The calcaneonavicular (spring) ligament complex is the soft tissue most often seen to fail in flatfoot pathology and is associated with deformity of the talonavicular joint. The spring ligament complex supports the talar head, preventing it from displacing into excessive plantar flexion/adduction. An anatomical reconstruction of the spring ligament should replicate this function. A new method of spring ligament reconstruction using autogenous flexor hallucis longus tendon transfer is reported. [Orthopedics. 2014; 37(7):467-471.]

The calcaneonavicular (spring) ligament complex functions to support the talar head, preventing it from displacing into excessive plantar flexion/adduction. An anatomical reconstruction of the spring ligament should replicate this function. However, successful reconstruction of this ligament has not been consistently achieved. Thus, there is a need for an ideal method to reconstruct the attenuated or torn spring ligament in treating this disorder.

A new method of spring ligament reconstruction wherein static and dynamic stabilization of the medial longitudinal arch is restored using autogenous flexor hallucis longus (FHL) tendon transfer is reported.

**Materials and Methods**

Spring ligament reconstruction was performed for adult patients with symptomatic flexible planovalgus deformity. To be included to undergo this type of surgery, patients had to meet either of the following criteria: (1) spring ligament rupture confirmed on magnetic resonance imaging (MRI) or (2) spring ligament dysfunction defined as talar head adduction and plantar flexion as seen on weight-bearing anteroposterior (AP) and lateral radiographs of the foot even if spring ligament continuity is present on MRI.

**Surgical Technique**

The patient was placed on the operating table in a semi-lateral position with the ipsilateral buttock elevated for medial displacement calcaneal osteotomy. After this procedure, the supporting bar and sandbag were removed. The patient was placed in supine position with the leg externally rotated. A curvilinear incision was made along the course of the FHL tendon at the level of the medial malleolus, which was extended to the navicular tuberosity and then to the base of the first metatarsal. Dissection was deepened to the posterior tibial tendon and its insertion into the naviculum. When there was a tibialis posterior tendon (PTT) rupture or diastasis of the accessory navicular from the navicular, the spring ligament was immediately exposed. When the PTT was intact, it was retracted and integrity of the spring ligament was confirmed. The spring ligament was either ruptured at the navicular attachment or slackened, which was clearly visualized by inversion of the foot. When there was no clear rupture of the spring ligament, a biopsy specimen was taken from the superficial layer...
of the spring ligament at the attachment into the navicular.

Another medial longitudinal incision was made from the first metatarsophalangeal joint to approximately 5 mm distal to the interphalangeal joint of the big toe. The FHL tendon was exposed at the plantar surface of the proximal phalanx of the big toe and cut at the level of the first metatarsophalangeal joint. A bone tunnel was made at approximately 1 cm proximal to the metatarsophalangeal joint using a 3-mm drill bit. The distal stump of the FHL was longitudinally separated along its midline cleavage line and half of it was passed from plantar to dorsal through the bone tunnel. It was then sutured to the other half for tenodesis at the end of surgery with the interphalangeal joint in neutral position.

The FHL was exposed at the midsole after plantar retraction of the abductor hallucis (Figures 1A). Krakow-suture weave is placed through the FHL tendon with nonabsorbable suture and pulled out through the proximal incision for harvesting (C).

The distal end of the FHL tendon was retrieved from the midsole and dissected from surrounding fascial tissues proximally to the sustentaculum tali (Figures 1B-C).

The dorsomedial aspect of the medial cuneiform and navicular was exposed by elevating the dorsal skin and subcutaneous flap, then drill holes (Figure 2A) were made for tendon passage through the medial cuneiform and naviculur. First, a hole with a diameter of 4.0 mm was made from dorsal to plantar approximately 7 mm distal to the medial cuneonavicular joint (B). Second, an oblique 4.0-mm diameter hole is made on the medial aspect of the navicular, starting dorsally and ending plantarly at the navicular tuberosity (C). Third, another hole is made at the sustentaculum tali from medial to lateral (D). Last, a guide pin is placed at the sustentaculum tali and its position checked under an image intensifier (E).
Figure 2C). Last, a hole was made at the sustentaculum tali from medial to lateral (Figure 2D). A guide pin was placed at the sustentaculum tali and its position checked under an image intensifier (Figure 2E). A hole with a diameter of 5.0 mm was made along the guide pin at the sustentaculum tali.

After tunnel creation, the graft insertion passed through these tunnels according to the sequence shown in Figure 3A. The FHL tendon was passed from plantar to dorsal through the medial cuneiform (Figure 3B), then dorsal to plantar through the naviculum (Figure 3C), and then medial to lateral through the sustentaculum tali (Figure 3D).

The tendon transfer was tensioned by pulling the non-absorbable suture while adducting the transverse tarsal joints and inverting the subtalar joint (Figure 3A). Preference is given to tensioning the tendon halfway between maximal and minimal tension. The graft was secured to the sustentaculum tali using a 5.5-mm bioabsorbable interference screw (Arthrex Ltd, Sheffield, United Kingdom). Additional fixation can be applied to the medial cuneiform and naviculum to ensure further stability of the graft (Figure 3A).

The sheath was closed in its entirety with absorbable suture, the abductor hallucis fascia was reapproximated, and the subcubaneous tissue and skin were closed in a standard manner. After wound closure, a short leg, well-padded, non-walking cast is applied. The authors recommend removing the cast, sutures, and pins at 3 weeks and applying a new short leg cast in which the patient is allowed protected weight bearing for an additional 3 weeks. The foot is examined radiographically; if the osteotomy has healed, no further casting is needed.

Discussion
The mechanical integrity of the medial longitudinal arch depends on the dynamic support of muscles, the static support of ligaments and joint capsules, and the manner in which the tarsal bones interlock. The
posterior tibial muscle-tendon unit is the main dynamic stabilizer of the hindfoot. After rupture of the posterior tibial tendon, the ligaments and joint capsules appear to tear, stretch, or rupture under increased stress. On the other hand, the spring ligament may fail before PTT dysfunction and excessive tension on the PTT may cause dysfunction. Failure of the PTT, the spring ligament, or both could lead to flatfoot deformity characterized by valgus alignment of the calcaneus, plantar flexion of the talus, and abduction of the forefoot with a resultant pronation deformity of the foot.2

The spring ligament complex has 2 distinct anatomical regions: the superomedial fibers and the inferior fibers. The superomedial fibers are the stronger and larger of the 2, originating from the superomedial aspect of the sustentaculum tali and anterior facet of the calcaneus to insert broadly on the edge of the medial navicular. The inferior fibers course from the anterior aspect of the sustentaculum tali to the inferior surface of the middle of the navicular. Together, the entire spring ligament complex provides the “sling like” support function for the talar head, preventing it from displacing into excessive plantar flexion/adduction. An anatomical reconstruction of the spring ligament should replicate this function.4

Several surgical treatment methods have been devised to mimic the function of the nor-
mal spring ligament. However, no spring ligament reconstruction technique has been shown to give consistent clinical success. Reconstruction using the peroneus longus tendon as a graft has been reported.\(^5\) Choi et al\(^5\) reported that the plantar reconstruction procedure routes the peroneus longus tendon in such a manner as to replicate the plantar fibers of the spring ligament complex, from the insertion at the base of the first metatarsal to the calcaneus; this serves to reinforce the “base” of the arch. However, it is unknown whether a procedure can be used that both reconstructs the entire spring ligament complex and corrects abduction of the talonavicular joint. Deland et al\(^6\) speculated that reconstruction of attenuated ligaments in conjunction with the tendon transfer might provide better results. Spring ligament reconstruction was done by transferring a portion of the superficial part of the deltoid ligament, with an attached bone plug, to the plantar medial aspect of the navicular. However, early clinical results with this type of reconstruction were disappointing. Deland\(^1\) suggested that the deltoid graft was not strong enough in patients with a relatively large deformity, and he recommended using it only for slight deformity. Because of this problem, he described a technique of reconstruction of the spring ligament with a free Achilles-tendon graft placed through drill holes in the navicular and calcaneus. However, he did not describe clinical or biomechanical results.

On examination, it is valuable to elicit the patient’s inability to perform single heel rise on the affected foot without pain or difficulty. Radiographic parameters that can be assessed include the standing AP talonavicular coverage angle and the AP-lateral talo-first metatarsal angle. In the current study, once the criteria to undergo this operation were fulfilled, additional imaging techniques were used, including the hindfoot alignment view, which usually revealed heel valgus. For its correction, the authors first performed a medial sliding calcaneal osteotomy.

The authors chose the FHL tendon for spring ligament reconstruction because of its origin from the deep posterior compartment of the leg, similar to the PTT. Both muscles have a synergistic action to plantar flex the ankle due to their similar line of pull. The authors positioned the graft between the anatomic location of the superomedial and inferior fibers of the normal spring ligament. They believe that this placement eliminates the need to separately reconstruct both components. In this position, the FHL tendon acts as a static stabilizer by serving as a buttress over the talonavicular articulation, thereby preventing talar head adduction (Figure 5) and plantar flexion (Figure 6). In the same way, the tendon also serves to dynamically stabilize the midfoot, especially during the stance phase of gait wherein the pull of the muscle elevates the longitudinal arch (Figure 7).

The procedure was performed in 23 patients. Long-term outcome is still unknown. Initial short-term assessment was done at a mean of 8.2 months (range, 6 to 13 months) postoperatively. The American Orthopaedic Foot & Ankle Society score had improved to 86.4°±3.31° (from 72.6°±7.05° preoperatively) at the last follow-up. Preoperatively, on weight-bearing AP and lateral radiographs, the mean±SD of the AP talo-first metatarsal angle, lateral talo-first metatarsal angle, and talo-navic-ular coverage angle were 21.8°±5.69°, 22.6°±11.34°, and 33.7°±17.64°, respectively. Postoperatively, the respective angles were 13.3°±6.04°, 9.0°±9.33°, and 20.8°±11.42°. Although clinical and radiological results improved in all cases, additional procedures such as lateral column lengthening or subtalar fusion may be necessary to obtain complete correction of radiological parameters.

Spring ligament reconstruction using the FHL tendon is a viable and effective method to restore the function of the normal calcaneonavicular ligament complex.

**REFERENCES**