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ORIGINAL STUDY

Anterior transfer of tibialis posterior tendon for treating drop foot : Technique of enforcing tendon implantation to improve success rate

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An absolutely convincing technique of anterior transfer of the tibialis posterior (TP) tendon for treating drop foot has not been developed.

Thirty-seven consecutive adult patients with drop foot owing to deep peroneal nerve injury were treated with bone-to-bone TP tendon transfer. The TP tendon with a small bony attachment was procured from the undersurface of the navicula and then transferred through a tunnel of the interosseous membrane. The navicular attachment was implanted in the tunnel of the navicula or intermediate cuneiform. Cancellous bone graft procured from the distal tibial metaphysis was packed into the tunnel inlet. Side-to-side tendon suturing was performed between the TP tendon and tibialis anterior tendon.

Thirty-one patients were followed for a mean of 2.8 years (range, 1.2-4.8 years), and all achieved satisfactory outcome for the ankle. All patients achieved a normal gait after one year and at the latest follow-up.

Conclusions : **The described technique may provide a high success rate. This surgical technique is not complex, and complications are few.**

Keywords : drop foot ; tibialis anterior ; tibialis posterior ; tendon transfer.

INTRODUCTION

Drop foot (equinus foot) is not an uncommon disorder, and can involve either bony or soft tissue pathology (*16,30*). Drop foot can be so disabling that patients' daily activities are severely disturbed. Steppage gait or hip hiking can greatly increase energy consumption and introduces the danger of falls while walking (*4,28*). The causes of drop foot are complex, and the treatment methods are various. Non-surgical and surgical techniques have achieved individual support (*12,26*). Currently, anterior transfer of the tibialis posterior (TP) tendon to replace lost dorsiflexion function of the tibialis anterior tendon is a common surgical procedure for the treatment of drop foot (*20,23,28,33,36*). However, the techniques of TP tendon transfer are various, and reported outcomes are inconsistent. No technique has been considered absolutely superior to the others.

When a tendon is rerouted to a new pathway, its muscle power will decrease at least one grade (*22,34*). Therefore, the TP tendon must be sufficiently powerful before it is transferred anteriorly. Moreover,

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after the transfer, the TP tendon must be implanted steadily in the new area. Then, the transfer can achieve maximal effects (*8,9*). Normally, bone-to-bone healing is more effective than tendon-to-bone or tendon-to-tendon anastomosis when a tendon is implanted (*9,27*). However, tendon-to-tendon anastomosis currently is widely used in the technique of TP tendon transfer (*20,23,28,33,36*). Such a surgical procedure can significantly affect the outcomes of tendon transfer. Therefore, it is hypothesized that anterior transfer of the TP tendon with bony attachment may increase the success rate of transfer. The purpose of this study was to prospectively develop a more convincing technique to increase the success rate in the treatment of drop foot. Hopefully, patients would be able to achieve the best functional outcome after anterior transfer of the TP tendon.

MATERIALS AND METHODS

Between May 2001 and December 2011, 37 consecutive adult (age, > 16 years) patients with unilateral drop foot were treated with the described technique at the author's institution. The author singly treated and followed all patients. Patients were aged 21 to 54 years (mean, 34 years) with a male-to-female ratio of 3:1. The causes of drop foot included 32 motorcycle or bicycle accidents, four working injuries, and one hip arthroplasty. All patients had complete loss of ankle dorsiflexion function for at least one year (mean, 1.8 years ; range, 1.2-3.4 years). Associated lesions included fractures of the ipsilateral femur or tibia in the patients with trauma causes, and developmental dysplasia of the hip in the patient with hip arthroplasty. All patients initially had received non-surgical treatment (splint, brace, and electric stimulation) for drop foot. They requested surgical treatment because of intolerance to long-term use of an orthosis. Surgical indications for this technique included complete loss of dorsiflexion function of the tibialis anterior tendon for more than one year, intact bone and cartilage structures in the ankle, full motor function of the TP tendon, and intolerance to non-surgical treatment.

In the outpatient department (OPD), history of drop foot was carefully evaluated. Ankle and foot gross appearances were examined, and radiography findings were reviewed. Possible associated diseases were investigated. Additionally, muscle power of the TP tendon was tested manually (*22*). Inclusion criteria for this study were drop foot treated with TP transfer owing to deep peroneal nerve palsy. Exclusion criteria were drop foot owing to spinal or central nerve injury, congenital or developmental ankle deformity, abnormal bony structures in the ankle, or drop foot treated with another technique.

Surgical technique

Under spinal or general anesthesia, the patient was placed on the operating table in the supine position. A pneumatic tourniquet was used routinely.

A 3-cm incision was made medially along the lower border of the navicula. The TP tendon with a 5 × 10-mm navicular attachment was procured. Second and third skin incisions of 2 and 3 cm, respectively, were made along the TP tendon tract behind the medial malleolus and distal tibia, 5 cm proximal to the joint line. Then, the end of the TP tendon with bony attachment was retracted upward and through the third incision (Fig. 1a).

A fourth skin incision of 3 cm was made along the lateral border of the distal tibia at the same level as the third incision. The interosseous membrane between the distal tibia and fibula was dissected with tissue scissors along the tibial cortex. Then, the tunnel was penetrated and enlarged with curved hemostatic forceps. Using a tendon passer, the TP tendon with bony attachment was transferred anteriorly through the interosseous membrane.

A fifth skin incision of 3 cm was made over the dorsal surface of the navicula and intermediate cuneiform, just lateral to the tibialis anterior tendon. The tibialis anterior tendon was retracted medially, and a bone tunnel of 1-cm diameter was made vertically on the navicula or intermediate cuneiform with a power reamer according to the procured TP tendon length. Three No. 2 Ethibond sutures (Johnson & Johnson, Somerville, NJ, USA) were looped on the TP tendon with bony attachment, and consequently, the tendon end was pulled through the tunnel (Fig. 1b). The Ethibond sutures were tightened with the ankle maintaining in mild dorsiflexion (Fig. 1c). Then, multiple No. 1 Dexon sutures (Johnson & Johnson, Somerville, NJ, USA) were applied between the TP tendon and tibialis anterior tendon in a side-to-side fashion. In patients with osteoporotic bone owing to disuse, a staple (Richards, Memphis, TN, USA) was augmented on the bone to secure the anchorage.

A bony window of 5 × 5 mm was made on the distal tibial metaphysic, and a few cancellous bone grafts were procured. Consequently, these bone grafts were packed on the tunnel inlet to completely seal the tunnel. The wound was closed with absorbable sutures and an ankle-foot orthosis was applied.

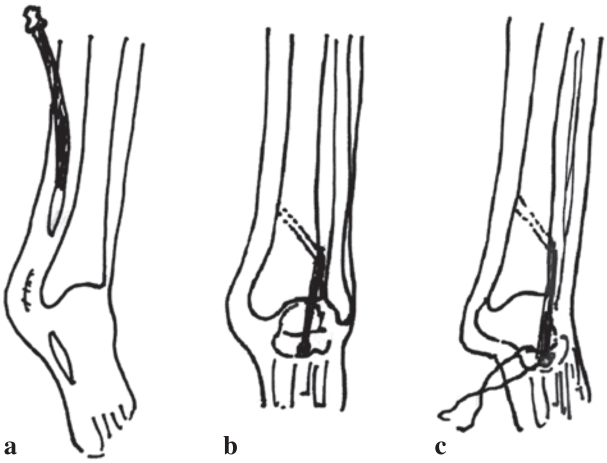

Fig. 1. — Procedure of anterior transfer of the tibialis posterior tendon is showed. (a) The tibialis posterior tendon with bony attachment is retracted upward through the third incision. (b) The tibialis posterior tendon with bony attachment is passed through the interosseous membrane and implanted into the navicular tunnel. (c) The bony attachment is pulled through the tunnel and tightened, while the ankle is kept in mild dorsiflexion.

Postoperatively, the patient was permitted to ambulate with protected weight bearing using crutches as early as possible. Patients were followed up at the OPD at 4 weeks, at which time the orthosis and crutches were discontinued. Progressive exercises and dorsiflexion of the ankle were encouraged. Then, patients were followed up at 3 months, 1 year, and whenever necessary.

To evaluate ankle function after tendon transfer, the Stanmore scoring system was used (*33,37*). This scoring system focused on situations after anterior transfer of the TP tendon. There were four grades, and a satisfactory outcome included an excellent or good grade. The score evaluated pain, need of orthosis, wearing normal shoes, functional outcome, muscle power, degree of active dorsiflexion, and foot posture. No bilateral muscle power and before and after the operation for muscle power comparison were performed because this system did not evaluate the recovery percentage of muscle power. A visual analog scale to evaluate pain was also not used.

For the convenience of comparison, a Fisher's exact test was used. A p value < 0.05 indicated statistical significance.

RESULTS

Thirty-one patients were followed up for at least one year (mean, 2.8 years ; range, 1.2-4.8 years ; Figs. 2 and 3). Six patients were lost to follow-up despite best efforts to contact them. The mean age of the 31 patients was 36 years.

There were no peri- or postoperative surgical complications, including deep infection or neurovascular injury.

Local pain was noted only for a short period after operation. After 3 months to the latest follow-up, no persistent and significant pain was reported. The tendon implanted site was pain-free.

The ankle-foot orthosis and crutches were used for 4 weeks. After 4 weeks to the latest follow-up, no orthosis was required and all 31 patients had progressively improved gait.

After 4 weeks, all 31 patients tried to wear normal shoes. At the latest follow-up, all 31 patients could wear normal shoes.

A gross limp was observed in all 31 patients at 4 weeks and at 3 months. A mild limp was observed in 7 out of 31 patients (22.6%) at one year. At the latest follow-up, all 31 patients presented no limp and could perform hiking or jogging exercise. However, no patient had participated in contact sports.

Active dorsiflexion of the ankle could not been performed at 4 weeks or 3 months in all 31 patients. However, at one year, all 31 patients could perform ankle dorsiflexion actively beyond the neutral position. At the latest follow-up, ankle dorsiflexion was a mean of 5^{o} (range, 3^{o}-10^{o}) beyond the neutral position. The muscle power of dorsiflexion was grade 4 according to the manual test (*22*).

Eight patients required lengthening of the Achilles tendon concomitantly during the TP tendon anterior transfer. The procedure was performed with the patient in the same supine position, and Z-lengthening was approached from the lateral aspect of the Achilles tendon. The wound was closed with non-absorbable sutures.

Gross appearance of the ankle was normal in all 31 patients at the latest follow-up. No acquired flat foot was observed or reported.

Ankle function improved from 31 unsatisfactory outcomes before treatment to 24 satisfactory outcomes at one year (77.4%, $p < 0.001$). At the latest follow-up (mean, 2.8 years), all 31 patients achieved satisfactory outcomes (100%, $p < 0.001$).

Fig. 2. — A 42-year-old woman sustained a left tibial plateau fracture due to a motorcycle accident (left-upper panel). Left drop foot was noted and persisted for 2.8 years. Anterior transfer of the tibialis posterior tendon was performed, and a satisfactory outcome was achieved with a 4.4-year follow-up.

DISCUSSION

In a normal gait cycle, the end of the stance phase (toe-off) keeps the ankle in 10º-26º of plantar flexion. Then, the swing phase starts and the ankle rises and is maintained in an inverted-V fashion up to 3º of dorsiflexion (Fig. 4) (*6,24,29*). Because the ankle in the stance phase is passively dominated by the foot, active contracture of the tibialis anterior is not prominent. However, in the swing phase, the ankle must actively rise via the tibialis anterior contracture to maintain the ankle upward to 3º of dorsiflexion. Therefore, as long as the ankle can maintain at least 3º of dorsiflexion in the swing phase, a normal gait is generally achievable. In the present study, all patients achieved active dorsiflexion ability of the ankle beyond 3º of dorsiflexion (mean, 5º ; range, 3º-10º), and no limps were observed at the latest follow-up.

Active plantar flexion of the ankle during a normal gait cycle is not important, and all ankle flexors are not evoked (Fig. 4) (*6,24,29*). However, during running, push-off of the forefoot to allow both feet to leave the ground requires the ankle to flex actively. In a normal ankle, the range of motion is from 20º-30º of dorsiflexion to 35º-45º of plantar flexion (*24*). Therefore, after TP tendon anterior transfer, as long as the ankle can be passively bent to 10º-26º plantar flexion, a normal gait is achievable. Active plantar flexion of the ankle is not always necessary for a normal gait during level walking. The Stanmore scoring system does not evaluate range of motion or active plantar flexion of the ankle (*33,37*). Clinically, it is relatively practical.

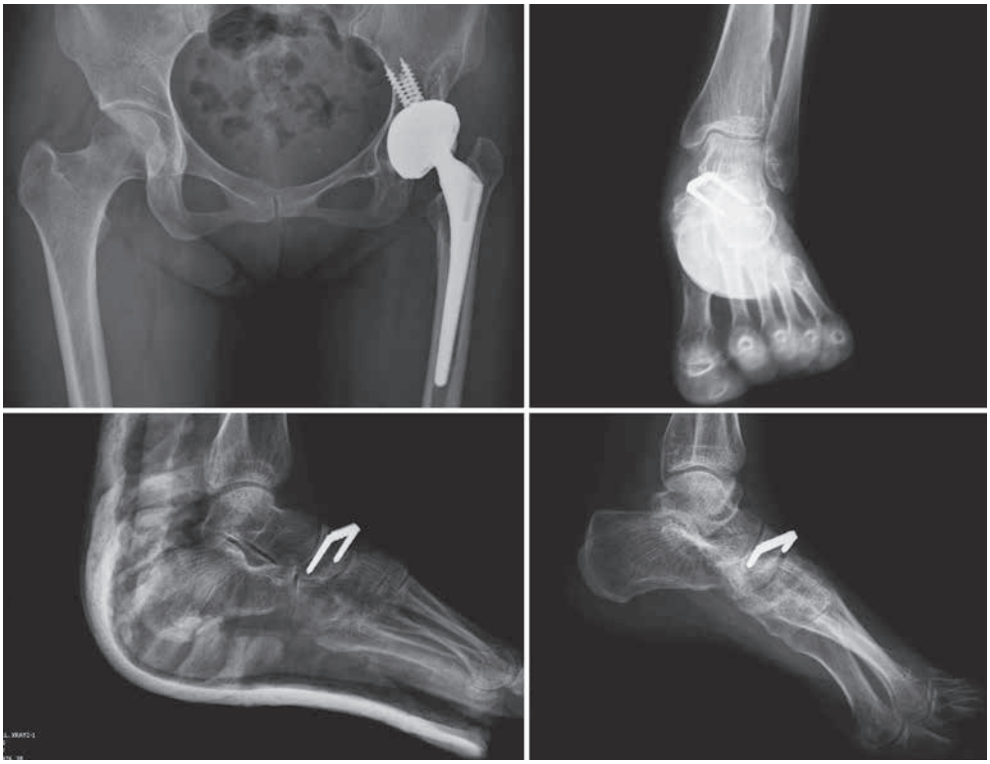

Fig. 3. — A 28-year-old woman sustained drop foot after treatment of developmental dysplasia of the left hip with total hip arthroplasty and lengthening of 5 cm (left-upper panel). Drop foot persisted for 2.2 years before anterior transfer of the tibialis posterior tendon was performed. A satisfactory outcome was achieved with a 3.6-year follow-up.

The pathology of drop foot consists of bone or soft tissues, and the latter is further composed of muscles or connective tissues (*16,30*). The etiologies of drop foot are complex and the treatment methods are various (*3,7,10,14,20,31,33*). To effectively treat drop foot, the involved pathology and etiology must be carefully investigated before treatment is initiated (*9,20*). Anterior transfer of the TP tendon to replace the dorsiflexion function of the tibialis anterior tendon is only one of common treatment methods, and unfavorable conditions must be excluded (*20,23, 28,33,36*)]. Not all patients with drop foot are suitable to undergo TP tendon transfer.

The most common indication to perform anterior transfer the TP tendon is peroneal nerve injury causing paralysis of the tibialis anterior (*20,23,28,33,36*). Extensors of all toes are also paralytic, but clinically, it does not introduce ambulatory disturbance (*21, 34*). Therefore, replacement of dorsiflexion function of the tibialis anterior tendon is the gold standard under such a situation. Tendon transfer for toe extensors is not absolutely necessary. Thus, the surgical technique can be greatly simplified. In particular, the TP tendon can be spared of splitting, which preserves tendon's strength (*8*). In order to maintain foot balance, some surgeons split the TP tendon or use double tendons and suture each branch to the tibialis anterior tendon and peroneus longus or toe extensors (*28,33,36*). This procedure increases the technical complexity, and the outcome is not better. The present study tried to develop a convincing surgical technique to maximize the TP tendon effects after anterior transfer.

Bone-to-bone healing is believed to be the most dependable technique when tenodesis is performed (*9,27*). Tendon-to-tendon or tendon-to-bone healing is inferior to bone-to-bone healing. In this technique, a bony attachment of the tendon is

Table I. — Comparison of the outcomes of various tibialis posterior tendon transfer techniques for treating drop foot

Studies	No. of cases	Patient age (mean, yr)	Route of TP	Satisfactory rate (%)	Stanmore score	Follow-up (yr)
Yeap *et al* 2001 (36)	12	28	Inter	83.3	---	7.5
Ozkan *et al* 2007 (19)	41	32	Circ	70.7	---	9.0
Bekler *et al* 2007 (1)	8	40	Circ	62.5	---	3.3
Kilic *et al* 2008 (11)	13	30	Circ	76.9	---	2.1
Vigasio *et al* 2008 (33)	16	26	Inter	81.3	78	2.0
Ozkan *et al* 2009 (20)	16	27	Circ	87.5	85	8.4
This study 2014	31	36	Inter	100	89	2.8

Circ, circumtibia ; Inter, interosseous membrane ; TP, tibialis posterior ; ---, unavailable.

preserved and grafted into the host bone. After bone healing is achieved, the function of the implanted tendon may be maximally regained. In the present study, a 100% success rate was achieved. All patients presented no limps during daily activities. Furthermore, all patients could participate in non-contact sports. Long-term loss of movement in the tibialis anterior may induce tendon atrophy. Side to side suturing the TP to the tibialis anterior is therefore risky for tear of the tibialis anterior. In addition, tendon suture healing is unsafe due to uncertain local blood supply. The failure rate is increased inferably.

In this study, during the operation, the TP tendon was side-to-side sutured to the tibialis anterior tendon. This procedure can extend the action of the TP tendon after anterior transfer. Anatomically, the tibialis anterior tendon reaches the medial cuneiform and first metatarsal base (*15,17*). However, the new insertion of the rerouted TP tendon is at the intermediate cuneiform or navicula. This performance depends on the length of the procured TP tendon, with avoidance of a bulged mass in the grafted area (*11,33*). Consequently, a larger leverage arm from the ankle to the tendon insertion area can maximize dorsiflexion torque. Additionally, both tendons were sutured together, and the immobilization periods can be shortened. Thus, ankle function may be recovered earlier (*23*). At the latest follow-up, all patients could raise the ankle at least 3° beyond the neutral position (mean, 5° ; range, 3°-10°) and achieved a normal gait.

In the literature, various surgical techniques of anterior transfer of the TP tendon have been reported. The TP tendon may be transferred through the circumtibia or interosseous membrane (*11,18,19,20, 23,25,34,36*), and the TP tendon may be transferred with an intact or split trunk (*13,20,23,28,32,34,36*). The TP tendon may be placed at different bones or sutured to the varied tendons (*20,23,28,34,36*). Therefore, outcomes of various techniques are inconsistent. Evaluated by the Stanmore score, all other TP tendon transfer techniques were inferior to bone-to-bone healing in the present study (Table I) (*1,19*).

Ankle arthrodesis may be used to treat drop foot, and the surgical technique is not complex. The recommended angle for ankle fusion is neutral (*2,35*). However, in the stance phase of a normal gait cycle, the ankle is required to reach 10° of dorsiflexion (Fig. 4) (*6,24,29*). Thus, a normal gait is impossible to achieve in a patient with ankle arthrodesis (*33*). If the patient receives TP tendon transfer, a normal gait is theoretically predictable.

There are several limitations in this study. First, the numbers of cases was small and follow-up period was short. As such, the final outcomes of this study may be not so convincing. Whether loss of the TP tendon may induce a significant acquired flat foot cannot be evaluated with only a 2.8-year follow-up. However, in a recent study with a 7.5-yr follow-up for the TP tendon transfer, acquired flat foot did not cause significant daily disturbance (*36*). Other multiple toe-flexors and short plantar muscles may maintain the framework of the longitudinal arch of the feet. Second, in this technique, the bony attachment of the TP tendon is grafted into the navicula. Consequently, the navicula may be damaged, and the long-term effects have not

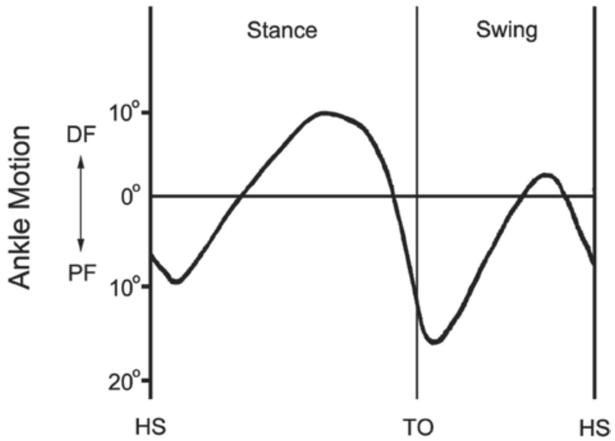

Fig. 4. — Line graph, showing changes in ankle angle during a normal gait cycle. DF, dorsiflexion ; HS, heel-strike ; PF, plantar flexion ; TO, toe-off.

been clarified. However, avascular necrosis of the navicula with pain was not reported and no limp was observed in all 31 patients in this study (5). The short-term follow-up confirms the merits of this technique. However, it may be necessary to continuously observe the long-term effects.

In conclusion, a more convincing TP tendon transfer technique for treating patients with drop foot was developed. With a short-term follow-up of 2.8 years, a high success rate was achieved. The technique is not complex, and the outcomes were excellent. For patients with adequate indications, the present technique may provide the optimal treatment.

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