Split versus full tibialis anterior tendon transfer in treatment of residual dynamic supination in treated idiopathic clubfoot by Ponseti method

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Background
Dynamic supination is a common sequelae following successful nonoperative treatment of clubfoot with the Ponseti technique. It is resulted from a strong tibialis anterior muscle and weak antagonists, particularly the peroneal and tibialis posterior muscles. Tendon-balancing procedure is the most reasonable solution. Use of tibialis anterior tendon transfer (TATT) in recurrent clubfoot deformities has been described since 1940.

Patients and methods
Through this study, we compare the results of split versus full TATT in the treatment of residual dynamic supination in treated idiopathic clubfoot by Ponseti method. Patients were divided into two groups. The first group (nine patients with 10 feet) (group I) consists of the patients who were managed with split tendon transfer and the second group (nine patients with 10 feet) (group II) consists of the patients who managed with full tendon transfer. Garceau and Palmer's clinical criteria and a grading system proposed by Thompson and colleagues were used for evaluation of the results of tendon transfer either split or full.

Results
A total of 18 children (13 males and five females) were involved in this study. The average of the age of the children in group I was 4.3 years and in group II was 4 years at the time of surgery. According to Garceau and Palmer's clinical criteria, in group I, the preoperative ratings of 10 feet were as follows: four feet were good and six feet were fair, with scores of 3 points and 2 points, respectively. The postoperative ratings were five feet were excellent and five feet were good, with scores of 4 points and 3 points, respectively, with a statistically significant improvement ($P<0.05$). In group II, the preoperative ratings of 10 feet were six feet were good and four feet were fair, with scores of 3 points and 2 points, respectively. The postoperative ratings were six feet were excellent and four feet were good, with scores of 4 points and 3 points, respectively, with a statistically significant improvement ($P<0.01$). In comparing the results of both groups, no statistically significant relation could be found ($P>0.05$). According to the grading system proposed by Thompson and colleagues for restoration of muscle balance, in group I, eight feet achieved good results and two feet achieved fair results, whereas in group II, seven feet achieved good result and three feet achieved fair results. In comparing the results of both groups, we found there was no statistically significant relation ($P>0.05$).

Conclusion
TATT is an excellent method of correcting residual dynamic clubfoot deformity and there is no significant difference in the results by either full transfer or split transfer, and the surgeon's preference plays a major role in selection of the procedure.

Keywords:
clubfoot, tibialis anterior, transfer

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Introduction

The term clubfoot refers to a congenital foot deformity characterized by equinus of the hindfoot, adduction of the midfoot, cavus may be present through midfoot, and varus of the forefoot [1]. Successful correction of clubfoot deformity generally is reported in 90–98% of children treated with Ponseti casting [2]. One of the most common sequelae of surgical treatment of congenital talipes equinovarus deformities (clubfoot) is dynamic supination from a strong tibialis anterior muscle and weak antagonists, particularly the peroneal and tibialis posterior muscles. It is also a common sequelae following the otherwise successful

nonoperative treatment with the Ponseti technique [3–10]. Residual forefoot deformity should be determined to be either dynamic (with a flexible forefoot) or rigid. Garceau first described the use of tibialis anterior tendon transfer (TATT) in recurrent clubfoot deformities [11]. Treatment methods include transfer of the entire tendon, either subcutaneously beneath the ankle retinaculum [8,10–18], above the ankle retinaculum to the dorsum or lateral aspect of the midfoot [19], or by a split TATT [16,20]. The latter technique was initially as described by Hoffer *et al.* [21]. Because dynamic supination and adduction often are caused by overactivity of the anterior tibial tendon and underactivity of the peroneal tendon, Kuo *et al.* [16] suggested that a tendon-balancing procedure is the most reasonable solution. Ezra *et al.* [19] also reported good results after transfer of the anterior tibial tendon in 27 previously treated clubfeet with residual dynamic supination deformities.

Patients and methods

This is a prospective study performed in Suez Canal University hospitals during the period from October 2007 to December 2013. The study was approved by the institutional ethics committee in Department of Orthopedics, Faculty of Medicine, Suez Canal University, Ismailia, Egypt. A total of 18 children with residual dynamic supination as a residual of treated idiopathic clubfoot deformity (13 males and five females) were involved in this study. The aim of this study is to compare results of split versus full TATT in the treatment of residual dynamic supination in treated idiopathic clubfoot by Ponseti method. Patients with clubfoot owing to causes other than idiopathic type such as neuromuscular disorders or patients with clubfoot not treated with Ponseti method were excluded from our study. These patients were divided into two groups. The first group (group I) consists of the patients who were managed with split TATT and the second group consists of the patients who were managed with full TATT.

Group I included nine children with 10 clubfoot, comprising six males and three females. One male child has bilateral involvement, five children have left-sided clubfoot and three children have right-sided clubfoot. Their ages ranged from 3 to 5.5 years, with an average age of 4.3 years at the time of surgery.

Group II included nine children with 10 clubfoot, comprising seven males and two females. One female child has bilateral clubfoot, four children have left-sided clubfoot, and four have right-sided clubfoot. Their ages ranged 4–6 years, with an average age of 4.5 years at the time of surgery.

The clinical criteria of Garceau and Palmer [13,14] was used for evaluation of the results of TATT in our patients, either split or full tendon transfer.

We compare preoperative and postoperative scores in each group. Their criteria were based on the presence or absence of metatarsus adductus, heel varus, and equinus. A normal-appearing foot, other than being smaller than the opposite side, was considered an excellent result (4 points), a mild deformity in one or two of the three parameters was considered a good result (3 points), moderate deformity in all three parameters but with less than 10° equinus was considered a fair result (2 points), and a severe deformity in all three parameters with greater than 10° of equinus was considered a poor result (1 point).

The grading system in this study was proposed by Thompson *et al.* [22] in their work to evaluate the restoration of muscle balance and the correction of the dynamic supination and were graded as follows: good, restoration of muscle balance; fair, partial restoration of muscle balance; and poor, no improvement. Good results demonstrated no further dynamic supination. The foot had a smooth dorsiflexion arc of motion. Fair results had improved function but still demonstrated mild dynamic supination on dorsiflexion. A poor result had no improvement.

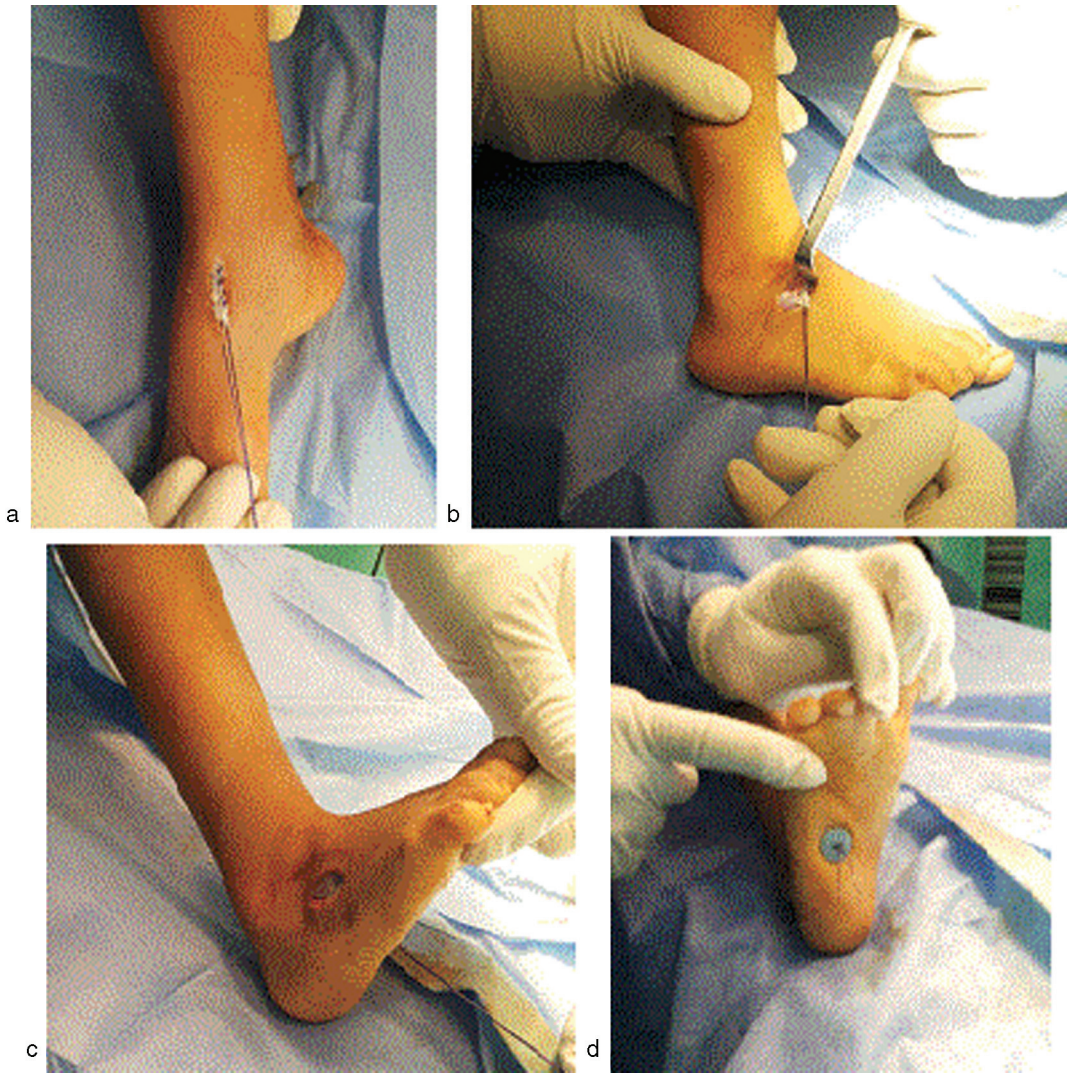
Preoperative and postoperative ankle range of motion or foot radiographs were not correlated as we were evaluating the results of the tendon transfer alone. The average length of the follow-up from tendon transfer surgery for all children was 2.7 years, with range from 2 to 4 years. Data were collected and analyzed using SPSS Software (Release 20.0 for Windows; SPSS Inc., Chicago, Illinois, USA).

When comparing the preoperative and postoperative rating score, a χ^2 was performed. Fischer's exact test was used when cell count is below 5. A difference was considered significant when P value less than or equal to 0.05.

Technique of tibialis anterior tendon transfer

(1) The patient is placed in a supine position and under general anesthesia.
(2) A tourniquet applied to the affected limb for 1 h. If the procedure takes longer time, the tourniquet

Figure 1



(a) Intraoperative photograph of full TATT showing the dorsomedial incision and harvesting the tibialis anterior tendon. (b) Intraoperative photograph shows the dorsolateral incision and transfer of the tibialis anterior to the cuboid bone. (c) Intraoperative photograph shows suture of the transferred tendon was expressed from the sole of the foot. (d) Intraoperative photographs show suture of the transferred tendon was tightened on a button. TATT, tibialis anterior tendon transfer.

must be deflated for 15 min and then inflated again.

(3) A longitudinal incision of 2–3 cm long was done dorsomedially over the medial cuneiform (Fig. 1a).
(4) Identification of the tibialis anterior tendon at its insertion was done.
(5) In case of full tendon transfer, the whole tendon is detached from its insertion. However, in case of split transfer, lateral half of the tendon is detached from its insertion (slip to medial cuneiform), and the split is continued proximally to the extent of the wound, preserving as much length as possible.
(6) In case of a split transfer, a second incision is done at the distal tibia 2–3 cm in length. Then the tibialis anterior tendon sheath is identified, and it is split longitudinally. However, in case of full transfer, this second incision is not needed as the detached tendon could be passed subcutaneously directly to the incision at the dorsolateral aspect of foot over the cuboid.
(7) Before the lateral half of the tendon is detached, continue splitting of the tibialis anterior tendon proximally through the second incision up to the musculotendeniuos junction.
(8) When the split in the tendon is complete, detach the lateral half, and bring it into the proximal wound.
(9) A third longitudinal incision of 2–3 cm length over the cuboid at the dorsolateral aspect of the foot is made (Fig. 1b).
(10) Make a drill hole in the cuboid and enlarge it to permit passage of the transferred tendon.
(11) Pass the transferred tendon distally from the proximal wound to the third distal wound over

the cuboid at the dorsolateral aspect of the foot. Note that the transferred tendon must pass under the extensor retinaculum.

(12) Attach a nonabsorbable suture to the end of the tendon, and pass it through the hole in the cuboid and express the suture from the planter aspect of the foot using a reloaded needle (Fig. 1c).

(13) Hold the foot in dorsiflexion, pull the tendon tight, and suture is tightened over felt and a button at the planter aspect of the foot (Fig. 1d).

(14) Wounds are closed in layers in the usual manner.

(15) Short leg cast was applied in dorsiflexion and eversion for 6 weeks.

Postoperative aftercare

After 6 weeks, cast and button were removed. Below-knee thermoplastic splint was applied and physiotherapy was started.

Results

Through this study, we compared the results of split versus full TATT in the treatment of residual dynamic supination in treated idiopathic clubfoot by Ponseti method. A total of 18 children (13 males and five females) were involved in this study.

These patients were divided into two groups: group I, split TATT, and group II, full TATT.

The average age of the children in group I was 4.3 years and in group II was 4 years at the time of surgery. The clinical criteria of Garceau and Palmer [13,14] was used for evaluation of the results of TATT in patients with either split or full tendon transfer.

As Table 1 shows, in group I, the preoperative ratings of 10 feet were four feet were good and six feet were fair, with scores of 3 points and 2 points, respectively. The postoperative ratings were five feet were excellent and five feet were good, with scores of 4 points and 3 points, respectively, with a statistically significant improvement ($P<0.05$). As Table 2 shows, in group II, the preoperative ratings of 10 feet were six feet were good and four feet were fair, with scores of 3 points and 2 points, respectively. The postoperative ratings were six feet were excellent and four feet were good, with scores of 4 points and 3 points, respectively, with a statistically significant improvement ($P<0.01$).

In a comparison of postoperative rating and score of feet in both groups according to Garceau and Palmer's criteria, no statistically significant relation could be found ($P>0.05$), as shown in Table 3.

Grading system proposed by Thompson *et al.* [22] in their work to evaluate the restoration of muscle balance and the correction of the dynamic supination was used in this study. As Table 4 shows, in group I, eight feet achieved good results and two feet achieved fair results regarding restoration of muscle balance, whereas in group II, seven feet achieved good result and three feet achieved fair results. In comparing the results of both groups, we found there was no statistically significant relation ($P>0.05$).

There were no complications reported in our patients such as infection, loosening of the transferred tendon from the new insertion at the cuboid bone, or overcorrection.

Discussion

The dynamic forefoot deformity was observed after clubfoot treatment with or without soft tissue releases. The forefoot deformities consisted of adduction and supination. The dynamic deformity should be differentiated from a rigid deformity, which often resulted from bony deformity or joint contracture [16]. This deformity resulted from a strong tibialis anterior muscle and weak antagonists, particularly the peroneal and tibialis posterior muscles. It is also a common sequelae following otherwise successful nonoperative treatment with the Ponseti technique [3–10]. Garceau first described the use of TATT in recurrent clubfoot deformities [11].

Table 1 Preoperative and postoperative rating and score of feet in group I (split tibialis anterior tendon transfer) according to Garceau and Palmer's [14] criteria

Rating, score	Preoperative TATT [*n* (%)]	Postoperative TATT [*n* (%)]
Excellent, 4 points	0 (0)	5 (50)
Good, 3 points	4 (40)	5 (50)
Fair, 2 points	6 (60)	0 (0)
Poor, 1 point	0 (0)	0 (0)

TATT, tibialis anterior tendon transfer. *P* value less than 0.05.

Table 2 Preoperative and postoperative rating and score of feet in group II (full tibialis anterior tendon transfer) according to Garceau and Palmer's [14] criteria

Rating, score	Preoperative TATT [*n* (%)]	Postoperative TATT [*n* (%)]
Excellent, 4 points	0 (0)	6 (60)
Good, 3 points	6 (60)	4 (40)
Fair, 2 points	4 (40)	0 (0)
Poor, 1 point	0 (0)	0 (0)

TATT, tibialis anterior tendon transfer. *P* value less than 0.01.

Table 3 Comparison of postoperative rating and score of feet in both groups according to Garceau and Palmer's [14] criteria

Rating, score	Group I (split TATT) [*n* (%)]	Group II (full TATT) [*n* (%)]
Excellent, 4 points	5 (50)	6 (60)
Good, 3 points	5 (50)	4 (40)
Fair, 2 points	0 (0)	0 (0)
Poor, 1 point	0 (0)	0 (0)

TATT, tibialis anterior tendon transfer. *P* value more than 0.05.

Table 4 Restoration of muscle balance in group I and group II according to Thompson *et al*. [22]

Rating	Group I (split TATT) [*n* (%)]	Group II (full TATT) [*n* (%)]
Good	8 (80)	7 (70)
Fair	2 (20)	3 (30)
Poor	0 (0)	0 (0)

TATT, tibialis anterior tendon transfer. *P* value more than 0.05.

Through this study, we evaluated and compared the results of split versus full TATT in the treatment of residual dynamic supination in treated idiopathic clubfoot by Ponseti method. As shown in Tables 1 and 2 that either split or full TATT was used; there were statistically significant relationships and improvements in both groups.

TATT in this study is a good method for treatment of residual dynamic supination in cases of treated clubfoot by Ponseti method.

Kuo *et al.* [16] in their work mentioned that the senior author changed preference for the procedure from full transfer to split transfer because of two complications in the full transfer patients. In one patient, the transferred tendon loosened at the transferred site, and the other foot was overcorrected, which required retransfer of the transferred tendon back to the medial aspect of the foot. It definitely does not imply that the full transfer is an inferior procedure. Garceau [11] originally passed the transferred tendon under the annular ligament, and also, we preferred to pass the transferred tendon under the retinaculum. Carroll [23] did indicate the preference for split transfer, so that there is still some dorsiflexion force on the medial side of the foot. Fennell and Phillips [24] in their study of unembalmed human lower extremities discovered that anterior tibial tendon fibers rotate 90° from the musculotendinous junction to the insertion on the medial cuneiform and first metatarsal bone. Lateral transfer of the first metatarsal released tendon produced a crossing over proximally of the tendon as fibers come from medial side of the musculotendinous junction. Lateral transfer of the medial cuneiform release produced no crossing over proximally, as the fibers come from the lateral side of musculotendinous junction.

We transferred tibialis anterior tendon onto cuboid bone in both groups. In Garceau's [11] original article, he transferred onto the fifth metatarsal bone unless tendon was too short; in that case, he transferred onto the cuboid bone. In the original article of Hoffer *et al.* [21] on split anterior tibial tendon transfer, they transferred onto the cuboid bone.

We also used a grading system proposed by Thompson *et al.* [22] in their work to evaluate the restoration of muscle balance and the correction of the dynamic supination.

We found that most of our patients restored muscle balance with subsequent correction of dynamic supination. However, there was no statistically significant relation between both groups. So, there is no preference between split or full TATT. Moreover, our data showed that TATT is a good method of correcting residual dynamic clubfoot deformity. However, there is no significant difference in the results by either full transfer or split transfer, and the surgeon's preference plays a major role in selection of the procedure. Kuo *et al.* [16] in their work showed that TATT is an excellent method of correcting residual dynamic clubfoot deformity, and the results by either full transfer or split transfer had no significant difference.

Conclusion

TATT is an excellent method of correcting residual dynamic clubfoot deformity, and there is no significant difference in the results by either full transfer or split transfer, and the surgeon's preference plays a major role in selection of the procedure.

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Conflicts of interest

There are no conflicts of interest.

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