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Occurrence of Lateral Ankle Ligament Disease With Stage 2 to 3 Adult-Acquired Flatfoot Deformity Confirmed via Magnetic Resonance Imaging: A Retrospective Study

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ABSTRACT

Lateral hindfoot pain associated with stage 2 to 3 adult-acquired flatfoot is often attributed to subfibular impingement. Preoperative magnetic resonance imaging (MRI) is generally performed to assess the extent of degeneration within the posterior tibial tendon, attenuation of medial soft tissue constraints, and degeneration of hindfoot and/or ankle articulations. The purpose of this study is to determine the incidence of lateral collateral ligament disease/injury associated with stages 2 and 3 adult-acquired flatfoot. The subjects were identified using a searchable computerized hospital database between 2015 and 2017. Stage 2 or 3 adult-acquired flatfoot deformity was confirmed in patients via chart review and MRI analysis. Lateral ankle ligament injury was confirmed using patient MRI results per the hospital radiologist and documented within the patients' chart. Inclusion criteria required that patients be diagnosed with Johnson and Strom stage 2 or 3 flatfoot deformity with documented lateral ankle pain and that preoperative MRI scans be available with the radiologist's report. Patient exclusion criteria included patients <18 years of age, patients with flatfoot deformity caused by previous trauma, tarsal coalition, neuropathic arthritis, patients with previous surgery, or patients with incomplete medical records. In total, 118 patients were identified with these parameters. Of the 118 patients, 74 patients (62.7%) had documented lateral ankle ligament injury on MRI. Of the 77 patients with stage 2 adult-acquired flatfoot, 55 (71.4%) had confirmed lateral ankle ligament injury on MRI. Of the 41 patients with stage 3 adult-acquired flatfoot, 19 (46.3%) had confirmed lateral ankle ligament injury on MRI. This study demonstrates a relatively high incidence of lateral ligament disease associated with adult-acquired flatfoot deformity. These findings might have long-term implications regarding ankle arthritis after surgical management of adult-acquired flatfoot.

Adult-acquired flatfoot deformity (AAFD) is largely characterized by pronation through the subtalar joint, leading to decreased medial longitudinal arch height and insufficiency of the soft tissue structures that support the medial arch. These changes cause gradual degradation of the posterior tibial tendon (PTT), resulting in posterior tibial tendon dysfunction (PTTD). PTTD affects approximately 5 million people in the United States alone (1,2).

Johnson and Strom's classification is used in the diagnosis of PTTD. Johnson and Strom's 3 stages, along with Myerson's addition of stage 4, can be used clinically to assess and classify patients with PTTD. Stage 1 is defined by symptoms confined to the PTT. Although there may be mild deformity, the PTT remains strong and shows minimal loss of function. Stage 2 is defined by increased symptoms, a reducible deformity, and weakness of the PTT. Stage 2 deformity includes pronation at the subtalar joint with possible abduction of the forefoot on the hindfoot. Patients with stage 2 PTTD are weaker during strength testing with a dysfunctional PTT. Stage 3 is defined by rigid deformity noted about the subtalar and midtarsal joints. Patients develop progressive symptoms, including lateral hindfoot pain. The hindfoot deformity is irreducible both manually and with the double heel rise. Lateral pain in stage 3 deformities is usually attributed to subfibular impingement, leading to pain in the sinus tarsi region of the subtalar joint. Last, stage 4 includes rigid or flexible deformity of the foot with ankle involvement. Patients with stage 4 deformity will show ankle valgus deformity on anteroposterior radiographs (1,2) (Table 1).

This classification staging system aids in the procedure selection for AAFD. Patients in stage 1 are usually treated conservatively with the use of bracing, antiinflammatory drugs, and physical therapy. Early

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Table 1
Johnson and Strom classification

Stage	Tendon	Deformity	Single Limb Heel Rise	Therapy
I	Peritendonitis with mild tendon degeneration	Mobile hindfoot, normal alignment	Normal with inversion of hindfoot	RICE, orthotics, bracing
II	Elongation and moderate tendon degeneration	Mobile hindfoot, valgus alignment	Difficulty or unable to perform with inversion of hindfoot	Tendon reconstruction peri-articular osteotomies
III	Elongation and severe tendon degeneration	Fixed deformity, valgus position	Unable to perform fixed valgus	Hindfoot fusion
IV	Elongation and severe tendon degeneration	Fixed deformity, valgus subtalar and ankle joint position	Unable to perform fixed valgus	Hindfoot fusion with ankle ligament reconstruction or fusion

Abbreviation: RICE, rest, ice, compression, elevation.

stage 2 deformities can be treated conservatively as mentioned previously, but late stage 2 deformities generally require surgical intervention. Surgical intervention for stage 2 deformity commonly involves joint-sparing osteotomies, tendon transfer or repair, and ligament reconstruction procedures. Stage 3 to 4 deformities require hindfoot arthrodesis procedures, including double or triple arthrodesis, and pan talar arthrodesis, as well as osteotomies, tendon transfers, and ligament reconstruction (1–10).

One aspect of flatfoot reconstruction that has not been discussed in the literature is reconstruction of the lateral ankle ligaments. Lateral pain associated with PTTD disorder has historically been attributed to subfibular impingement of the fibula and lateral wall of the talus on the calcaneus and sinus tarsi, respectively. Malicky et al (11) verified such findings with CT examination of the lateral foot and ankle. Their study revealed that overall, the prevalence of sinus tarsi impingement was 92% and the prevalence of calcaneofibular impingement was 66% in the flatfoot group versus 0% and 5%, respectively, in the control group. It is therefore not uncommon to overlook lateral collateral ankle ligament injury as a cause of pain.

Magnetic resonance imaging (MRI) is commonly performed at our facility to evaluate patients with PTTD for both diagnostic purposes and surgical planning. Lateral ankle ligament injury is a common incidental finding on MRI and should be considered as a pain generator. Lateral ankle impingement pain may be derived from lateral ankle ligament injury secondary to the biomechanical changes within the foot and increased stress placed on the soft tissues surrounding both ankle and subtalar joints during the mechanical changes noted during the progression of AAFD. Although there are many studies that have demonstrated deltoid and spring ligament insufficiency using MRI, there are virtually no studies evaluating the incidence of lateral ankle ligament disease in AAFD (12–16).

Evaluation of the anterior talofibular ligament (ATFL) via MRI has been shown to be very accurate. Numerous authors have discussed diagnosis of lateral ankle ligaments injuries using MRI. Cho et al (17) were able to diagnose 100% of their patients' ATFL injuries confirmed via arthroscopic evaluation. Kim et al (18) observed that MRI via 2 radiologists had a sensitivity of 83.6% and 76.4%, respectively; specificity of 91.7% and 83.3%, respectively; negative predictive value of 71.0% and 60.6%, respectively; and a positive predictive value of 95.8% and 91.3%, respectively. Thus, it has been established that MRI is a valuable tool in determining ATFL injury (Figs. 1 and 2).

Lateral hindfoot pain associated with stage 2 to 3 AAFD has long been attributed to subfibular impingement. We evaluated the incidence of lateral collateral ligament disease/injury associated with AAFD. Furthermore, we consider lateral collateral ligament disease as a possible pain generator in stages 2 and 3 AAFD. If shown to be significant, consideration should be made to include lateral ankle ligament reconstruction in association with flatfoot reconstruction. This may preserve ankle function and limit the progression of ankle osteoarthritis.

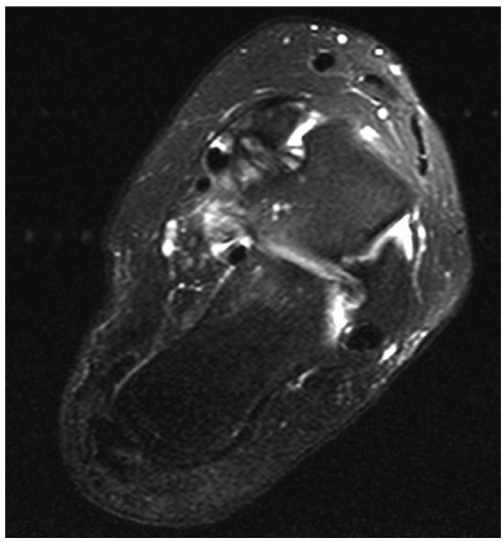

Fig. 1. Magnetic resonance axial T2 scan showing an anterior talofibular ligament injury.

Patients and Methods

The subjects were identified using a searchable computerized hospital database between 2015 and 2017. Patients with stage 2 or 3 AAFD were confirmed via chart review and radiographic analysis. Of the initial search, 174 patients were identified. Of the 174 patients with ICD-10 codes indicating a patient with flatfoot deformity including PTTD, adult-acquired flatfoot, and adult-acquired deformity of the foot, 118 feet in 115 patients met inclusion criteria for the study.

To be included in the study, patients must have been diagnosed with Johnson and Strom stage 2 or 3 flatfoot deformity with documented lateral ankle pain and have a preoperative MRI and radiologist report available with MRI scans. Patient exclusion criteria included patients <18 years of age, patients with flatfoot deformity secondary to previous trauma or neuropathic arthritis, patients with previous surgery, or patients with incomplete medical records.

Data were compiled that included the age of the patient, patient sex, Johnson and Strom classification stage, lateral ankle ligament injury identified on MRI, and prior surgical procedures. Lateral ankle ligament injury was identified via the radiologist's report and was visually confirmed by the primary author (S.P.). Statistical analysis was performed via an independent statistician, compiling the incidence of lateral ankle ligament injury associated with either stage 2 or stage 3 AAFD and comparing the 2 groups.

Statistical Methods

All analysis began with assessment of the normality of the data using the Shapiro-Wilk test. Continuous variables were reported as mean $\pm$ standard deviation and categorical data as counts and percentages. Non-normally distributed data were reported as median with the range of the data. Continuous variables were compared by the independent samples t test or Mann-Whitney U test, as appropriate. The χ^2 test was used to determine the association between ATFL injury and stage of AAFD. Odds ratios and their corresponding 95% confidence intervals were reported to show the association between these 2 variables. A value of $p \leq .05$ on 2-tailed testing was considered statistically significant. Confidence interval calculations for binomial proportions were done using a

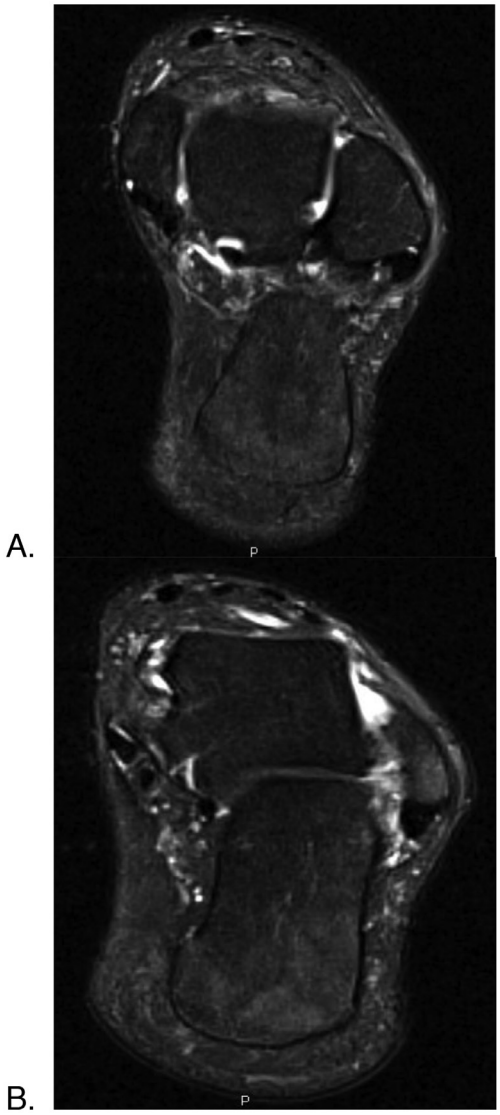

Fig. 2. Magnetic resonance axial T2 scan showing an intact anterior talofibular ligament (*A*) and subfibular inflammation (*B*).

program entitled Confidence Interval for a Proportion (www.sample-size.net/confidence-interval-proportion) from the University of California San Francisco Clinical & Translational Science Institute. All other statistical analyses were performed using IBM SPSS Statistics, version 24.0 (IBM Corp., Armonk, NY).

Results

The study population was composed of 115 patients, including 118 feet, which were gathered using the hospital's electronic medical record system between August 1, 2015, and June 1, 2017. Of the 118 feet evaluated, there were 77 (65.25%) patients found within the stage 2 group and 41 (34.75%) patients in the stage 3 group, respectively. Mean age at the time of enrollment was 51.9 ± 13.3 (median, 54.5; range 18 to 74) years. Within the adult-acquired flatfoot stage 2 group, the average age was 50.6 ± 15.0 years. Average age of the stage 3 population was 54.3 ± 9.2 years (Table 2). All of the patients included met the inclusion criteria of having documented AAFD with lateral ankle/sinus tarsi pain and preoperative MRI.

The prevalence of ATFL injury among the 118 feet with adult-acquired flatfoot stages 2 and 3 combined was 62.7% (95% CI 53.3% to 71.4%). The prevalence of ATFL injury among the 77 patients diagnosed with stage 2 adult-acquired flatfoot was 71.4% (95% CI 60.0% to 81.2%). The prevalence of ATFL injury among the 41 patients diagnosed with stage 3 adult-acquired flatfoot was 46.3% (95% CI 30.7% to 62.6%) (Table 2).

Table 2
Characteristics of the study population

Variable	Mean ± SD or No. (%)
Stage 2	77 (65.25)
Age in years (n = 77)	50.6 ± 15.0
Sex (n = 77)	
Male	16 (20.8)
Female	61 (79.2)
+ Anterior talofibular ligament injury by MRI	55 (71.4)
− Anterior talofibular ligament injury by MRI	22 (28.6)
Stage 3	41 (45)
Age in years (n = 41)	54.3 ± 9.2
Sex (n = 41)	
Male	17 (34.75)
Female	24 (58.5)
+ Anterior talofibular ligament injury by MRI	19 (46.3)
− Anterior talofibular ligament injury by MRI	22 (53.7)
Stages 2 and 3 combined	118 (100)
Age in years (n = 118)	51.9 ± 13.3
Sex (n = 118)	
Male	33 (27.9)
Female	85 (72.1)
+ Anterior talofibular ligament injury by MRI	74 (62.7)
−Anterior talofibular ligament injury by MRI	44 (37.3)

Abbreviations: MRI, magnetic resonance imaging; SD, standard deviation.
Continuous data are shown as mean ± SD and categorical data as no. (%).

Of the 44 feet that did not have ligamentous injury, 9 patients had a documented reason for their lateral ankle pain. Seven of these 9 patients had documented inflammation within the sinus tarsi consistent with subfibular impingement. When the other 2 patients were examined, 1 had documented ankle effusion and the other was diagnosed with an osteochondral lesion of the lateral talar dome.

When comparing stage 2 and 3 patient cohorts, 71.4% of the feet evaluated with stage 2 AAFD were shown to have lateral ankle ligament injury associated with their deformity. Four patients within this population were shown to have documented inflammation within the sinus tarsi. Stage 3 patients were shown to have a lower rate of lateral ankle ligament injury in that 46.3% of the feet evaluated had lateral ankle ligament injury, with 5 patients having documented alternative findings, including 1 patient with a lateral OCD lesion, 1 patient with a lateral ankle joint effusion, and 3 patients with sinus tarsi syndrome (Table 3).

The median age for stage 2 and 3 patients combined did not differ significantly between patients with (median 55.5, range 18.0 to 83.0, n = 74) and without (median 53.0, range 19.0 to 69.0, n = 44) ATFL injury ($p = .38$). However, stage 2 patients with ATFL injury were significantly

Table 3
Characteristics of patients and feet with versus without ATLF injury by MRI

Variable	With ATFL Injury by MRI (n = 74)	Without ATFL Injury by MRI (n = 44)	*p* Value
Overall data	74 (62.7)	44 (37.3)	< .05*
Age in years	53.1 ± 13.3	50.0 ± 13.3	.38
Age stage 2	53.4 ± 14.7	43.7 ± 13.6	.009*
Age stage 3	52.1 ± 8.2	56.3 ± 9.6	.14
Staging			
Stage 2	55 (71.4)	22 (28.6)	
Stage 3	19 (46.3)	22 (53.7)	
Yes stage 2 vs stage 3	55 (71.4)	19 (46.3)	.007*
Sinus tarsi syndrome	4 (5.4)	3 (6.8)	

Abbreviations: ATFL, anterior talofibular ligament; MRI, magnetic resonance imaging.
* Significant value.

older (53.4 ± 14.7 years, n = 55) than stage 2 patients without ATFL injury (43.7 ± 13.6, n = 22) (t [75] = −2.68, p = .009; 95% CI of the difference −16.98 to −2.49). The mean age of stage 3 patients did not differ significantly between patients with (52.1 ± 8.2, n = 19) and without (56.3 ± 9.6, n = 22) ATFL injury (p = .14). There was a significant difference between stages 2 and 3 deformity with respect to patient sex: 61 women (79%) and 16 men (21%) vs 24 women (58.5%) and 17 (41.5%) men ($p < .5$). The presence of lateral ankle ligament injury on preoperative MRI was 71.4% (55 of 77) in the stage 2 flatfoot group and 46.3% (19/41) in the stage 3 flatfoot group. Stage 2 patients were significantly more likely to have ATFL injury than stage 3 patients. A χ^2 test examined the association between ATFL injury and stage of adult-acquired flatfoot. The association was statistically significant: χ^2 (1) = 7.2, p = .007. Results show that 71.4% (55 of 77) of stage 2 feet had ATFL injury compared with 46.3% (19/41) of stage 3 feet. Patients with stage 2 deformity were 2.9 times more likely to have an ATFL injury than those patients in stage 3 (95% CI 1.316 to 6.367).

Discussion

Lateral hindfoot pain in association with PTTD may not be fully understood. Pain is typically attributed to subfibular impingement. However, there is very little evidence indicating the occurrence of subfibular impingement and the frequency in which it causes inflammation to the local area that would be associated with pain.

Malicky et al (11) evaluated, through computed tomographic scans, the occurrence of sinus tarsi and calcaneal fibular impingement within a flatfoot population. Their study revealed that 92% of the 19 patients showed signs of sinus tarsi impingement via the fibula. They also showed that 66% of the patients showed signs of calcaneofibular impingement. Thus, they concluded that lateral hindfoot impingement may occur in a stepwise fashion (11).

The study of Malicky et al (11) demonstrated results showing that subfibular impingement exists; however, with the limitations of computed tomography, those authors were not able to identify the inflammatory cause of pain within the local area. Our study showed that 62.7% of our patient population had MRI evidence of ligamentous injury. It is reasonable to attribute a component of lateral ankle pain to ligament disease as opposed to impingement alone. Our study also demonstrated that this occurrence was significantly more prevalent in the stage 2 population than in the stage 3 population. This may be secondary to the increased motion within the stage 2 population as opposed to the stage 3 population in which there is fixed deformity. In addition, our study showed only 5.9% of our population having documented inflammation within the sinus tarsi region consistent with subfibular impingement as the sole cause of lateral hindfoot pain with stage 2 or 3 flatfoot.

This data might explain why there is such a difference between stages 2 and 3 AAFD relative to age. On average, patients with stage 2 AAFD who generally showed signs of ATFL injury were 10 years older than those patients without ATFL injury (53.4 ± 14.7 years vs 43.7 ± 13.6 years). These data potentially show that the longer a patient has a flexible deformity, the more likely chronic inflammation and stress at the ankle joint level will lead to lateral ankle ligament disease. However, patients with stage 3 AAFD showed markedly different results. Patients with ATFL injury in the stage 3 group were generally younger (52.1 ± 8.2 years vs 56.3 ± 9.6 years). Stage 3 age results may be the result of a chronic rigid position. Theoretically, if a patient is locked in a valgus position with limited hindfoot motion, there is less strain to the soft tissues over that period of time. As such, the lateral ankle ligaments may be able to heal over time.

These results regarding age might indicate that lateral ankle ligament injury is a component part of the progressive nature of AAFD. This develops in conjunction with sinus tarsi syndrome and subfibular impingement. It is the authors' belief that the initial pain is secondary to subfibular impingement and sinus tarsi syndrome. However, over time, the collateral ligaments begin to attenuate owing to chronic inflammation and mechanical stress. They become diseased and incompetent over time. Nevertheless, as the patient's deformity becomes more rigid, there is less mechanical strain on the lateral ankle ligaments allowing time for the ligaments to heal.

There are several limitations to this study. One limitation is the number of patients. A larger population might be more meaningful in determining the percentage of patients with lateral ankle ligament injury associated with adult-acquired flatfoot. Another limitation is the

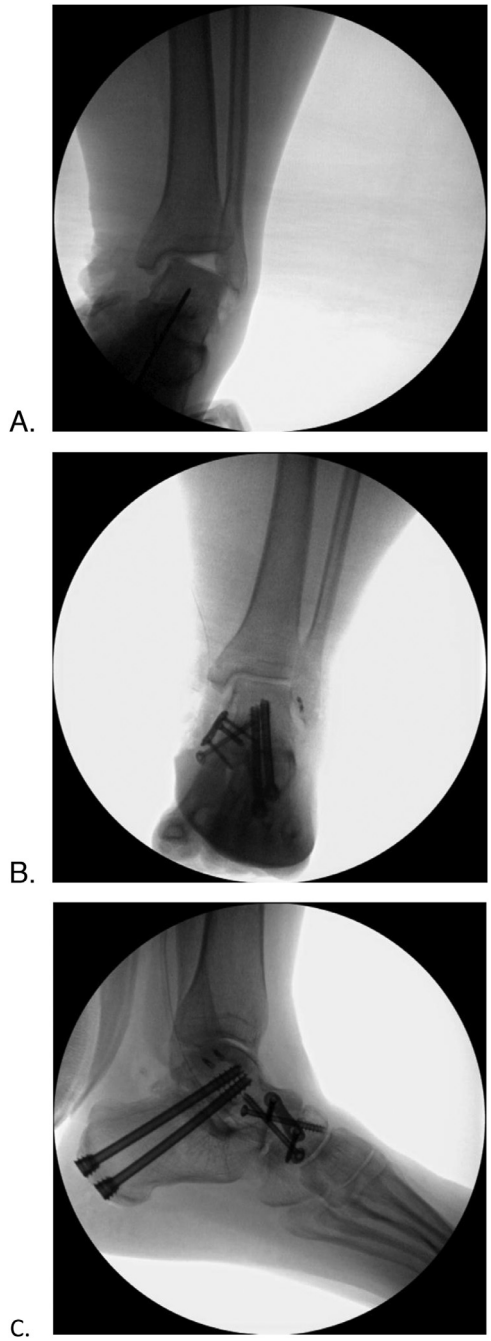

Fig. 3. Intraoperative radiographs status post flatfoot reconstruction with lateral ankle stabilization. (*A*) Stress radiograph of ankle. (*B*) Anteroposterior ankle view. (*C*) Lateral ankle view.

lack of follow-up on the patient population. Further research including the rate of ankle arthritis and lateral ankle instability following adult flatfoot reconstruction would have been valuable. The senior authors within the study primarily treat tertiary referrals from outside practitioners; thus, our study represents a more advanced disease group compared with the standard population. Finally, our study is limited in that although the MRI results show inflammation and disease to the lateral ankle ligaments, minimal clinical evaluation of the ankle ligaments is documented. Future studies including both MRI and clinical evaluation of the lateral ankle ligaments would be beneficial.

In conclusion, although previous research has attributed lateral ankle pain in adult-acquired flatfoot to subfibular impingement, this study demonstrates a relatively high incidence of lateral ankle ligament disease that may be responsible for a portion of the patient's symptoms. This was identified more frequently in stage 2 deformity. These findings might have long-term implications regarding ankle arthritis following surgical management of adult-acquired flatfoot. Further studies to investigate the significance of our findings might include lateral ankle ligament stress testing in those patients with positive MRI findings (Fig. 3). Additionally, radiographic evaluation for ankle arthritis after adult-acquired flatfoot surgery comparing patients with and without lateral ankle stabilization would be worthwhile.

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