Correction of idiopathic congenital clubfoot using the ponseti technique: radiologic assessement

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Background
Clubfoot is a three-dimensional deformity in which the calcaneopedal complex rotates under the talar–tibial–fibular complex. The deformity includes four components: metatarsus adductus, cavus, hindfoot varus, and equinus. The Ponseti method consists of serial manipulation and casting for the correction of cavus, metatarsus adductus, and hindfoot varus; however, equinus is corrected by means of percutaneous Achilles tenotomy. The Ponseti method depends on clinical assessment. In our study, we used radiological assessment in combination with clinical assessment for the evaluation of correction of the clubfeet using the Ponseti method and early detection of pseudocorrection and lastly for the evaluation of the effect of percutaneous Achilles tenotomy on the correction of equinus deformity.
Patients and methods
Twenty-eight patients with clubfoot (20 patients) were included in this study. There were 12 boys and eight girls and their ages averaged 2 weeks (range=1 day to 3 weeks). All of them were treated with weekly manipulation and casting, followed by fluoroscopic evaluation after the fifth to sixth cast. Percutaneous Achilles tenotomy was performed when the foot could be abducted to 70° in relation to the leg with restoration of the anteroposterior talocalcaneal angle to 30° and the foot can be dorsiflexed to less than 10° with the lateral tibiocalcaneal angle more than 70°.
Results
Pirani score was used for the assessment of the deformity at presentation, at final removal of cast before bracing, and at latest follow-up. Pirani score improved from average 2.5 at first presentation to 0.5 at final removal of cast, to 0.25 at latest follow-up. At removal of the last cast, the foot could be abducted to an average of 70° in relation to the leg, with restoration of the anteroposterior talocalcaneal angle to an average of 37°, and the foot can be dorsiflexed to an average of 25° above right angle with restoration of lateral tibiocalcaneal angle to an average of 68°. Percutaneous Achilles tenotomy improved equinus by an average of 20° and the lateral tibiocalcaneal angle by an average of 19°. There were no complications such as infection, vascular injury, or recurrence.
Conclusion
The Ponseti method is an excellent method for the treatment of clubfoot, and we found that the addition of radiographic to clinical evaluation helps in the better assessment of correction and early detection of pseudocorrection to avoid recurrence or development of rocker bottom deformity. All components of clubfoot would be corrected by stretching, but equinus usually needs percutaneous tenotomy, which helps acute correction of the deformity.

Keywords:
clubfoot, ponseti method, radiologic evaluation

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Introduction

Idiopathic clubfoot is a developmental malformation, as normally the developing foot turns into clubfoot during the second trimester of pregnancy [1]. It has been recognized since ancient Egypt; Pharaohs and Tutankhamun had clubfoot, and this condition was described by Hippocrates [2]. The incidence of clubfoot is approximately one in every 1000 live births and is more common in boys [3]. The deformity includes four components: metatarsus adductus, cavus, hindfoot varus, and equinus. Clubfoot is a three-dimensional malformation with its center in the talocalcaneonavicular articulation and the axis of malformation is the interosseous talocalcaneal ligament [2]. The calcaneopedal block rotates under the talar–tibial–fibular complex (approximating the navicular bone to the medial malleolus and the

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calcaneal tuberosity to the lateral malleolus) [4]. Treatment in clubfoot aims at correction of the deformity to obtain functional, plantigrade, pain-free foot. Classically, treatment includes the application of multiple casts, followed by extensive surgery correcting the deformity during the first year of life. Results, however, showed deterioration over time, with only 27% remaining good or excellent after 30 years of age [5]. In the USA, the use of extensive surgical release during the first year of life fell from 70% in 1996 to just 10% in 2006 [6]. In recent times, treatment is mainly conservative, avoiding extensive soft tissue release, and surgery is limited to cases with failed conservative methods [7,8]. Ponseti reported avoiding extensive surgery in 89% of cases with his technique [9]. The Ponseti method consists of a reduction stage of weekly manipulation and application of casts. The initial casts correct the cavus deformity by supinating the forefoot and dorsiflexing the first metatarsal, thereby aligning the forefoot with the hindfoot. To correct the varus and adduction, the supinated foot is abducted while counter-pressure is applied with the thumb against the head of the talus [8]. In the final cast, if 70° of foot abduction in supination and more than 10° of dorsiflexion can be obtained, treatment with casting is continued for two or three casts before bracing. If 70° of foot abduction can be obtained but less than 10° of dorsiflexion, percutaneous tenotomy of the tendoachilles is indicated, followed by 3 weeks of casting. If abduction is less than 70° and the anterior tubercle of calcaneus is not felt, posteromedial release is indicated [9,10]. The maintenance stage starts after the last cast with 24 h splinting for 3–4 months, followed by night-time splinting until 3–4 years of age. Recurrence is mainly due to noncompliance with splinting. Neglected or relapsed cases with excessive scaring can be gradually distracted as described by Ilizarove [11]. Ponseti did not recommend the standard use of radiographs; instead, he suggested that palpation alone should be used to assess correction [1]. Pulak *et al.* [9] also depended on clinical angles for the assessment of correction. Beaty [3], Bergerault *et al.* [4], Radler *et al.* [12], and El-Mesalamy [13] used radiological angles for the assessment of correction before and after tenotomy and to detect subtle midfoot changes that would point to the development of a rocker-bottom foot. The aim of our study was to describe the radiographic changes in the infant foot throughout treatment with the Ponseti technique for the assessment of correction, correlation between clinical and radiological finding for decision making, and to determine the effect of percutaneous Achilles tenotomy on correction of equinus deformity.

Patients and methods

Inclusion criteria

All cases with idiopathic clubfoot from birth up to 3 weeks treated with weekly casting and percutaneous Achilles tenotomy after fifth to sixth cast were included in the study. This study approved by the Ethical committee of Zagazig University, Zagazig, Egypt.

Exclusion criteria

All patients with clubfoot who were older than 3 weeks, cases without tenotomy, and cases that needed posteromedial release were excluded. Moreover, nonidiopathic cases were excluded as cases with arthrogryposis and spina bifida.

Twenty-eight patients with clubfeet (20 patients) were included in this study. There were 12 boys and eight girls. The right foot was affected in seven cases, the left foot was affected in five cases, and in eight cases clubfoot was bilateral. Their ages averaged 2 weeks (range=1 day to 3 weeks). All of them were treated with weekly manipulations and casting, followed by percutaneous Achilles tenotomy during the period from October 2009 to December 2011 in the Orthopedic Department, Zagazig University Hospitals. All cases of clubfoot presented to our outpatient clinic were evaluated clinically for exclusion of other disorders such as arthrogryposis and spina bifida. Only cases with idiopathic clubfoot were included. Initially, all cases were evaluated with Pirani scores; the initial score averaged 2.5 (range=2–4). The age at presentation averaged 2 weeks (range=1 day to 3 weeks); six cases presented within the first week, seven within the second week, and the remaining seven cases presented within the third week. All cases younger than 2 weeks were treated with manipulation by their parents in supination and abduction until the skin can withstand plaster, and then we started manipulation and casting at the age of 2 weeks.

Technique of manipulation and casting

From the second week onward all feet were manipulated by abducting the foot in supination while pressure is applied to the lateral aspect of the talar head to prevent rotation of the talar head within the ankle mortise. An above knee well-molded cast was applied in the corrected position. Within 7–10 days, the ligaments can be stretched again, and hence the cast is removed and the foot manipulated again. Usually, cavus is corrected with the first cast, and then forefoot adduction and heel varus is corrected by abducting the foot while pressure is applied to the talar head.

At the fifth to sixth cast, the degree of foot abduction in relation to the leg and the degree of ankle dorsiflexion were measured using a goniometer, and all cases were evaluated under fluoroscopy for the evaluation of the anterior talocalcaneal angle (in anteroposterior view) to confirm rotation of the calcaneus under the talus and the tibiotalar angle (in lateral view) to assess the degree of equinus and the need for percutaneous Achilles tenotomy:

(1) All cases with abduction of foot to 70° in relation to the leg (anterior talocalcaneal angle more than 30°) and dorsiflexion of 10° or more (lateral tibiotalar angle of 70° or less) continued casting for three casts followed by bracing. These cases were not included in the study.
(2) All cases with abduction of foot to 70° in relation to the leg (anterior talocalcaneal angle more than 30°) and dorsiflexion of less than 10 (lateral tibiotalar angle more than 70°) were in need for percutaneous Achilles tenotomy. All these cases were included in the study.
(3) All cases with abduction of foot less than 70° in relation to the leg (anterior talocalcaneal angle less than 30°) are in need for posteromedial release. Percutaneous Achilles tenotomy was performed in some of these cases to facilitate casting until posteromedial release was performed. These cases were not included in the study.

Technique of percutaneous Achilles tenotomy

Tenotomy was performed under general anesthesia (Fig. 1a–c) through a small incision of about 4 mm on the medial side of the tendon 1 cm above its insertion with a sharp-tipped knife blade no. 11, and then the foot was gently forced into dorsiflexion. The amount of correction is measured under fluoroscopy (Fig. 1d and e). Above knee cast is applied in the corrected position for 3 weeks and then the cast is removed. In our study, we changed the cast after tenotomy after 1 week to put the foot in overcorrection. On final cast removal, all feet were evaluated under fluoroscopy (Fig. 2a–d) and using the Pirani score.

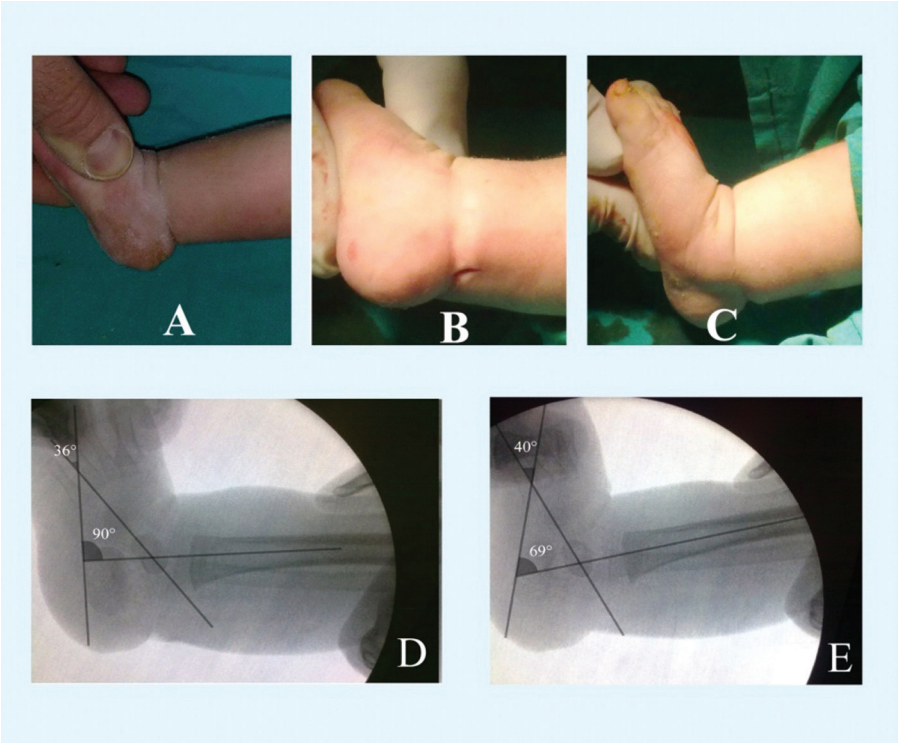
Splinting

Dennis Brown splint was applied for 24 h for 3–4 months, and then during night-time for 3–4 years.

Follow-up

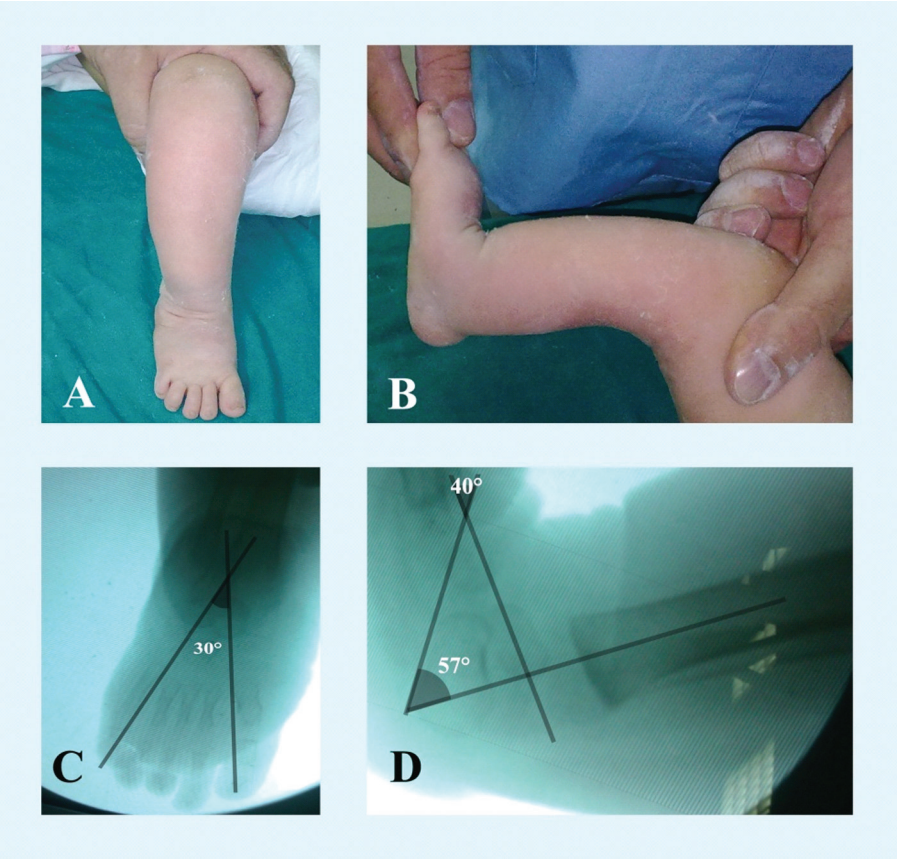
All cases were followed up monthly for 3 months to monitor compliance of the baby to the brace, followed by every 3 months for 1 year, and then every 6 months for 3–4 years. Parents were instructed for

Figure 1



(a) Foot cannot be dorsiflexed to right angle before tenotomy. (b) Percutaneous Achilles tenotomy. (c) Foot can be dorsiflexed above right angle after tenotomy. (d) Tibiocalcaneal angle before tenotomy 90°. (e) Tibiocalcaneal angle after tenotomy 69°.

Figure 2



(a) At final removal of cast fully corrected adductus. (b) At final removal of cast fully corrected equines. (c) At final removal of cast anteroposterior talocalcaneal angle 30°. (d) At final removal of cast lateral tibiocalcaneal angle 57°.

early signs of recurrence, such as varus tilt of the heel, progressive tightening of tendocalcaneus, and adduction of forefoot. Follow-up averaged 18 months (range=12–24 months).

Results

All our cases were followed up for an average of 18 months (range=12–24 months). At latest follow-up Pirani score averaged 0.25 (range=0.0–0.5). All our cases reached full correction before bracing. All cases reached full correction after an average of seven casts (range=6–8 casts), including the cast applied after tenotomy. Total time of casting averaged 10 weeks (range=8–12 weeks). At last correction (Tables 1 and 2) the foot can be abducted to an average of 70° (range=65–75°) in relation to the axis of the leg with restoration of anterior talocalcaneal angle to an average of 37° (range=32–50°). Percutaneous Achilles tenotomy improved foot dorsiflexion at the ankle clinically by an average of 20°, and improved lateral tibiocalcaneal angle by an average of 19°, with very little change in the lateral talocalcaneal angle of average 3° and anteroposterior talocalcaneal angle of average 2°. No complications occurred in our cases or no infection, and percutaneous Achilles tenotomy was performed without complications of vascular injury.

Discussion

Clubfoot is a developmental malformation as the normally developing foot turns into clubfoot during the first trimester of pregnancy. The deformity principally is rotation of the whole foot around the talus, which is fixed in the ankle mortise. In other words, the calcaneopedal component rotates around the talotibiofibular component in plantar flexion and adduction, with shortening of posteromedial structures. The deltoid and tibionavicular ligaments and the tibialis posterior tendon are thickened and merge with the plantar calcaneonavicular ligament. All these thickened ligaments have excessive collagen fibers, which are densely packed, have abundant cells, and arranged in wavy appearance called crimps, and hence it is stretchable. When stretched, the crimps reform within days, and hence stretching and manipulations are repeated weekly [1]. The tendoachilles has excessive collagen near its insertion

Table 1 Changes in clinical angles before and after percutaneous Achilles tenotomy

Foot clinical angles	After manipulation average (range)	After tenotomy average (range)
Foot abduction N (70°)	70° (65–75°)	70° (65–75°)
Foot dorsiflexion N (10°)	5° (–10 to 5°)	25° (15–25°)

Table 2 Changes in radiological angles before and after percutaneous Achilles tenotomy

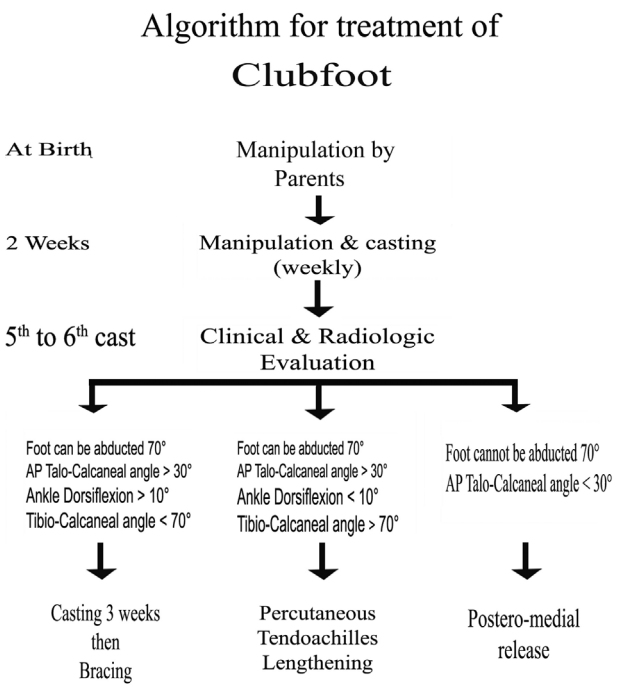
Foot radiological angles	After manipulation average (range)	After tenotomy average (range)
AP talocalcaneal angle	37° (32–50°)	39° (35–52°)
Lat. talocalcaneal angle	40° (32–46°)	43° (35–48°)
Lat. tibiocalcaneal angle	87° (83–92°)	68° (58–67°)

but is not stretchable. Thus, Ponseti depends on manipulations and weekly stretching for the correction of the cavus, forefoot adduction, and heel varus and on percutaneous Achilles tenotomy for the correction of equinus. In our study, we found that cavus, adductus, and heel varus are corrected by means of manipulations, but equinus is corrected using tenotomy of tendoachilles.

During the course of treatment, Ponseti depends on clinical palpation of the talar head and anterior calcaneal tuberosity for the evaluation of reduction of calcaneopedal complex over the talus [1]; others such as Beaty [3] and Radler *et al.* [12] consider radiologic evaluation as an integral part of evaluation. In our study, we found that radiologic evaluation is a useful adjunct to clinical evaluation in the following points:

(1) Rotation of calcaneus under the talus is essential for correction of the adduction and varus, which can be tested through abduction of the foot about 70° in relation to the leg; this cannot be confirmed clinically, especially in obese babies. Moreover, false correction may occur at the midtarsal joint; therefore, measurement of talocalcaneal angle in the anteroposterior view is important. Normally, this angle ranges between 30 and 55°. In our study, after manipulation of forefoot, we found that at the fifth to sixth cast the angle is restored to an average of 37° (range=32–50°).
(2) Correction of equinus should be carried out at the ankle joint, which could be tested through dorsiflexion of the foot to 10° above the right angle, as false correction may occur at the midtarsal joint with the development or rocker bottom deformity. Thus, evaluation of lateral tibiocalcaneal angle is important. Normally, this angle in stress dorsiflexion lateral view ranges between 10 and 40°. In our study, percutaneous tendoachilles tenotomy was performed when foot cannot be dorsiflexed to more than 10° above the right angle, with tibiocalcaneal angle of more than 70°. Moreover, with tenotomy we get acute correction of equinus of average 20° (range=18–23°) and improved lateral tibiocalcaneal angle by average 19° (range=17–21°).

Figure 3



Algorithm for the treatment of clubfoot.

Radiology has a role in confirming clinical findings and decision making. In correlation between clinical and radiological finding we can conclude an algorithm (Fig. 3) for the treatment of clubfoot. As the foot reaches 10° dorsiflexion (lateral tibiocalcaneal angle 70°) and 70° abduction (anteroposterior talocalcaneal angle 30°), we can continue casting and bracing. Less than 10° dorsiflexion (lateral tibiocalcaneal angle more than 70°) needs tenotomy and less than 70° abduction (anteroposterior talocalcaneal angle 30°) needs posteromedial release. These figures are comparable to the clinical findings of Staheli [1] and Pulak *et al.* [9] and to the radiological finding

of Beaty [3], Bergerault *et al.* [4], Radler *et al.* [12], and El-Mesalamy [13].

With percutaneous Achilles tenotomy, equinus deformity was corrected clinically by 20° and radiologically by 19°. This is comparable to the results obtained by Radler *et al.* [12] and El-Mesalamy [13]; tibiocalcaneal angle improved by 17° in both studies.

Percutaneous Achilles tenotomy was performed without complications of vascular injury. Dobbs *et al.* [14] retrospectively reported four cases of serious bleeding out of 200 clubfeet operated by means of percutaneous Achilles tenotomy. The cause of bleeding was injury of the peroneal artery in three cases and lesser saphenous vein in one case.

The six-point Pirani score is internationally used for assessment with the Ponseti method. It studies the three morphological elements of the hindfoot (rigidity of equinus, emptiness of the heel, and severity of posterior crease) and of the midfoot (curvature of the lateral border, reducibility of lateral head of the talus, and severity of medial crease), attributing 1 point for severe, 0.5 points for moderate, and 0 for no deformity. The lower the score, the better is the prognosis. In our study, Pirani score improved from average 2.5 to 0.5 at removal of last cast and to 0.25 at latest follow-up.

Conclusion

The Ponseti method is an excellent method of treatment for clubfoot; it avoids the complications of extensive surgery and gives painless, mobile, normal-looking foot. The combination of clinical and radiological evaluation facilitates decision making between continuing cast, Achilles tenotomy, and posteromedial release. Percutaneous Achilles tenotomy, although it is a minor procedure, it gives acute correction of equinus deformity.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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