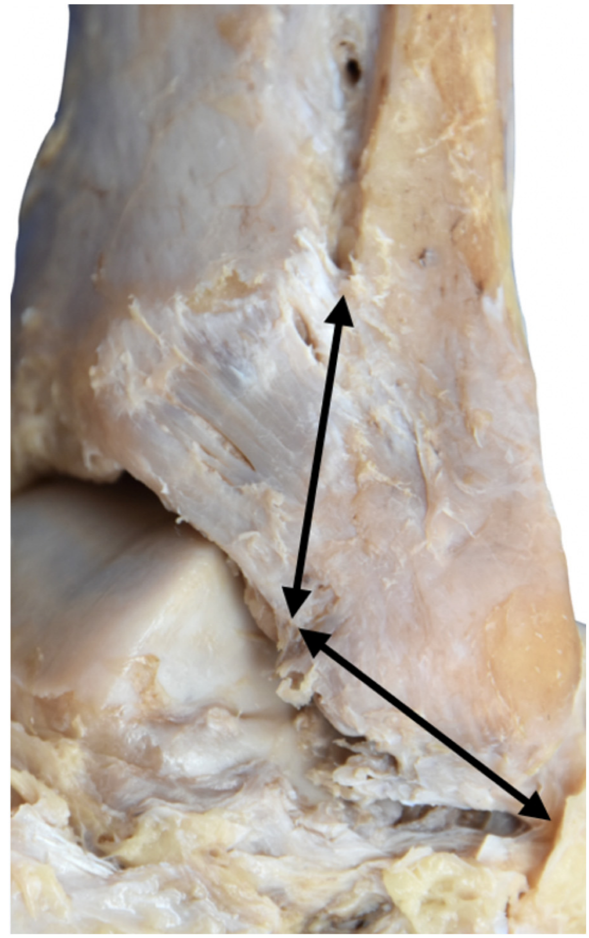

Fig. 1. Anatomy dissection picture illustrating the measurements taken of the AITFL and its distance from the distal margin of the fibular.

3.1. Radiographic analysis

All patients entered into our ankle fracture database from December 2014 to July 2018 were evaluated. Only ankle fractures who had undergone CT imaging were included in this study, to allow accurate measurement of the fracture fragments. All fractures which were identified to have sustained a Wagstaffe fracture, underwent further analysis. The measurements of the Wagstaffe fracture fragment were completed using our departmental imaging software (Vue PACS, Carestream, Version 11.4.1.0324). All ankle fractures containing a Wagstaffe fracture were measured, from the distal most fracture line to the distal margin of the fibular and the length from proximal to distal of the Wagstaffe fragment by two independent reviewers. The measurements taken are demonstrated in Fig. 2. Syndesmotic diastasis was defined as >5 mm gap between fibula and incisura on CT, and further tested intraoperatively on live screening [9,10].

3.2. Statistics

Continuous variables are presented as mean and 95% confidence intervals, whereas categorical and qualitative variables are expressed as numbers and percentages. Normality tests were performed, and for continuous variables where the criteria for normality and equality of variances were fulfilled the Student *t*-test was used for statistical testing. Alternatively, the Mann-Whitney *U* test was performed.

Two-way mixed effects model, where people effects are random and measures effects are fixed, was used to determine Pearson correlation coefficient for the measurements between the two reviewers. The minimum value for Pearson correlation coefficient was kept at 0.6 for the study to be significant as interpreted according to Landis and Koch [11] where slight agreement, 0.00–0.20, fair agreement 0.21–0.40, moderate agreement 0.41–0.60, substantial agreement 0.61–0.80 and almost perfect agreement greater than 0.81. For the reliability of Pearson correlation coefficient, confidence interval was set at 95%. All data was assessed using SPSS Version 25.0 (SPSS Inc., IBM, Chicago, IL).

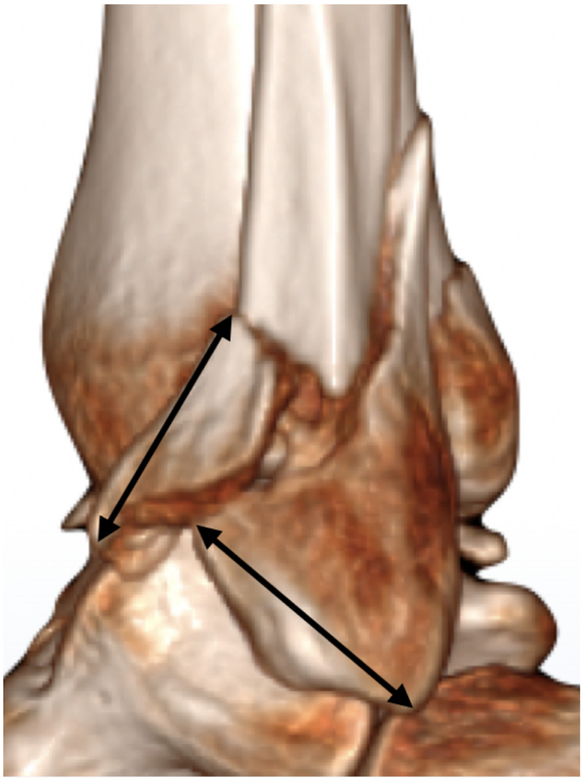

Fig. 2. Picture illustrating the CT 3D surface rendering of a 0.5 mm slice ankle CT with measurement of the Wagstaffe fragment length and its distance from the distal margin of the fibular.

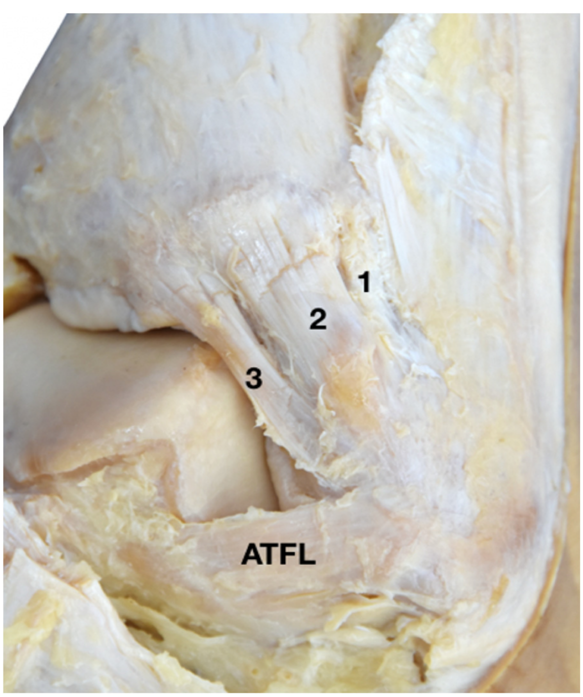

Fig. 3. Picture illustrating the three fascicles of the AITFL, superior (1), middle (2) and inferior (3). In this specimen the inferior fascicle was distinct from the ATFL fibular insertion. In 64% of examined cadavers, this was not the finding however, with the inferior fascicle of AITFL and ATFL being confluent.

4. Results

There were 25 unpaired cadaveric legs for dissection. On anatomical dissection, the AITFL origin was located on the anterior fibular (Wagstaffe) tubercle with an average length of 21.61 mm (95% CI 20.22, 22.99). The average distance of the distal aspect of the AITFL footprint to the distal fibula margin was 11.60 mm (95% CI 10.49, 12.71). The AITFL was present in three distinct bands in 84% of specimens (n = 21) (Fig. 3), the superior, middle and inferior fascicles. Two specimens had four distinct bands and two specimens had five distinct bands. In 64% (n = 16) of specimens the inferior fascicle of the AITFL blended with the anterior talar fibular ligament (ATFL).

On analysis of the ankle fracture database, 310 ankle fractures were found in the time period analysed. A total of 151 had relevant CT imaging and could therefore be included for further analysis. A Wagstaffe fragment was identifiable on 40 ankle fractures (26.5%). The average age of the patients was 52.2 years. Classification of the ankles containing a Wagstaffe fragment revealed 36 were supination external rotation injuries, 2 were supination abduction injuries and 2 were pronation external rotation injuries [12].

On average the length of the Wagstaffe fragment was 17.88 mm (95% CI 16.21, 19.54). The average distance from the distal tip of the fibula to the Wagstaffe fracture fragment was 21.40 mm (95% CI 19.78, 23.01). On analysis, there was a statistical difference in both the length of the Wagstaffe fragment compared to the length of the AITFL fibular origin ($p < .001$) and the distance from the tip of the fibular to the Wagstaffe fracture compared to the tip of the fibular to the AITFL origin ($p < .001$). There was good correlation between reviewers for CT fragment measurement, and near perfect correlation between reviewers for AITFL measurement (Table 1).

Of the 40 ankle fractures with Wagstaffe fracture fragments, there was a total of 22 syndesmosis instabilities on clinical testing under radiographic guidance. The average length of the Wagstaffe fragment associated with syndesmotic instability on testing was 17.92 mm (95% CI 15.79, 20.06). The average Wagstaffe fracture length in syndesmotic stable ankle fractures was 17.84 mm (95% CI 15.05, 20.63). The difference was not statistically significant ($p = 0.655$). The average length of tip of fibular to fracture in ankles with syndesmotic instability was 21.98 mm (95% CI 19.39, 24.56). The average length of tip of fibular to fracture in ankles without syndesmotic instability was 20.82 mm (95% CI 18.64, 22.99). There was no significant difference in Wagstaffe fragment size between ankles with syndesmotic stability and those without ($p < .501$).

5. Discussion

This study has not only indicated that the presence of a Wagstaffe fragment is not pathognomonic of a syndesmotic injury, but also that the size of the fragment is significantly smaller than the AITFL foot-print on the fibular. In our study, the AITFL had an origin to the anterior fibular (Wagstaffe) tubercle with an average length of 21.61 mm (95% CI 20.22, 22.99). This is similar to previous studies describing the lengths ranging from 12 to 20 mm [13,14]. On average the length of the Wagstaffe fragment was smaller than the AITFL origin, with an average size of 17.88 mm (95% CI 16.21, 19.55). The site of fracture was situated in the proximal part of the AITFL origin. Combining these findings, on average almost half the AITFL origin is not involved with the fractures we have witnessed (Fig. 4). It can therefore be assumed that for an anterior syndesmosis instability to occur with an ankle fracture in the presence of a Wagstaffe fragment, a ligamentous injury has to also occur. Neither the presence nor the size of fracture fragment conferred syndesmotic instability on testing.

Park et al. described a retrospective study where Wagstaffe fractures were present in 14% of operatively treated ankle fractures

Table 1
The average measurements of both the Wagstaffe fragment size and AITFL footprint by two independent reviewers.

	Size of Wagstaffe Fragment on CT			
	Mean	95% Confidence interval		Pearson Correlation Co-efficient
		Lower	Upper	
Reviewer 1	18.83	17.20	20.45	.739[a]
Reviewer 2	16.94	15.23	18.64	
	Size of AITFL Footprint on fibular			
	Mean	95% Confidence interval		
		Lower	Upper	
Reviewer 1	21.49	20.14	22.85	.977[a]
Reviewer 2	21.72	20.31	23.13	

[a] Correlation is significant at the .01 level (2-tailed).

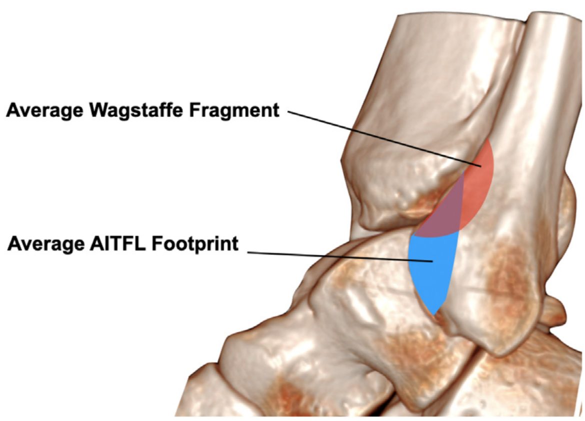

Fig. 4. Schematic illustration of average footprint of AITFL compared to the average location of the Wagstaffe fragment.

(13 out of 94), and in those who had a Wagstaffe fragment present, displayed syndesmotic instability in 87% of cases (11 of 13) [3]. These figures differ significantly from our study; however, the patient demographic may be significantly different between the studies. In our study we only included fractures which had undergone CT, unlike Park et al. who reported on radiographs. This decision was made to validate the size of the Wagstaffe fragment accurately, but it may have inadvertently biased the more complex fracture patterns where CT was required for surgical planning. It is interesting however, that the syndesmotic instability incidence is less in the study with possible bias toward the more complex fracture patterns. Other authors, Schepers et al., found an associated syndesmotic injury rate in patients with a Wagstaffe fragment to be 44.7 percent which is similar to our finding [4].

We found in the majority of the specimens, the AITFL had 3 distinct bands, superior, middle and inferior fascicles (Fig. 3). This has previously been identified by a number of authors [14–16]. In almost 2/3^{rds} of the dissected specimens, the inferior fascicle of the AITFL blended with the anterior talo-fibular ligament. This finding is supported by Kageyama et al., that examined 100 feet from 52 cadavers, finding that the AITFL and ATFL were connected in 44 of 100 feet (44%) at the fibular attachment. The fractures also occurred on average more distal to the AITFL insertion, with the distance from fibular tip to Wagstaffe fragment being 9.58 mm (95% CI 8.80, 10.36) compared with the distance from fibular tip to AITFL insertion of 11.60 mm (95% CI 10.49, 12.71) [17]. It is therefore recommended that there should be a high index of suspicion for combined ATFL injuries in cases where a Wagstaffe fragment is present.

A number of authors have described the treatment of ankle fractures with Wagstaffe fracture fragments. Schepers et al. described a retrospective study of 252 surgically treated ankle fractures with 65 patients with an associated Wagstaffe fragment. In the cohort with a Wagstaffe fragments, 42 patients of them underwent fixation. The AITFL avulsion fracture was fixed using direct fixation of the fragment in 13 (20%), the placement of a syndesmotic screw (indirect fixation) in 17 (26.2%), or a combination of direct fixation and placement of a syndesmotic screw in 12 (18.5%). A further study by Shi et al. looked at the 435 ankle fractures over a 3-year period and included 13 patients who had a Wagstaffe fracture. All of these patients underwent surgery and inspection for evidence of a syndesmosis injury. They described Wagstaffe fractures with combination of Wagstaffe and Chaput fragments but reported the ligament attachment of the AITFL to be larger and broader than the actual bony fragment [18]. Other AITFL reconstruction techniques not including Wagstaffe fractures have been reported. Both Yasui et al. [19] and Nelson et al. [20] reported on anatomical reconstruction of the AITFL using tendon grafts and Teramoto et al. reported on using suture tape [21]. All techniques reported good early outcomes, but no comparison has been made with traditional syndesmotic fixation.

We accept limitation with our study. We had 25 cadavers which is an acceptable number for cadaveric analysis, however a larger number would have given us a better understanding of the variability of the anatomy. As previously stated only patients with a CT scan were included, thus it is possible we have only included more complex ankle fractures with Wagstaffe fragments.

6. Conclusion

The AITFL fibular origin was more distally located and larger than the Wagstaffe fracture fragments seen in our institution. Therefore, this suggests that a ligamentous failure will also have to occur to result in syndesmotic instability.

Conflicts of interest

We have no conflicts of interest to declare from the authorship team.

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