RESEARCH ARTICLE

Evaluation of Clinical and Radiological Results of Calcaneal Lengthening Osteotomy in Pediatric Idiopathic Flexible Flatfoot

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Abstract

Background: Flexible idiopathic flatfoot is the most common form of flatfoot. First line treatments are parental reassurance and conservative measures; however, surgical treatment may be needed in some cases. A number of surgical techniques with varying results have been described in the literature. Here, we present our clinical and radiological outcomes of calcaneal lengthening osteotomy for pediatric idiopathic flexible flatfoot.

Methods: Calcaneal lengthening osteotomy was performed in 20 patients, 30 feet, with idiopathic flexible flatfoot that were resistant to conservative treatment between 2007 and 2011. Patients were evaluated according to ACFAS universal evaluation scoring scale and radiographic indexes. The mean follow up duration was 23.1 ± 9.9 months.

Results: The average age was 10.4 ± 0.9 years. Achilles tendon lengthening was performed in 28 feet. ACFAS score at the final follow up had improved significantly compared to pre-operative score (37 to 88, *P<0.0001*). Radiographic parameters also showed significant improvement after surgery ((*P<0.0001*)). Distal segment displacement and hardware irritation as postop complications were observed in 2 and 3 cases, respectively, with no long-term clinical impact.

Conclusion: Calcaneal lengthening osteotomy is an appropriate and safe operation in symptomatic idiopathic flexible flat foot that is resistant to conservative treatment.

Level of evidence: IV

Keywords: Flat foot, Idiopathic, Pediatric, Radiograph, Surgery

Introduction

Flat foot or pes planus is a term implying that normal medial longitudinal arch of the foot has become flat. It is one of the most common deformities referred to orthopedic surgeons and pediatricians. It can be either idiopathic or associated with generalized pathological conditions including connective tissue disorders, neuromuscular abnormalities or foot pathologies such as tarsal coalition or posterior tibial tendon insufficiency. Flatfoot may be flexible or rigid, depending on whether the appearance of the medial longitudinal arch changes upon weight bearing (1, 2).

Idiopathic flexible pes planus (IFPP) is the most common form, which can vary in magnitude between individuals. The initial and most often main treatment is parental reassurance along with conservative measures including shoe modifications and stretching

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exercises. However, surgical treatment may be needed in some cases (3-6).

A number of surgical techniques including soft tissue and bone modifications have been described for the correction of flat foot deformities. Each procedure comes with its own set of advantages and disadvantages and have yielded varying results. "Calcaneal lengthening osteotomy" is one of these procedures (2, 7, 8).

Although "calcaneal lengthening osteotomy" was first described decades ago, there are still controversies regarding patient selection and the surgical technique; including the site of osteotomy, amount of lengthening, type of graft, the fixation device and whether to perform additional soft tissue procedures. Clinical studies on this subject are sparse and patients requiring operative correction have various etiologies including cerebral palsy, myelomeningocele, and connective tissue disorders. The idiopathic group is small and rarely requires surgery. Herein we report the clinical and radiological outcomes of calcaneal lengthening osteotomy in IFPP (9-24).

Materials and Methods

During January 2007 to March 2011 all patients undergoing calcaneal lengthening osteotomy for idiopathic flexible flatfoot in our center were included in this study. All operations were performed by the first author. Prior to considering surgical corrections all patients went through at least six months of conservative treatment such as weight loss, shoe modification, orthosis, activity modification, physiotherapy, stretching exercises and short courses of NSAIDs. Those who failed conservative treatment with consistent fatigue and functional disturbance were then considered for surgery. All patients with a rigid or non-idiopathic flatfoot, vascular or sensory pathology and non-ambulators were excluded from the study.

Surgical technique

The patient was positioned supine. Tourniquet could be used for hemostasis. A longitudinal incision was placed from 1 centimeter proximal to the calcaneocuboid joint to sinus tarsi (modified lateral Ollier). The sural and superficial branches of peroneal nerve were protected. The plane of dissection was between extensor digitorum brevis dorsally and the peronei on the plantar side. The calcaneocuboid joint was identified without opening the joint capsule. Either a Freer or periosteal elevator was inserted in sinus tarsi to locate the middle facet. An osteotomy was then created in between middle and anterior facet of subtalar joint approximately 1 to 1.5 cm proximal to calcaneocuboid joint. A k-wire was inserted longitudinally in a posterior to anterior direction from the calcaneal tuberosity, passing through osteotomy site and calcaneocuboid joint to stabilize the distal segment and avoid it's dorsal displacement.

Two Schanz pins, one in the proximal and one in the distal fragments, were used to distract the osteotomy. The size of the graft was estimated according to the amount of distraction required to gain clinical correction [Figure 1]. Autogenous graft could be harvested from the ipsilateral proximal tibia. A k-wire could be enough to stabilize the osteotomy; but we occasionally used a supplementary staple to mitigate the collapse of the osteotomy. In cases where ankle dorsiflexion was less than 10 degrees, Achilles tendon lengthening was undertaken to achieve a plantigrade foot.

A longleg non-weight-bearing cast was applied. At 6 weeks post-op the K-wire was removed in the clinic and a short-leg cast was applied. Full weight bearing was allowed after detecting radiographic union, usually between weeks 10 to 12 post surgery and gradually increased to full weight bearing according to the imaging. All patients were revisited in clinic in the third, sixth and twelfth week post-surgery and every 6 months thereafter.

Scoring and Follow-up

Patients were evaluated according to ACFAS Universal Evaluation Scoring Scale, Module 3, which is designed to evaluate rear foot including flat foot. This system consists of two parts. The first part is subjective parameters including pain, appearance and functional capacities. The second part is about objective parameters including radiologic evaluation and function, with 50 points each adding up to a total of 100 points.

Standard anteroposterior (AP), true lateral, and long axial view radiographs were taken pre and post

Figure 1. Amount of distraction estimated according to clinical correction. A longitudinal k-wire used before distraction.

Table 1. Measurement method of radiologic parameters

Radiologic parameter	Definition
Talocalcaneal Angle in Antero-Posterior view	Angle between axis of the talus (line midway between the medial and lateral edges) and axis of the calcaneus (line tangent to the lateral edge)
Talocalcaneal Angle in Lateral view	Angle between longitudinal axis of the talus (line bisecting the dorsal and plantar edges) and calcaneal inclination axis (line from most inferior portion of the calcaneal tuberosity to the most distal and inferior point of the calcaneus at the calcaneocuboid joint)
Talus-First Metatarsal Angle in Antero-Posterior view	Angle between axis of the talus and longitudinal axis of the first metatarsal (line midway between the medial and lateral edges)
Talus-First Metatarsal Angle in Lateral view	Angle between longitudinal axis of the talus and longitudinal axis of the first metatarsal (line midway between the dorsal and plantar edges)
Calcaneal Inclination Angle in Lateral view	Angle between calcaneal inclination axis and horizontal axis (supporting surface)
Medial Longitudinal Arch Angle in Lateral view	Angle between calcaneal inclination axis and longitudinal axis of the first metatarsal
Talo-Horizontal Angle in Lateral view	Angle between longitudinal axis of the talus and horizontal axis
Talonavicular Angle in Antero-Posterior view	Angle between talar joint inclination (line connecting medial and lateral edges of talar head articular surface) and navicular joint inclination (line connecting medial and lateral edges of navicular articular surface at the level of talonavicular joint)
Talonavicular Angle in Lateral view	Angle between longitudinal axis of the talus and longitudinal axis of the navicular (line midway between the dorsal and plantar edges)
Navicular-First Cuneiform Angle in Lateral view	Angle between longitudinal axis of the navicular and longitudinal axis of the first cuneiform (line midway between the dorsal and plantar edges)
Calcaneal Length in Lateral view	Distance between the midpoint of a vertical line through the anterior calcaneus, parallel to the calcaneocuboid joint to the most posterior aspect of the calcaneus
Calcaneus-Fifth Metatarsal Angle in Antero-Posterior view	Angle between axis of the calcaneus (line tangent to the lateral edge) and longitudinal axis of the fifth metatarsal (line midway between the medial and lateral edges)
Calcaneal-Tibial Angle In Long Axial view	Angle between mid-diaphyseal line of the tibia to the mid-diaphyseal line of the calcaneus
Calcaneal Translational Displacement in Long Axial view	Distance between mid-diaphyseal line of the tibia to the mid-diaphyseal line of the calcaneus at level of the most distal part of the calcaneus

operatively. AP radiographs were used to measure talo-first metatarsal, talo-calcaneal, talonavicular, and calcaneus-fifth metatarsal angles [Table 1].

Lateral radiographies were used to measure talo-first metatarsal, calcaneal inclination, talocalcaneal, medial longitudinal arch, talo-horizontal, talonavicular, and naviculo-first cuneiform angles as well as calcaneal length in millimeter [Table 1].

Long axial view was used to measure calcaneal-tibial angle and calcaneal translational displacement in millimeter [Table 1].

Statistical analysis was performed using SPSS 13, using chi-square test; independent-samples T-test; and paired-samples T-test. A *P-value* of less than 0.05 was considered as statistically significant.

Results

Data for 20 patients, 30 feet, is reported in our study of whom 12 were boys and 8 were girls. Six boys and four girls had bilateral surgery. The mean age at the time of surgical intervention was 10.4 ± 0.9 (range: 8-12.5 years). We used a staple along with a k-wire in 24 cases. Achilles tendon was lengthened in 28 feet. The mean follow up time was 23.1 ± 9.9 months (range: 9-50 months).

At final follow up, ACFAS scoring scale showed significant improvement in both subjective and objective parameters in each individual case. The mean ACFAS score was 37 pre-operatively and 88 at final follow up (*P<0.0001*) [Figure 2].

All radiographic parameters also showed significant improvement after surgery (*P<0.0001*) [Table 2] [Figure 3].

(A)

(B)

(C)

(D)

Figure 2. A 10 year-old-boy with idiopathic flexible flat foot before (A,B) and two years after (C,D) calcaneal lengthening osteotomy.

Table 2. Radiographic parameters before and after surgery

Parameter	Pre Operation Average (SD)	Post Operation Average (SD)	Correction Average	*P. Value*
Talocalcaneal Angle in Anteroposterior view	34.9 (3.7)	25.1 (3.9)	9.8	< 0.0001
Talocalcaneal Angle in Lateral view	48.9 (3.8)	41.6 (4)	7.3	< 0.0001
Talus-First Metatarsal Angle in Anteroposterior view	29.9 (3.6)	9.5 (1.5)	20.4	< 0.0001
Talus-First Metatarsal Angle in Lateral view	28.1 (3.4)	4.6 (2.3)	23.5	< 0.0001
Calcaneal Inclination Angle in Lateral view	7.5 (2)	21 (1.9)	13.5	< 0.0001
Medial Longitudinal Arch Angle in Lateral view	154.2 (4.1)	130 (19.9)	24.2	< 0.0001
Talo-Horizontal Angle in Lateral view	41.4 (4.7)	20.6 (4.1)	20.8	< 0.0001
Talonavicular Angle in Anteroposterior view	30.1 (2.8)	13.5 (2.7)	16.6	< 0.0001
Talonavicular Angle in Lateral view	4 (1.4)	1.7 (1.3)	2.3	< 0.0001
Navicular-First Cuneiform Angle in Lateral view	24.9 (3.1)	2.6 (1.6)	22.3	< 0.0001
Calcaneal Length in Lateral view	54 (6.2)	62.4 (6.1)	8.4	< 0.0001
Calcaneus-Fifth Metatarsal Angle in Anteroposterior view	23.2 (4.2)	3 (1.9)	20.2	< 0.0001
Calcaneal-Tibial Angle In Long Axial view	12.1 (2.1)	3.8 (1.8)	8.3	< 0.0001
Calcaneal Translational Displacement in Long Axial view	10.4 (1.7)	5.6 (1.9)	4.8	< 0.0001

A mean of 8.4 mm calcaneal lengthening was achieved. There were no overcorrections. Two patients had symptom free distal segment displacement on radiographs. In 3 out of 24 cases where a staple was used, removal was required to alleviate symptoms of irritation., the irritated skin and peroneal tendons were seen in two and one cases, respectively. No degenerative changes in adjacent joints, such as the calcaneocuboid, and no donor site complications were seen. Clinical and radiographic union was achieved in all the patients. The graft did not collapse or resorb in any of the cases.

Discussion

Idiopathic flat foot can vary in magnitude amongst patients. Although asymptomatic in most, the severity of symptoms and functional disturbance is severe in a few cases and may not respond to conservative measures. These patients enter a vicious cycle of physical limitation due to foot pain, calf muscles strain, callosity, and ankle sprain as well as limitations in choosing a shoe. This restricted mobility results in obesity, which in turn exacerbates their symptoms (1, 2).

A number of reports demonstrate that conservative measures control the symptoms in most patients; however, surgery has to be considered where a non-operative approach fails and the symptoms have an effect on the quality of life (2-8).

Calcaneal lengthening osteotomy, first described by Evans in 1975 is one of the surgical techniques for the treatment of flat foot (25). In 1983, Phillips evaluated patients who underwent “Evans” technique. He reported satisfactory results at long term follow up (26). In 1995 Mosca modfied Evans’ technique with addition of medial cuneiform osteotomy to achieve a more balanced correction (9).

Unlike most other previous studies, we reported the outcomes of surgical intervention on idiopathic flexible flat foot. In Mosca’s cohort, 26 out of 31 flat feet were due to neuromuscular disorders (9). Dogan et al. reported only 4 idiopathic flat feet in a total of 13 patients who underwent the calcaneal lengthening osteotomy (27). Although idiopathic flexible flat foot is the most common type, the efficacy of surgery on this group is yet to be robustly reported.

Our study indicates that calcaneal lengthening osteotomy is an appropriate technique for the correction of the idiopathic flexible flat foot. Performing soft tissue procedures alone on these patients resulted in considerable failure. (2) Although there are lots of techniques and modifications available for soft tissue reconstruction and in recent studies there is a trend toward more anatomic spring ligament and posterior tibialis tendon reconstructions (28). Arthrodesis restricts range of motion leading to early degenerative changes in adjacent joints. (2) Arthroereisis of the subtalar joint with synthetic implant may cause foreign body reactions, infection, pain, incomplete deformity correction, and need for another surgery (2).

Our experience has shown that the most appropriate

(A)

(B)

(C)

Figure 3. Postoperative radiograph. A,B) AP and lateral standing radiograph shows improvement of radiologic parameters. C) Radiologic union and normal calcaneocuboid joint in oblique radiograph.

age for calcaneal lengthening osteotomy is between 8 to 10 years old mirroring findings from a number of other studies.

While Evans used tibial autograft, other studies have advocated the use of iliac crest autografts as well as allografts (19, 20, 25, 29, 30). We used tibial autograft, as described by Evans, but, did not observe any complications at the osteotomy or the donor site.

A reported complication of calcaneal lengthening osteotomy is displacement of distal segment and subluxation of the calcaneocuboid joint (31, 32). We inserted a k-wire before distraction passing through proximal and distal segment and calcaneocuboid joint can help.

Another reported complication of calcaneal lengthening osteotomy is degenerative changes in calcaneocuboid joint as a result of excessive pressure induced by lengthening. Our cohort did not develop degenerative changes or pain in the calcaneocuboid joint (17). This, we believe, was achieved by limiting the distraction of the osteotomy to less than 1 cm and avoiding injury to calcaneocuboid joint capsule.

A number of methods are reported for stabilization of the osteotomy including simple use of a plaster for locking the plates (22). Hardware irritation due to the staple was one of our complications. Further studies are needed to define the optimal fixation method for increasing the stability, reduction in the length of cast immobilization, and minimizing the hardware irritation. However, the expenses of this new method must also be considered.

Bourdet et al. divided flat feet into 4 categorize according to radiographic parameters. In this study, calcaneal lengthening osteotomy is recommended for midtarsal and to some extent, mix category. On the other hand, calcaneal lengthening osteotomy is not recommended in the subtalar category and is contraindicated in pes plano cavus (33).

We believe a satisfactory result in this surgery relies on two factors: appropriate patient selection and surgical technique.

We recommend this surgery for patients with considerable symptoms resulting in functional disturbance, who have failed to respond to conservative treatments for 6 months. We don't recommend this surgery for cosmetic indications. The need for the confirmation of the diagnosis cannot be over emphasized.

Calcaneal lengthening osteotomy is indicated in midtarsal flat foot which is distinguishable from subtalar type by physical examination. The lateral column in midtarsal flat foot is short and there is a significant abduction in forefoot and "too many toe sign" is positive. Furthermore, subtalar motion is relatively well preserved and hind foot valgus is not prominent. Standardized standing radiographies confirm the clinical diagnosis. Radiographs also help to rule out other pathologies. In the lateral radiograph, the first talometatarsal angle reveals loss of the medial arch. Talonavicular and naviculocuneiform angles define where the medial arch sags. In the midtarsal type the deformity is in the naviculocuneiform joint as denoted by the angle, whereas in the subtalar type the main deformity is from the talonavicular joint. The calcaneal inclination angle is measured on the lateral radiograph. As a measure of hind equinus this index has been evaluated by the lateral tibiotalar angle. If a normal or increased calcaneal inclination angle is seen in a patient with flat foot, pes plano valgus is unlikely and pes plano cavus should be suspected. This is important to note as calcaneal lengthening osteotomy is contraindicated in this type.

Standing calcaneus-fifth metatarsal angle can be measured in the AP view. This angle helps us to choose the appropriate surgical technique and in measuring the correction following the osteotomy. It is more useful than talofirst metatarsal angle on the same projection. A negative calcaneus-fifth metatarsal angle demonstrates forefoot abduction and shortening of lateral column associated with the midtarsal type. After performing calcane-al lengthening osteotomy this angle becomes closer to zero. A positive angle becomes pos-itive can indicate overcorrection.

The AP talocalcaneal angle is a radiolographic index for hind foot valgus. This angle in-creases significantly in flat foot patients with subtalar pathology. Our study mirrors find-ings in other reports where this angle does not correlate with the magnitude of calcaneal valgus. Patients with flat foot, whose main pathology is in midtarsal, may show substantial clinical valgus with only slightly increased talocalcaneal angle. It should be noted that this angle decreases normally during aging. Calcaneal tibial angle and calcaneal translational displacement, which can be measured on the long axial view, are better indexes for radio-logic evaluation of valgus (34).

Radiographic indications we use for choosing a calcaneal lengthening osteotomy for the correction of flexible flat foot include sagging of naviculo-first cuneiform angle in lateral view and negative calcaneus-fifth metatarsal angle in AP view.

Attention to details throughout the treatment process form the cornerstone for achieving satisfactory results. Appropriate patient selection as well as technical (pre-, intra- and post-operative) considerations is crucial factors.

Pre operative preparation tips

- Placing a Povidone-iodine pad
- Appropriate standing radiographies
- Full explanation of the surgical process and post operative care to patient and parents

Intra-operative tips

- Full thickness flaps avoiding undermining of the skin incision
- Meticulous protection of surrounding soft tissues. Medial plantar nerve and artery whilst performing the osteotomy, sural nerve and peroneal sheath and tendons during the sur-gical dissection and exposure and avoiding injuries to the capsule of calcaneocuboid joint.
- Release of plantar periosteum if the calcaneum completely to allow a medial hinge upon opening of the lateral cortex. This action minimizes the risk of subluxation and dispropor-tionate pressure to adjacent joints particularly the calcaneocuboid and subsequent pain.
- Insertion of a longitudinal k-wire across the calcaneocuboid joint before distraction to mitigate the risk of subluxation [Figure 1].
- Distraction by shanz pin or a Hintermann type distractor, mitigates a degree of crushing that can occur at the osteotomy edge with the use of a lamina spreader. This allows for a more accurate measurement of the osteotomy gap and graft insertion [Figure 1].
- Technical precautions while harvesting a graft from proximal of the tibia and periosteal repair [Figure 4].

Figure 4. Harvesting graft from ipsilateral proximal tibia and periosteal repair.

Figure 5. Orientation of grafts superiorly and inferiorly o preserve cortical buttress and avoiding collapse.

- Correctly inserting the graft to avoid collapsing [Figure 5].
- We advocate additional fixation with staples or H-plates to supplement k-wires if the stability of the osteotomy is in doubt.
- Most patients with flat foot have an associated Achilles tendon tightness. After placement of the graft and fixation of the osteotomy, the Achilles tendon length is assessed and lengthening performed if there is limitation of dorsiflexion. (This is required in the vast majority of cases, if not then the diagnosis may be pes plano cavus).
- We estimated the graft size clinically according to the amount of distraction that gained clinical correction [Figure 1]. Although some studies suggested intra operative radiography after distraction, we relied more on the clinical criteria as the numerous radiographic measurements and criteria may be counterproductive. The maximum graft size should be limited to 10 mm. Larger gaps may cause overload of the calcaneocuboid joint, displacement, pain and early degenerative changes.
- Technical precaution of calcaneal surgery for suturing and wound closure

Postoperative tips

- Foot elevation and splint for 48 to 72 hours and controlling compartment syndrome or wound problems
- To take radiographies in periods mentioned above
- Non-weight bearing long leg cast for 6 weeks. The K-wire is removed and non-weight bearing cast reapplied.
- Gradually increasing weight bearing after radiologic union, around 10 to 12 weeks post-surgery.

- Post cast removal physical therapy to restore ankle range of motion and regain the strength lost during cast immobilization.

In conclusion, calcaneallengthening osteotomy in juvenile and adolescent patients with idiopathic flexible flat foot is a safe and effective procedure, but appropriate patient selection and meticulous attention to detail in regard to the technical aspects of the procedure can result in an excellent outcome.

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