P45 technology reveals bow-and-arrow sign in human ankle

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To the Editor: Recent studies have shown that the morphology of bone *in vivo,* including the shape, diameter, length, curve, and alignment of the bone, adapt to long-term loads both before and after skeletal maturity. The deformation and rate are different according to the magnitude of strain, the mode of action, position and the quality of bone of the strain, which is named by law of dynamic deformation of bone.[1] Here, we found that the existence of circular bone trabecula in the calcaneus by P45 plastination technology. It might be caused by the force conduction to the flexor digitorum brevis during the contraction of the triceps surae according to this law.

P45 plastination technology is a tissue sectioning technology that enables the specimen to be closer to its natural state, and visualizes the clear and accurate anatomical structures for observation.[2] In current clinical anatomy research, in most cases, it is still necessary to manually dissect the relevant structures/tissue to analyze the anatomical information. However, for technical reasons, manual dissection could not guarantee the integrity and clarity of tissue, especially in the study of soft tissue. As a result, manual dissection often fails to preserve a clear boundary. P45 technology can make up for this deficiency. So far, due to the high structural integrity and clear imaging of soft tissue on P45 sections, this technology has been widely applied to scientific research.[3] Based on the sagittal P45 plastination sections of four human feet, this study found that the mechanical model of human ankle was similar to that of a tensioned bow with an arrow. Clinically, the discovery of this mechanical model might have significant implications for fascia-related researches.

The triceps surae includes gastrocnemius and soleus, the soleus starts from the supraposterior part of the fibula and tibia, and muscle fibers of soleus extended downward with the tendon of gastrocnemius to merge the Achilles Tendon, which ends at the calcaneus. The triceps surae contribute to stability of the ankle and knee joints preventing the body from lean forward. At the sole of foot, the flexor digitorum brevis starts from the calcaneus and ends at the base of the 2nd to 5th middle phalange. When walking or running, the flexor digitorum brevis forms a "trampoline" under the foot arch, which can alleviate the shocks to the foot arch. Generally, the calcaneus seems to be a compression strut to the ankle joint, undertaking the double force from the Achilles Tendon and the flexor digitorum brevis [Figure 1A and 1B].

In recent years, some scholars speculated that the dynamic deformation of human bones is a long-term physiological activity in either developing and matured bones, lead to constant changes in mass, density, morphology, hardness, and strength of human bones.[3] Mechanical stimulation has a great influence on bone growth, and trabeculae bone are arranged along the direction of principal stress. During a particular exercise or daily walking, the flexor digitorum brevis is elongated when the plantar flexion, storing elastic potential energy for the next dorsiflexion and alleviating the shocks to the foot arch. While walking, with the traction forces coming from the Achilles Tendon and the flexor digitorum brevis, the calcaneus is pushed forward to the tibiotalar fulcrum, balancing the tension forces of the muscles in posterior tibial area, as an arrow was pushed by the tautened bowstring [Figure 1B]. Therefore, the triceps surae and the flexor digitorum brevis muscle were bow strings, the calcaneus was the arrow, and the tibia-talus-scaphoid-toe constituted the arch stalk, which was also consistent with the previous myofascia chain.[4] Up to date, research information regarding fascia *in vivo* was limited, lead to a faint understand of fascia and adjacent tissues. This lack of anatomical information was an obstacle for understanding the mechanical relationship between fascia and joints. According to Wolff law, the trabecular bone should be arranged with the main loading, which is in vertical direction. In this study, as shown on the application P45 plastination sections, we confirmed the existence of circular bone trabecula in the inferoposterior part of the calcaneus, which might be caused by the force conduction to the flexor digitorum brevis during the contraction of the triceps surae.

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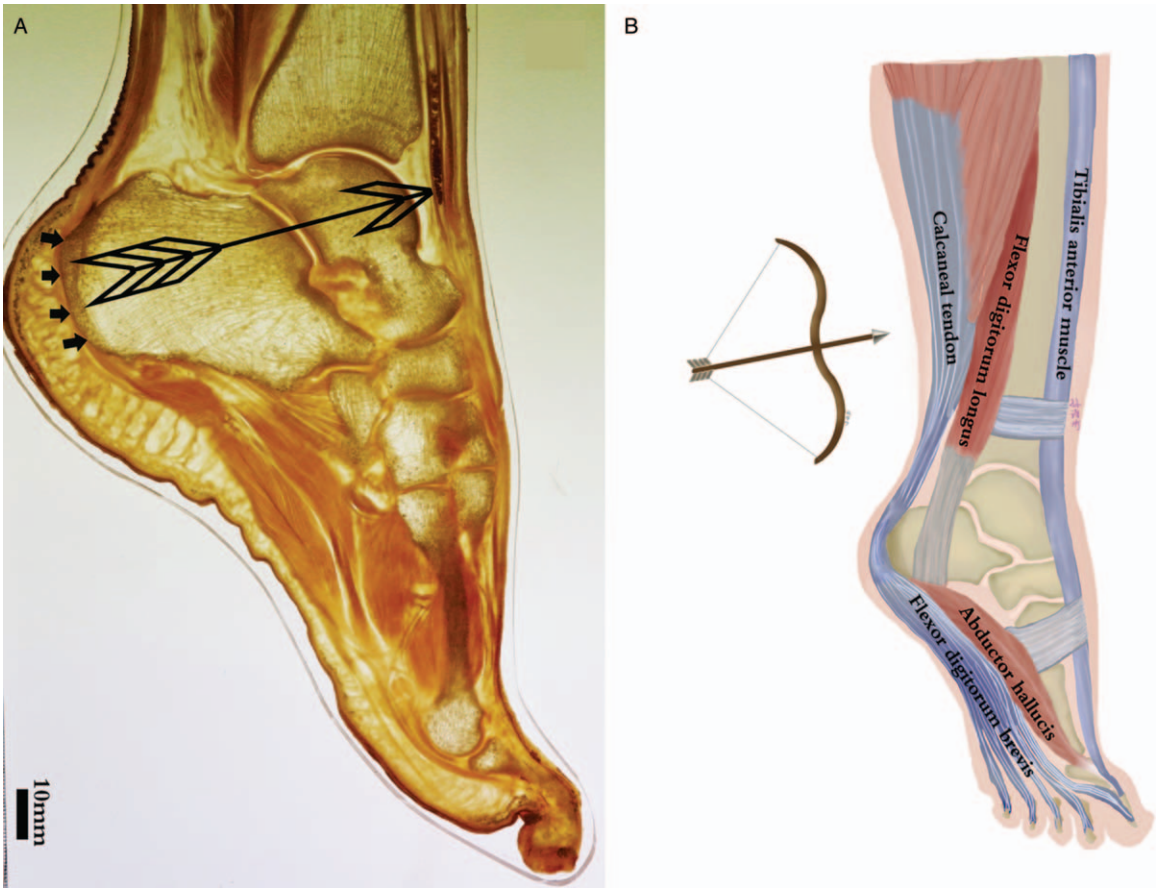

Figure 1: Ankle paramedian sagittal P45 plastination section and pattern diagram. (A) The paramedian sagittal P45 plastination section of foot. Arrow: While walking, with the traction forces coming from the Achilles Tendon and the flexor digitorum brevis, the calcaneus is pushed forward to the tibiotalar fulcrum, balancing the tension forces of the muscles in posterior tibial area, as an arrow was pushed by the tautened bowstring. Arrow head: circular bone trabecular; (B) Pattern diagram of foot. The triceps surae and the flexor digitorum brevis muscle were bow strings, the calcaneus was the arrow, and the tibia-talus-scaphoid-toe constitute the arch stalk.

The discovery of bow-and-arrow sign of the ankle joint allows physical therapists to optimize the treatment by better understanding the mechanical mode of the ankle joint against some unexplained pathologies caused by improper posture problems of knee and/or ankle. In the adjustment of patients with flatfoot and high arch, in addition to restoration of the function of the flexor digitorum brevis, it is significant to evaluate the condition of the patient's knee joint, such as varus knee, valgus knee. Moreover, since there is no unified treatment for calcaneal fractures,[5] treatment effects are different as well, this makes the clinicians hard to evaluate the treatment efficiency. As a result, the discovery of the special mechanical properties of calcaneus, which termed as "bow-and-arrow sign," could be essential for unification and evaluation of the therapeutic treatment to calcaneus fracture.

Collectively, bow-and-arrow sign may be an inspiring discovery to further understand the "myofascial line," and provides new visions on the treatment of calcaneal fracture.

Conflicts of interest

None.

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