ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Author's translation
Acta Orthop Traumatol Turc 2007;41(4):259-265

Surgical restoration of drop foot deformity with tibialis posterior tendon transfer

Düşük ayak deformitesinin posterior tibial tendon transferi ile düzeltilmesi

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Amaç: Düşük ayağın cerrahi tedavisinde posterior tibial tendonun ayak bileği önünde felçli tendonlara transferi, sadece felç olmuş kasların işlevini restore etmekle kalmamakta, aynı zamanda ayağın medialindeki deforme edici kuvveti de ortadan kaldırmaktadır. Çalışmamızda düşük ayak nedeniyle posterior tibial tendon transferi uygulanan olgular değerlendirildi.

Çalışma planı: Düşük ayak sorunu nedeniyle posterior tibial tendon transferi yapılan 41 hasta (24 erkek, 17 kadın; ort. yaş 32; dağılım 11-73) çalışmaya alındı. Olgularda ortalama paralizi süresi 51.5 aydı (dağılım 4-240 ay). Ameliyat öncesi düşük ayak açısı ortalama 30.9° (dağılım 15°-55°) idi. Posterior tibial tendonu, insersiyon noktasından ayırılıp kruris orta hatta proksimale, sonra da sirkumtibial yoldan ayak dorsaline taşınarak iki dala ayırıldı. Dallardan biri anterior tibial tendona, diğeri de ekstansör hallusis longus, ekstansör digitorum longus ve peroneus tertius tendonlarına transfer edilerek tespit yapıldı. Tendon transferi sonuçları Carayon ve ark.nın ölçütlerine göre değerlendirildi. Ortalama takip süresi 107.9 ay (dağılım 12-254 ay) idi.

Sonuçlar: Ameliyat sonrası aktif dorsifleksiyon açısı ortalama 7.6°, plantar fleksiyon açısı 21.8°, iki açının toplamı 30.4° bulundu. Sonuçlar altı ayakta (%14.6) mükemmel, 23 ayakta (%56.1) iyi, yedi ayakta (%17.1) orta, beş ayakta (%12.2) kötü idi.

Çıkarımlar: Düşük ayakta posterior tibial tendon transferi ile, ayakta aktif dorsifleksiyonun yeniden kazandırılmasında ve parmakların fleksiyon deformitesini önlemekte oldukça başarılı sonuçlar elde edilmektedir.

Anahtar sözcükler: Ayak bileği/cerrahi; düşük ayak/etyoloji/cerrahi; ayak deformitesi, edinsel; peroneal sinir; tendon transferi/yöntem; tendon/cerrahi.

Objectives: The transfer of the tibialis posterior tendon to the paralysed tendons on the anterior aspect of the ankle not only restores the function of the paralyzed muscles, but also removes the deforming force on the medial aspect of the foot. In this study, we evaluated patients who underwent tibialis posterior tendon transfer for the treatment of drop foot.

Methods: The study included 41 patients (24 males, 17 females; mean age 32 years; range 11 to 73 years) who underwent tibialis posterior tendon transfer for drop foot. The mean duration of paralysis was 51.5 months (range 4 to 240 months). The mean preoperative drop foot angle was 30.9° (range 15 to 55 degrees). The tibialis posterior tendon was first detached from its insertion and carried proximally on the crural midline, then transferred to the dorsum of the foot through the circumtibial route, where it was split into two parts. One strip was attached to the tibialis anterior tendon, and the other to the extensor hallucis longus, extensor digitorum longus, and peroneus tertius tendons. The results were evaluated according the criteria of Carayon et al. The mean follow-up was 107.9 months (range 12 to 254 months).

Results: The mean postoperative active dorsiflexion was 7.6°, plantar flexion was 21.8°, and their sum was 30.4°. The results were excellent in six feet (14.6%), good in 23 feet (56.1%), moderate in seven feet (17.1%), and poor in five feet (12.2%).

Conclusion: Tibialis posterior tendon transfer in drop foot yields highly successful results in the restoration of active dorsiflexion and prevention of flexion deformity in the toes.

Key words: Ankle joint/surgery; clubfoot/etiology/surgery; foot deformities, acquired; peroneal nerve; tendon transfer/methods; tendons/surgery.

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Submitted / *Başburu tarihi:* 09.10.2006 **Accepted / *Kabul tarihi:*** 28.06.2007

Irreversible lesions of the peroneal nerve or the dorsiflexor muscles of the foot and ankle result in loss of foot dorsiflexion and eversion, a condition known as drop foot.[1,2]As a result, the foot cannot be adequately lifted off the ground during swing phase of walking. An extra flexion of the hip and knee is thus required with ipsilateral elevation of the hip. Walking is facilitated with foot-ankle orthosis that prevents plantar flexion more than neutral.[3] In time, with the contribution of tibialis posterior tendon, equinovarus deformity develops.[4,5]

The aim of treatment in drop foot is dorsiflexion of the foot and restoration of normal heel-toe gait.[6,7] Tenodesis, arthrodesis, and tendon transfer are among surgical treatment options for drop foot.[8-10] Anterior transfer of tibialis posterior tendon both serves to adequately restore lost tibialis anterior muscle function, and to eliminate a potent deforming force on the medial aspect of the foot.[5]

The first tendon transfer for the treatment of drop foot was described by Ober in 1933. Ober transferred the tibialis posterior tendon through the circumtibial route and inserted it on the third metatarsal bone. Ober carried the posterior tibial tendon anteriorly through the circumtibial route and inserted to the third metatarsal bone. In 1954 Watkins made the same transfer via the interosseous route. Successful results with both techniques are reported in the surgical treatment of drop foot.[6,8,11,12] The pathway of the transferred tendon (circumtibial versus interosseous), type of insertion (re-insertion of tendon to bone versus tendon to tendon suture), the recipient tendons (tibialis anterior per se versus tibialis anterior/toe extensors/ peroneus longus and brevis tendons) and the tension of the transfer are important technical aspects still debated today.[13]

In this study, our preferred technique of tibialis posterior transfer for the treatment of drop foot and retrospective analysis of 41 cases are presented.

Patients and methods

A total of 63 patients underwent tibialis posterior transfer between 1981-2004, and among these, 41 cases who had at least 1 year follow up were included in the study. There were 24 males and 17 females. Mean age was 32.4 (11-73). The paralysis was in the right foot in 19 patients and left foot in 22. Mean duration of paralysis was 51.5 (4-240 months). Drop foot was due to leprosy in 9 patients, laceration in 7, gunshot in 5, crush injury due to traffic accident in 4, disc hernia sequela in 4, disc hernia surgery sequela in 3, iatrogenic injury in 3, earthquake injury in 2, blunt injury in 1, tumor resection in 1, complication of cast in 1, and injection sequela in 1. Mean preoperative drop foot angle was 30.9 ° (15-55).

Preoperative evaluation and rehabilitation

Goniometric measurements in preoperative evaluation are performed with the patient lying supine. The vertical axis of the foot is accepted zero degrees. According to this, in cases where dorsiflexion is less than neutral, dorsiflexion is expressed as negative values.[9] Exercises for isolated use of the tibialis posterior tendon were taught to the patient and strengthening exercises were applied (Figure 1). In patients who had passive dorsiflexion less than 20°, achilles tendon stretching exercises were performed. Musculoskeletal stability, foot and ankle x-rays were evaluated.

Surgical technique

In patients who have inadequate passive range of motion in the ankle joint, the first procedure is "Z" lengthening of the Achilles tendon using standard and open technique to provide unlimited extension of the ankle.[7]

Tendon transfer procedure is made using 3 incisions (Figure 2a): the first incision, 3-4 cm long, is made on the navicular bone on the medial aspect of

Figure 1. Isolated contraction and strengthening of tibialis posterior muscle.

bone. The insertion point of tibialis posterior (TP) tendon on tuberosity of the navicular bone is reached (Figure 2b); the tendon is detached from the insertion point, and when necessary, the tip is thinned (Figure 2c) and finally freed. A second 10 cm long incision is made on the cruris, with the distal edge ending 4-5 cm above the medial malleolus (Figure 2d). The deep fascia is cut a few millimeters medial to the tibia, and a suitable bed for the gliding of tendon is created (Figure 2e). Flexor digitorum longus muscle is retracted medially (Figure 2f) and muscle-tendon junction of tibialis posterior is reached (Figure 2g). The tibialis posterior is pulled proximally (Figure 2h), and the muscle belly is freed, taking care to preserve the neurovascular structures around it (Figure 2i). The third incision (Figure 2j) is made on the dorsal aspect of the foot, parallel to the ankle crease and approximately 4 cm distal to the line joining the malleoli. This incision should be long enough to permit access to the tibialis anterior, extensor hallucis longus (EHL), extensor digitorum longus (EDL) and peroneus tertius (PT) tendons (Figure 2k).

After the preperation of the tendons for transfer, the next step is the passage of the tibialis posterior tendon onto the dorsal aspect of the foot, whenever possible this is achieved by the *Andersen tendon carrier*. As the handle of the passer is kept on the basis of the 5th metatarsal bone, the body of the tool is placed on the point marked on the midline of the ankle (Figure 2j,l). That position gives the tip of the passer the best location to catch the tendon, and achieves biomechanically the most appropriate subcutaneous tract for the tendon (Figure 2m). The free edge

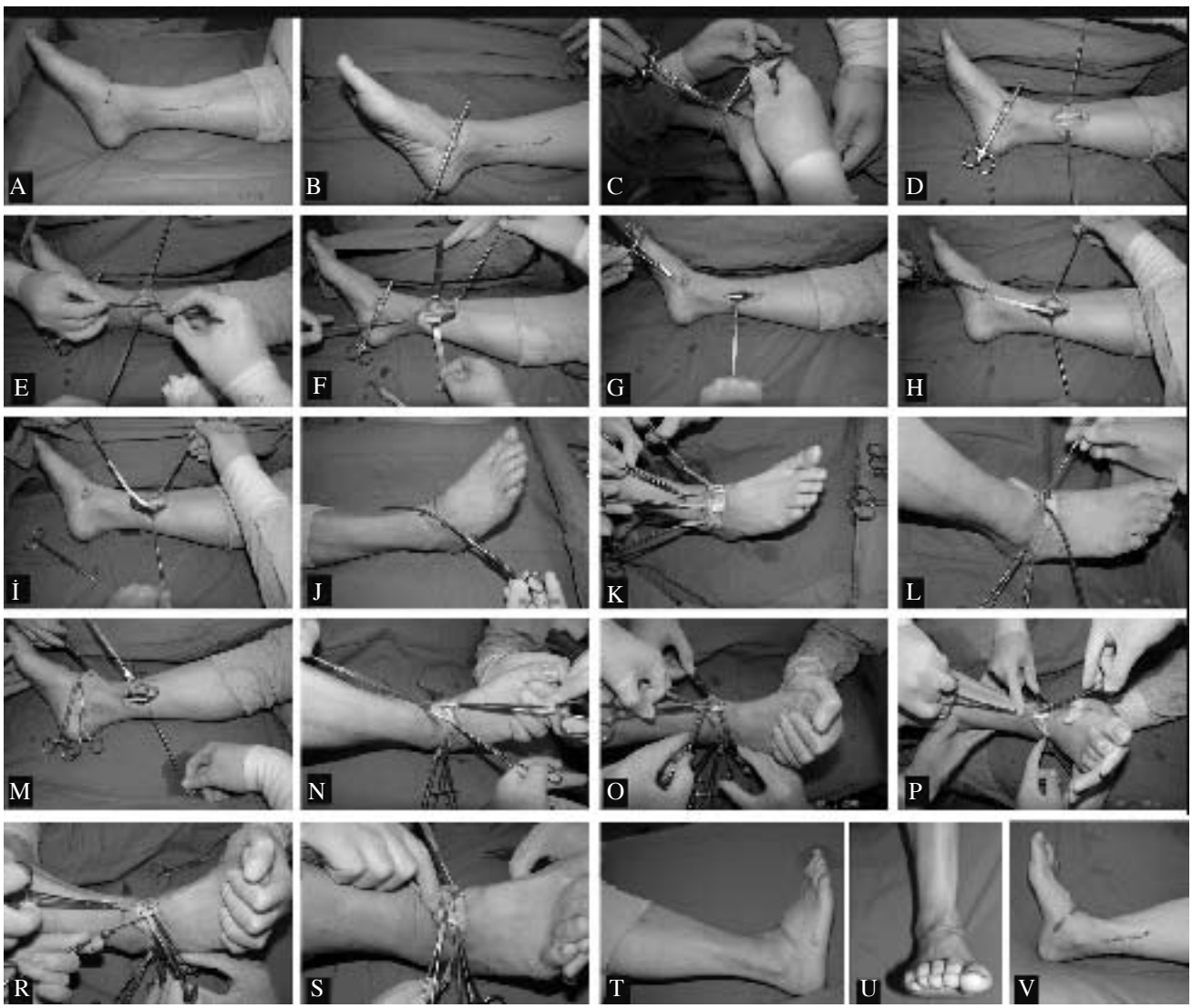

Figure 2. Stages of posterior tendon transfer operation.

of the tibialis posterior tendon is taken out through the incision on the anterior aspect of the ankle and separated into two slips (Figure 2n). As the knee is kept at 60-70° flexion and the ankle at 20-30° dorsiflexion and slight pronation, the medial half of the tendon is passed through a slit in the tibialis anterior tendon. The transfer is fixed with 2/0 nonabsorbable sutures as maximum tension applied to tendon ends (Figure 2o,p).

The lateral slip of the tibialis posterior tendon is passed through slits opened in extensor hallucis longus and extensor digitorum longus tendons (Figure 2r,s). The ankle is brought into 20-30° dorsiflexion and the posterior tibial tendon is sutured to both tendons separately under tension. Next, the remainder of the tibialis posterior tendon is sutured to the peroneus tertius tendon, thus the effect of tibialis anterior tendon in inverting the foot is tried to be neutralized (Figure 3). Following the completion of transfers, the tension on the extensor tendons on the dorsal aspect of the foot should be slightly visible (Figure 2t) and the toes should come into extension by tenodesis with plantar flexion of the foot (Figure 2u,v).

The incisions are closed, and a circular long leg cast is applied with 30° knee flexion and 20° ankle dorsiflexion. In our recent cases, we use a thermoplastic splint prepared preoperatively and that keeps the knee in 30° flexion and the ankle in 20° dorsiflexion.

Postoperative follow up and rehabilitation

On the fourth postoperative week, the circular cast is lowered below the knee, and at the end of 6th week it is removed and replaced by foot and ankle orthosis at neutral position, which will be worn for 4-6 weeks.

Figure 3. Tendon transfer: TP>TA+EHL+EDC [2,3,4,5] +PT.

Active dorsiflexion is inititated with re-education of the transferred muscle, and plantar flexion is not allowed during this time. Gait education is also given to prevent the disordered gait from interfering with the use of the transfer. At the end of the 3rd postoperative month, the patient is allowed to apply full load to the

Figure 4. Drop foot deformity due to injury of the peroneal nerve by gunshot.

Table 1. The evaluation criteria of Carayon et al. for the evaluation of patients who underwent tibialis posterior tendon transfer for drop foot.

	Excellent	Good	Moderate	Poor
Active dorsiflexion	>15°	5-15°	No active dorsiflexion Drop foot totally corrected Plantar flexion is possible up to 10 degrees	Presence of plantar flexion that prevent ankle motion, minimal dorsiflexion
Active plantar flexion	>30°	15-20°		
Active ROM	>40°	20-30°		

foot (Figure 4a and 4b). The results were classified according to the classification developed by Carayon et al.[9], as excellent, good, moderate and poor (Table 1). The evaluations were made by measuring active dorsiflexion, plantar flexion and the addition of the two. Mean follow up was 107.9 (12-254) months.

Results

In a total of 41 cases, 13 had severe restriction in passive dorsiflexion and underwent achilles tendon lengthening. Mean postoperative active dorsiflexion was 7.6° (-15-(+20)). Mean postoperative active plantarflexion was 21.8° (5-40). The sum of mean postoperative active dorsiflexion and plantar flexion was 30.4° (5-60). One patient sustained rupture of the tendon due to a fall during the early postoperative period, and 2 patients with leprosy developed superficial infection that required wound care and eventually resulted in poor outcome. In two patients with herniated disc sequela, the results were poor due to lack of patient compliance. There were no inversion deformities.

According to Carayon evaluation criteria, the results were excellent in six (14.6%), good in twenty-three (56.1%), moderate in seven (17.1%), and poor in five (12.2%).

Discussion

Drop foot has diverse etiologies, such as neurologic (peripheral nerve injury, neuropathy, lumbar radiculopathy, cerebral lesions) or muscular (extensor muscle injury, compartment syndrome) causes. The most common cause of drop foot is peroneal injury. In addition to being more prone to injury due to its location, the peroneal division of the sciatic nerve has poor regeneration potential compared with the tibial divison. [14] Despite advances in nerve physiology and microneurosurgery, a significant percentage of patients with peroneal nerve injury and subsequent drop foot require tendon transfer for restoration of normal gait.[15] Therefore, in peroneal nerve injury, the nerve should be repaired first during the early phase, and tendon transfer should be applied to patients without sufficient neurologic recovery. Tendon transfers were also applied in patients with peroneal nerve repair with an "internal splint" purpose, and was shown to improve nerve regeneration significantly.[16]

When compared with other surgical options such as arthrodesis or tenodesis, the golden standard in the treatment of drop foot is tendon transfer. Although some authors suggest that tibialis posterior transfer functions solely as a tenodesis, an active dorsiflexion of 15-30° is reported in numerous series.[7] The limited excursion of the tibialis posterior muscle, 2 cm, as a donor is its major disadvantage. The excursions of the tendons that it is going to replace is 3-5 cm. Therefore, for adequate dorsiflexion, the tension of the transfer must be adjusted cautiously. Despite the fact that many studies describe the technique, only few give information on the adjustment of transfer. Soares used tendon-tendon insertion and reported that between the time of suture and discharge from

Figure 5. Postoperative foot and ankle movements of the case.

the hospital, there would be a 10° decrease in dorsiflexion, and a further 5-10° decrease during follow up. Therefore he suggested to suture the tendons while the ankle is kept at 20° dorsiflexion, foreseeing this decrease. During transfer, we keep the ankle at 20-30° dorsiflexion and the tibialis posterior tendon tight. In cases with longstanding drop foot, the achilles tendon may be shortened. As we applied in our cases, achilles lengthening can be carried out in patients who have less than 20° dorsiflexion.

The most controversial aspect of tibialis posterior transfer is the route by which the tendon be carried to the dorsum of the foot. Although the interosseous route is more physiologic from the viewpoint of direction, the greatest disadvantage of this method is the risk of adhesion, especially if the window is kept narrow.[8,18] This method also carries the risk of vessel injury. The circumtibial route has a longer movement arm, which increases the mechanical advantage with respect to power, however the movement range decreases.[7] Clinical studies comparing both methods have remained inconclusive. In their biomechanical study, Goh et al. found that the interosseous route was more effective in dorsiflexion.[13] On the other hand, Soares' study shows that both methods yield above neutral dorsiflexion in 80% of the patients, and from the viewpoint of dorsiflexion both methods are equally successful.[17] In our series, we did not face the problems previously described for the circumtibial route, such as foot inversion or cosmetic problems like the visibility of the tendon in the subcutaneous tunnel. In addition, the Andersen tendon passer facilitated easy transfer of the tendon anteriorly. We prefer the circumtibial route due to low risk of adhesion and ease of application.

According to Carayon's evaluation criteria, the results were excellent in six patients (14.6%), good in twentythree (56.1%), moderate in seven (17.1%), and poor in five (12.2%). In the case series of 20 patients reported by Hove, mean dorsiflexion was 5°, plantar flexion was 40°, and total active motion was 40°.[8] In our series, mean active dorsiflexion was 7.6°, plantar flexion was 21.8°, and total active range of motion was 30.4°. Five patients in our series were found to have poor outcomes according to the evaluation criteria.

An important aspect of tendon transfer is the type of fixation. The tendon can be fixed using a tunnel opened in the tarsal or metatarsal bones. However, this may cause neuropathic arthropathy in tarsal joints. [7,19] Pull out sutures may cause problems in patients who have sensory problems like neuropathy or leprosy. Adjustment of tendon in bone fixation is difficult, and the sutures may loose tension in time. The drop of the forefoot and toes cannot be prevented.[8] The shift of the fixation point medially or laterally may result in varus or valgus deformities. The length of the tendon may be inadequate and prevents fixation of the tendon to the desired location.[20] Rodriquez reported using transfer of the tibialis posterior tendon passed through the interosseous membrane to the tibialis anterior tendon and to the peroneus longus tendon passed in front of the lateral malleolus, along with a slip of the tibialis posterior tendon tenodesed directly on the second cuneiform, enabled balance of the ankle during dorsiflexion and prevented varus or valgus deformity.[3] In that article, the effect of the tenodesis of the tibialis posterior tendon to the second cuneiform on plantar flexion was not described.

Due to the insertion point of tibialis anterior and its axis, any tension on this tendon results in dorsiflexion and also inversion. In our technique, to prevent this we split the tendon longitudinally into two, and suture one half to tibialis anterior. The other half is passed through the extensor hallucis longus, extensor digitorum longus and finally through peroneus tertius tendons, and then fixed. This both prevents inversion and aids eversion. Although this second half of the transfer shows a tenodesis effect and does not provide active toe extension, the inclusion of these tendons to transfer prevents dropping of the toes and forefoot. The tendon-tendon technique equally distributes tractional forces on the forefoot and therefore enables a more physiologic function. Tendon to tendon technique does not require a wide dissection, does not cause injury to the tarsal bones, and allows the surgeon to fine adjust the tension. The use of two branches instead of one provides balance between the medial and lateral aspects of the foot, preventing isolated 1st metatarsal elevation and dorsal bunion deformity.

Different methods have been proposed to evaluate the results of tibialis posterior transfer. In this study, the evaluation was made with Carayon's criteria described in 1967.[9] In order to make a more objective evaluation, Yeap et al. developed the Stanmore scoring system that was composed of 7 parts, including pain, need for orthosis, ability to wear normal shoes, activity level, muscle power of ankle dorsif-

lexion, degree of active ankle dorsiflexion, and foot posture.[21] In our recent cases, we are prospectively using this system.

There is still ongoing discussion on the pathway of the transferred tendon and method of fixation in the surgical restoration of drop foot with tibialis posterior tendon transfer. In this series, satisfactory results in the treatment of drop foot were achieved by transfer of the tibialis posterior tendon using circumtibial route and fixation to tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius tendons. The technique is easy to apply and allows fine adjustment of foot position. Educating the patient on isolating the function of the tibialis posterior function and strengthening is important.

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