

Stair-shaped Achilles tendon lengthening in continuity – A new method to treat equinus deformity in patients with spastic cerebral palsy



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ABSTRACT

Background: Equinus of the ankle is a common deformity in spastic cerebral palsy. Achilles tendon lengthening is one of the effective options for the treatment of equinus deformity.

Methods: In the study, a new stair-shaped Achilles tendon lengthening (ATL) procedure that preserves of the tendon continuity was performed in 28 tendons with equinus deformity (20 patients, mean age = 10.5 ± 2.6 years). The results were compared with a group of patients treated with the Z-lengthening procedure. During the latest follow-up visit, the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot scale score was much higher in the stair-shaped ATL group than in the Z-lengthening group ($p < 0.05$).

Results: The two groups showed similar surgical correction angle after ATL ($37.2 \pm 3.5^\circ$ for stair-shaped ATL and $36.1 \pm 4.5^\circ$ for Z-lengthening). During the latest follow-up visit, the correction angle in the Z-lengthening group decreased to $21.6 \pm 4.3^\circ$, which was lower than in the stair-shaped ATL group ($29.0 \pm 3.1^\circ$; $p < 0.05$). In addition, the data regarding the time required by each patient before being able to start rehabilitation and walking as well as gaining better stability for running indicated that the stair-shaped ATL group recovered significantly quicker than the Z-lengthening group.

Conclusions: The stair-shaped ATL procedure resulted in a successful correction of the equinus deformity in spastic cerebral palsy, with the advantage of preserving a degree of continuity without a complete section of the tendon. This confers greater antigravity stability and quicker recovery in patients.

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1. Introduction

Foot equinus is the most common deformity in children with spastic cerebral palsy (CP) [1]. Approximately 90% of the deformities observed in cerebral palsy occur in the ankle and foot regions [2]. The incidence of equinus is around 75% [3]. Spastic equinus deformity must be treated in patients able to walk. Untreated foot disorders may lead to fixed contractures and proximal compensatory deformities requiring surgical intervention. Achilles tendon lengthening is one of the effective options for the treatment of equinus deformity. Different techniques have been developed, such as Z-plasty [4], the Vulpius technique, the Baker technique [5], the White slide elongation technique [6], the so-called pie-crust technique used in capsular release [7], and

other variants of these methods. With the use of these techniques, the continuity of the tendon is first disrupted and then requires suture repair to restore its continuity after transection. The immediate postoperative tensile strength of the lengthened tendon is mainly reliant on the suture. Thus, the postoperative immobilization period varies from 3 to 7 weeks and is mandatory to ensure healing before returning to full function or exercise.

The purpose of this study was to develop a new method of tendon-lengthening in which tendon continuity is preserved. This should result in a preserved inherent tensile strength which might decrease the postoperative immobilization period, thus leading to a quicker recovery. Because Z-lengthening is the most common procedure performed at our institution for equinus contracture, this procedure was selected for comparison in this study.

2. Materials and methods

Patients with equinus contracture for whom conservative treatment failed were chosen for surgical lengthening of the Achilles tendon. Patients with a fixed contracture of the

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gastrocnemius and soleus (i.e., a lack of dorsiflexion of the foot from the neutral position, even with the knee in flexion and under anesthesia) were selected to undergo Z-lengthening or stair-shaped Achilles tendon lengthening.

From Sept. 2013 to Dec. 2015, 37 CP patients (53 limbs) received surgery to correct the equinus foot deformity in our department. The residual ankle varus deformity or claw toe deformity was identified following the Achilles tendon procedure, and another tendon lengthening such as the one from tibialis posterior, flexor hallucis longus, or flexor digitorum longus was subsequently performed. The maximal passive dorsiflexion angle (knee in full extension) was recorded preoperatively, postoperatively, and during the latest follow-up visit for the two groups using a manual goniometer. The surgical correction and long-term correction angles were also compared between the two groups. An informed consent was obtained from all patients or their parents.

2.1. Operative techniques

All the procedures were performed by a senior foot and ankle orthopedic surgeon. The patients were placed in a supine position after receiving general anesthesia. After skin preparation, sterilizing, and draping, the affected limb was exsanguinated to reduce bleeding. A posteromedial curved skin incision, 6–8 cm long, was made at the lower third of the lower leg (Fig. 1a). By blunt dissection, the Achilles tendon was exposed.

2.1.1. Z-shaped Achilles tendon lengthening

Firstly, a Z-lengthening was performed by making a long longitudinal split down the center of the tendon. The tendon was divided by cutting in either the left or right direction at the top and the bottom of the slit, to complete the Z shape. The ankle was then dorsiflexed to the neutral position with the knee extended and the foot placed in neutral position. The tendon in tension was then sutured. The paratenon, then the skin, were meticulously closed to minimize adhesions. The width of the obtained tendon was half of the original Achilles tendon width.

2.1.2. Stair-shaped Achilles tendon lengthening

The Achilles tendon was divided into two parts equal in width. The stair-shaped cuttings involved a Z-shaped lengthening of one half of the Achilles tendon at upper end, and a similar Z-shaped lengthening of the other half of the tendon at its lower end (Fig. 1). The minimum distance between the proximal and distal Z-shaped cuttings should be 3 cm. The portion of the tendon between these two Z-lengthenings, remains intact. Following the Z-shaped cuts, the ankle is dorsiflexed to neutral for primary tendon lengthening or up to 10°–15° past neutral for revised cases with the knee extended and the foot is placed in neutral. After dorsiflexion, the intact bundle is seen to lengthen, probably because fibres in the intact portion of the tendon between these two z-cuts, will slide past each other. Then the cutting ends were sutured using 1-0 polyester braided sutures. The slit length has been calculated preoperatively according to that each centimeter lengthening can increase 12-degree dorsiflexion. Finally, the paratenon, then the skin, were meticulously closed to minimize adhesion.

2.2. Postoperative management

After surgery, all patients treated with stair-shaped ATL received below-knee casts without weightbearing, which were removed after two week postsurgery. The below-knee casts were also applied in the group of Z-lengthening, but were removed after four weeks postsurgery. After that, a walking boot was applied for short walk in both groups until the muscle balance was established. The gentle active and passive ankle dorsiflexion and heel lifting exercises are gradually recommended, when the pain could be tolerated, the muscle power was adequate, and muscle balance was achieved. Any participation in active sports are permitted after next 6 weeks. We collected information about each patient's postoperative recovery from evaluation of clinic follow-up and medical records.

2.3. Assessment of results

We evaluated the maximal passive dorsiflexion angle (full knee extension) preoperatively, postoperatively, and during the latest

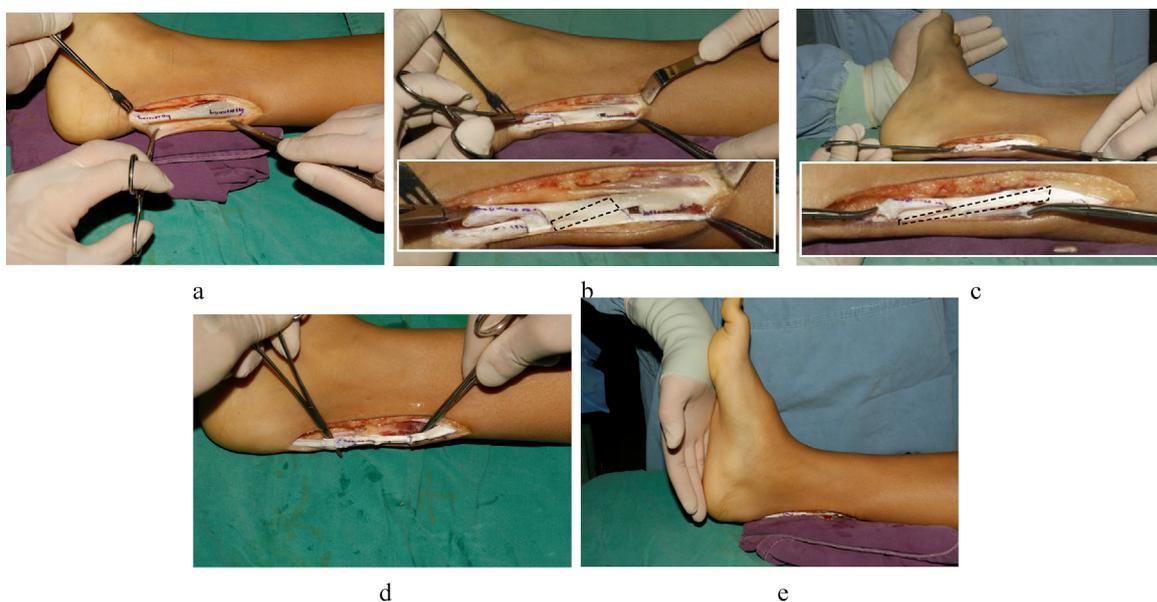


Fig. 1. The stair-shaped Achilles tendon lengthening procedure: (a) the Achilles tendon was explored by blunt dissection and the Z-shaped marks were drawn on the Achilles tendon; (b) the stair-shaped cuttings involved a Z-shaped lengthening of one half of the Achilles tendon at upper end, and a similar Z-shaped lengthening of the other half of the tendon at its lower end. The portion of the tendon in the square was intact; (c) the ankle was dorsiflexed, the continued bundle was elongated which showed in the square; (d) the cut ends were subsequently sutured; (e) the ankle can be maintained in neutral postsurgery.

follow-up visit. We also assessed the clinical outcome of these two techniques by using the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot scale before surgery and during the latest follow-up visit. The surgical correction and long-term correction angles were also documented. The recovery time after surgery and any of the postoperative complications were also noted.

2.4. Statistical method

The difference in the maximal passive dorsiflexion angle (knee in full extension) between the two groups was analyzed by Stata 12.0. (Stata Corp., College Station, TX, USA) The dorsiflexion angles after surgical correction and long-term correction were also compared. In addition, the time required before starting rehabilitation, returning to a walking training, and acquiring improved speed and stability was documented and analyzed by Stata 12.0.

3. Results

The demographics of the two groups are shown in Table 1. A total of 53 cases with equinus deformity were treated in 37 patients (19 males and 18 females, mean age 11.1 ± 2.8 years) and were followed up for 19.5 ± 5.4 months (range from 10 to 29 months). There was no statistically significant differences in terms of sex, age and diplegia/monoplegia distribution between stair-shaped ATL and Z-lengthening group (all $p > 0.05$). The maximal passive dorsiflexion angle (full knee extension) were evaluated preoperatively, postoperatively, and during the latest follow-up visit, which were summarized in Table 2. There was no difference between the two groups regarding the AOFAS score assessed before surgery ($p > 0.05$). However, during the latest follow-up visit, the AOFAS score was significantly higher in the stair-shaped ATL group than in the Z-lengthening group ($p < 0.05$). Before surgery, the maximal passive dorsiflexion angle measured in the Z-lengthening group was not statistically different from that measured in the stair-shaped ATL group ($-14.3 \pm 4.3^\circ$ vs. $-13.3 \pm 3.6^\circ$, respectively; $p > 0.05$). After surgery, there was no statistical difference between the two groups regarding the maximal passive dorsiflexion angle (knee in full extension). The two groups obtained similar surgical correction degree after ATL ($37.2 \pm 3.5^\circ$ for stair-shaped ATL and

Table 1
Characteristics of the two groups.

Surgical intervention	Stair-shaped ATL	Z-lengthening
Number of limbs (53)	28	25
Number of patients (37)	20	17
Diplegia/monoplegia	12/8	10/7
Sex (male/female)	10/10	9/8
Age (years)	10.5 ± 2.6	12.0 ± 3.0

Table 2
Time evolution of the AOFAS score and the maximal passive dorsiflexion angle (knee in full extension).

Group	Stair-shaped ATL (n = 28)	Z-lengthening (n = 25)
AOFAS score preoperatively	43.1 ± 8.5	41.5 ± 12.1
AOFAS score during the latest follow-up visit [*]	68.2 ± 10.2	58.5 ± 10.4
Preoperative angle	$-13.3 \pm 3.6^\circ$	$-14.3 \pm 4.3^\circ$
Postoperative angle	$22.8 \pm 2.4^\circ$	$23.3 \pm 2.7^\circ$
Angle at the latest follow-up visit [*]	$18.1 \pm 3.0^\circ$	$13.2 \pm 3.1^\circ$
Surgical correction angle	$36.1 \pm 4.5^\circ$	$37.2 \pm 3.5^\circ$
Long-term correction angle [*]	$29.0 \pm 3.1^\circ$	$21.6 \pm 4.3^\circ$

^{*} There was significant difference between two groups ($p < 0.05$).

Table 3
Milestones of recovery after surgical correction.

Group	Stair-shaped ATL (n = 28)	Z-lengthening (n = 25)
Postoperative days of recovery (days)		
Return to rehabilitation [*]	14.2 ± 5.7	39.2 ± 6.8
Return to walking training [*]	23.1 ± 6.0	60.5 ± 7.1
Stability for running [*]	45.3 ± 5.3	105.4 ± 10.5

^{*} There was significant difference between two groups ($p < 0.05$).

$36.1 \pm 4.5^\circ$ for Z-lengthening). During the latest follow-up visit, the correction angle in the Z-lengthening group decreased to $21.6 \pm 4.3^\circ$, which was lower than in the stair-shaped ATL group ($29.0 \pm 3.1^\circ$; $p < 0.05$). The data on patients' recovery after surgical corrections are summarized in Table 3. The time needed for patients to begin rehabilitation, walking training, and to gain stability for running was significantly shorter in the stair-shaped ATL group than in the Z-lengthening group (all $p < 0.05$).

4. Discussion

Equinus deformity caused by contracture of the triceps surae is a common finding in patients with cerebral palsy and may be treated surgically by ATL [8]. Current clinical techniques for tendon-lengthening, such as Z-plasty etc., completely disrupt the tendon and then reconstruct it with sutures to attain additional length. The mechanical integrity of the tendon that is fully transected, reconfigured, and then repaired will initially depend on the ability of the sutures to bridge the disrupted collagen bundles. Therefore, a sufficiently long immobilization period after operation (from 3 to 7 weeks) is required to ensure healing before returning to full function or exercise. Blasier and White [9] reported that a three-week immobilization period after sliding lengthening must be sufficient, while other researchers suggested a four-week immobilization period with short leg cast after Z-lengthening of the Achilles tendon [10]. Renshaw et al. [11] recommended 6 weeks of a short leg cast after triple-cut sliding lengthening. However, a prolonged ankle immobilization following surgery can bring many disadvantages, such as muscle weakness, joint contracture, slow recovery and rehabilitation, and delayed return to unrestricted daily activity [12].

Lin et al. [12] introduced a novel ATL method in continuity to treat equinus deformity, in which mesh tenotomy of the tendinous portion of the gastrocnemius and soleus fasciae was performed. The mesh tenotomy included multiple transverse 5–8-mm cuts, around 5×5 cuts (row \times column), with at least a 3–5 mm distance between cuts. This mesh cutting method allowed earlier movement after a one-week immobilization period with below-knee casts. Farshad et al. [13] developed another method of helical cutting for tendon-lengthening in continuity. Helical cutting reliably leaves the tendon in continuity, can offer improved resistance to tensile loads, which allowed early exercise. In the present study, we created a stair-shaped cutting in which tendon continuity was not fully disrupted, the preservation of this continuity being potentially favorable not only to postoperative tensile strength and early movement but also to healing since the nutritive paratendon [14] was not fully disrupted. The two-week immobilization period after the stair-shaped tendon lengthening was sufficient. Because of this shorter immobilization period, larger passive movement angle, greater correction angle and a better AOFAS score were observed after the stair-shaped ATL surgery.

The recurrence of equinus deformity after a surgical intervention is common in patients with CP. Joo et al. have reported a recurrence rate of up to 43.8% [15]. Several authors have found that

the age of the patient at the time of initial surgery was the major factor associated with the recurrence of equinus deformity. Joo et al. demonstrated that among children with hemiplegia and diplegia, the younger children (below 8 years old) showed a higher rate of recurrence compared with the older children. Rattey et al. reported that ATL performed at a young age (below 4 years old) was a significant predictor of recurrence in patients with diplegia. Katz et al. [16] found that the recurrence 5 years after surgery was higher than 2 years post-surgery. Thus, they suggested that the recurrence of equinus deformity after ATL may take five years to become apparent. In our study, there was no recurrence in both groups during the latest follow-up visit. According to previous conclusions, two reasons may contribute to the result observed in our study: first, the patients involved in our study were all beyond eight years old; second, the follow-up period was shorter than the recommended period and therefore, mid-term or long-term follow-up is required to further evaluate the recurrence rate.

Calcaneal gait is another great concern in the treatment of equinus deformity in patients with CP. It is a significant iatrogenic complication after ATL procedures. It often results from overlengthening or muscle weakness. Segal et al. [17] defined a calcaneal gait as a mean ankle dorsiflexion superior to 14° during the stance phase. The stair-shaped ATL procedure does not completely sever the tendon, the remaining continuous bundle decreases the risk of overlengthening the Achilles tendon. Therefore, no calcaneal gait was observed after surgery in the stair-shaped ATL group.

5. Conclusions

The stair-shaped cutting is a technique in which tendon continuity is not fully disrupted. The preservation of this continuity might not only result in a quicker recovery but also in a more adequate correction of the equinus deformity without calcaneal gait. Therefore, the stair-shaped ATL technique is an alternative candidate to treat Achilles tendon contracture in patients with CP.

Conflict of interest

The authors declare that they have no conflict of interest.

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