**Anatomy of the lateral plantar ligaments of the transverse metatarsal arch. The lateral Lisfranc ligament**

**Abstract**

Whilst the anatomy of the Lisfranc complex is well understood, the lateral tarsometatarsal ligamentous structures, in contrast, are less well studied. Our aim in this study was to identify an anatomical explanation as to why the 2nd to 5th metatarsals function as a unit in homolateral and divergent midfoot injuries.

**Methods**

Eleven cadaveric lower limbs, preserved in formaldehyde, were examined at the University of Liverpool Human Anatomy and Resource Centre. Each of the lower limbs were dissected to identify the plantar aspect of the transverse metatarsal arch.

**Results**

On removal of the long plantar ligament, the peroneal longus tendon was visible as was its insertion onto the 1st metatarsal base. A lateral Lisfranc (which was a transverse suspensory metatarsal ligament) spanned between the **bases of the** 2nd and 5th metatarsals in all specimens with an average length of 33.7mm and width of 4.6mm. This ligament has not previously been described in the literature. It was noted that in all specimens, that the long plantar ligament blended with the lateral Lisfranc ligament. In addition to the lateral Lisfranc ligament, separate intermetatarsal ligaments were identifiable connecting each metatarsal.

The long plantar ligament provides a connection through the lateral Lisfranc ligament connecting the transverse and longitudinal arches of the foot.

**Conclusion**

In conclusion, we have found a plantar ligament, that provides connection, through the long plantar ligament, of both the transverse and the longitudinal arches. Its spanning from the 2nd to the 5th metatarsal explains **the observation that in some cases lateral instability can be overcome when the middle column is stabilised**.

Keywords

Lisfranc, Lateral Lisfranc, tarsometatarsal ligament, injury, transverse metatarsal arch

**Introduction**

The tarsometatarsal articulation (Lisfranc joint) is a complex interplay of articular congruity, ligaments and supporting tendons. The 2nd metatarsal is the keystone to the transverse metatarsal arch, and its site and ligament attachments are crucial to the function and stability of the midfoot. The ligamentous anatomy of the tarsometatarsal joint is complex and has been described as being variable in its course.9 The Lisfranc ligament is considered to be the primary stabiliser of the midfoot. The Lisfranc ligament is an interosseous ligament, originating from the lateral aspect of the medial cuneiform and inserting on the medial aspect of the second metatarsal base.3 De Palma et al also described additional dorsal and plantar ligaments supporting the Lisfranc ligament, although biomechanical studies have shown the Lisfranc ligament to be stronger and stiffer than the supporting ligaments.13

The tarsometatarsal joint complex can be divided in to three columns based on their relative movement. **Chiodo** and Myerson proposed a classification in 2001 based on columns with the medial column comprising of the 1st metatarsal and medial **cuneiform** articulation, the middle column comprising the 2nd and 3rd metatarsal articulation with intermediate and lateral cuneiform and lateral column (4th and 5th metatarsal and cuboid articulation).2 Ouzounian’s analysis of the differing motion showed the middle column to be the most stable with approximately 0.6 mm of dorsal-plantar sagittal plane motion, the medial column with a greater degree of movement of approximately 3.5 mm of sagittal motion and the lateral column with the greatest degree of movement of approximately 13 mm in the sagittal plane. 11

In our department we have undertaken the treatment of Lisfranc injuries based on the above column theory. We observed that in the divergent and homolateral injuries as described by Hardcastle5 and Myerson10, the middle and lateral column act together in the majority of cases (figure 1). Although the ligaments of the medial aspect of the transverse arch have been extensively investigated, the lateral aspect of the transverse arch has not received the same level of scrutiny. The studies that do comment on the middle and lateral columns state that the stability of the middle and lateral columns is maintained by individual intermetatarsal ligaments.14 Our aim in this study was to identify an anatomical explanation as to why the 2nd to 5th metatarsals function as a unit in homolateral and divergent midfoot injuries.

**Methods**

The study was performed in the Human Anatomy Resource Centre at the University of Liverpool. Images were taken with permission, under the Human Tissue authority licence held by the Human Anatomy Resource Centre. We dissected 11 formalin embalmed unpaired cadaveric feet. All the feet used in our study were amputated at the level of the proximal tibia. All feet were morphologically normal, without any surgical scars or signs of previous trauma. Tissue was obtained from cadavers bequeathed under the regulations of the Human Tissue Authority, UK to the University of Liverpool.

**Dissection**

Dissection was undertaken by four individuals, two trained anatomists and two foot and ankle surgeons. Each dissection was undertaken in the same sequence for all cadaveric specimens. Any variation in anatomy was discussed by all authors and documented. Dissection was commenced by initially lifting the skin from above the malleoli, posteriorly, extending across the planter aspect of the foot to the metatarsal heads. On the lateral side the superior and inferior peroneal retinaculum was carefully dissected and the peroneus longus and brevis inspected. The **plantar** aponeurosis and the 1st and 2nd plantar layers were then dissected and excised. Upon reaching the 3rd layer the peroneus longus tendon was once again identified behind the lateral malleolus and then followed down in to the plater aspect of the foot. In all specimens we found that the long plantar ligament formed the roof of the peroneus longus canal, blending with the canal before inserting on the metatarsal bases.

The long plantar ligament and peroneus longus canal were carefully removed in combination with the peroneus longus tendon to allow observation of the ligamentous attachments of the metatarsal bases. The observed ligaments were measured using a digital caliper accurate to 0.1mm.

**Results**

Upon removal of the long planter ligament, and subsequent deroofing of the peroneus longus canal, the peroneus longus could be easily traced to its insertion on the peroneus longus tubercle on the 1st metatarsal base. This was present in all cases (figure 2). Careful dissection of the peroneus longus tendon out of its canal, allowed identification of an obvious ligament originating from the 5th metatarsal base and inserting on the lateral plantar aspect of the 2nd metatarsal (figure 3). We have termed this ligament the lateral Lisfranc ligament (a transverse suspensory metatarsal ligament). This ligament was present in all 11 specimens. The average length of the ligament 33.7mm. The average width of the ligament was 4.6mm in the middle portion of the ligament as it spans from the 2nd to the 5th metatarsal. All specimen measurements are seen in table 1.

The lateral Lisfranc Ligament formed the basis of the floor and distal aspect of the peroneus longus canal. The ligament fibres were distinct in comparison to the peroneus longus tunnel sheath, and with careful dissection we were able to remove the tunnel sheath without damage to the ligament. The lateral ligament origin on the 2nd metatarsal base was distinct. On removal from its insertion it was possible to peel the ligament laterally, with no obvious connection to the 2nd, 3rd and 4th metatarsal bases until its further insertion on the 5th metatarsal base. Figure 4 illustrates the suspensory effect of the lateral Lisfranc ligament. On removal of the lateral Lisfranc ligament separate intermetatarsal ligaments were identifiable connecting each metatarsal, as described in the literature.1, 14

The long plantar ligament blends partially with the lateral Lisfranc ligament on the medial third of the ligament in all specimens **(Figure 5).** This was associated with the crossing of the peroneus longus tendon across the lateral Lisfranc ligament, with no blending of fibres lateral to the crossing. The long plantar ligament had further insertions on the metatarsal bases of the lateral column. This relationship provides a deep ligamentous connection through the lateral Lisfranc ligament, connecting the transverse metatarsal arch to the longitudinal arches of the foot.

**Discussion**

The finding of the lateral Lisfranc ligament has significant clinical ramifications. The three column classification theory of midfoot injuries by Chiodo and Myerson, has been expanded by Schepers and Rammelt who also proposed a column method based on the literature of biomechanics at the tarsometatarsal level.2, 12 We suspect that in the majority of homolateral and divergent types of tarsometatarsal injuries that the lateral Lisfranc ligament to remain intact. Based on the column classification, the middle and lateral columns are bound by the lateral Lisfranc ligament and as such the reduction and stabilisation of the middle column will usually normalise the lateral column without intervention. Mayne et al. undertook a cadaveric study on the stability of the Lisfranc injury, and as part of the study divided the 2nd, 3rd and 4th intermetatarsal ligaments.8 When dorsal displacement was further tested, only the 3rd tarsometatarsal joint showed an increase in movement. This finding is now explained with the discovery of the lateral Lisfranc ligament as it suspends the 3rd metatarsal.

In our analysis of the lateral component of the transverse metatarsal arch showed the lateral Lisfranc ligament combines with the long plantar ligament, connecting the transverse arch to both longitudinal arches. Gwani et al found on a radiographic study of 76 participants that the deformation or elevation of the medial arch consequently resulted in similar movements of the lateral and transverse arches and vice versa. 4 This finding was explained by the authors to occur due to the Windlass mechanism. Welte et al also identified an interplay between the windlass and arch-spring mechanisms that aids in regulation of energy storage within the foot.15 The finding of the connection between the lateral Lisfranc ligament and the long plantar ligament adds another **possible** facet to why the arches of the foot have synchronous movement.

Ker et al described the functioning medial longitudinal arch as working in a similar way to a spring, gaining the energy during the contraction phase and then releasing part of it in the push-off phase.7 They concluded that dysfunction of the medial arch worsens dynamism and energy usage during the walking or running gait. **It is possible that the** orientation of the lateral Lisfranc ligament, means that during a normal gait cycle, it will stretch in stance phase and release this energy in push off phase. Holowka et al found in a kinematic comparison study between humans and chimpanzees, that the push off phase of gait was driven in humans by a dramatic plantarflexion and adduction of the midfoot joints during the second double-limb support period. 6 Although primarily driven by the interplay between the peroneus longus and tibialis posterior muscles, the lateral Lisfranc ligaments orientation means as the transverse metatarsal arch shortens during push off there would be a release of energy resulting in a crimping of the midfoot, thus increasing the rigid lever arm of the forefoot.

The intermetatarsal ligaments of the lesser rays have been previously investigated. Authors describe the dorsal tarsometatarsal ligaments to occur in seven to nine distinct bands, the interosseous intermetatarsal ligaments to occur in 4 distinct bands, and the plantar tarsometatarsal bands to occur in 9 separate bands. 1, 14, 16 None of these previous studies have mentioned the lateral Lisfranc ligament. We cannot identify any previous description of the lateral Lisfranc ligament in the literature. We feel its previous description may have been overlooked due to its association with the long plantar ligament and peroneus longus canal. When the peroneus longus is being removed with its canal, in previous investigations, we suspect it was removed en bloc to further assess the plantar intermetatarsal and tarsometatarsal ligaments.

**Conclusion**

In conclusion, we have found a plantar ligament, that provides connection, through the long plantar ligament, of both the transverse and the longitudinal arches. Its spanning from the 2nd to the 5th metatarsal explains **that in combination with the intermetatarsal ligaments** the homogenous nature of a divergent tarsometatarsal joint injury and why middle and lateral columns **often** move as one. This study has clinical significance in the observation that in some cases, **lateral column instability** can be overcome when the middle column is stabilised.

**References**

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**Figures**

Figure 1 – Pre and post-operative radiographs, showing displacement of the middle and lateral columns, which normalise with reduction and fixation of the middle column.

Figure 2 – Dissection of the plantar aspect of the foot with removal of layers 1 and 2. The long plantar ligament has been removed, showing the course of the peroneus longus tendon and its insertion on the 1st metatarsal. The lateral Lisfranc ligament is visible under the peroneus longus tendon.

Figure 3 – 2 examples of plantar dissection with the peroneus longus tendon removed. The lateral Lisfranc ligament is clearly demonstrated in both cases transversing the plantar aspect of the transverse metatarsal arch from the 2nd to the 5th metatarsal.

Figure 4 - Schematic of the cross-section and 3D anatomy of the lateral Lisfranc ligament showing its suspensory attribute from the 2nd to the 5th metatarsal. It creates a suspensory effect across the transverse metatarsal arch, therefore any loss of arch due to fracture or displacement will detension this structure. This also illustrates the importance of the 2nd metatarsal in the transverse metatarsal arch.

**Figure 5 – Staged dissection of the plantar aspect of the foot with coloured references showing the long plantar ligament (LPL), peroneus longus (PL) and Lateral Lisfranc ligament (LLL). The images are orientated with the calcaneum superiorly, 1st metatarsal (1st MT) lower left and 5th metatarsal (5th MT) lower right. Image a (upper and lower) shows the LPL traversing across the plantar aspect of the foot from the calcaneum to the forefoot, covering the peroneus longus PL and LL. Image b (upper and lower) shows the long plantar ligament has been cut and the PL has been removed from its tunnel and reflected over the 1st metatarsal, from its insertion, in the lower left hand corner. Image c (both upper and lower) shows the LPL has been reflected inferiorly with forceps, revealing the extent of the LLL and on the LPL insertion into the medial aspect of the LLL.**