Ilizarov Technique Combined with Additional Procedures for the Correction of Equinocavovarus Foot Deformity in Adults

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Abstract

Background: The Ilizarov technique has been used to treat equinocavovarus foot deformity and has shown good results. However, these results were mostly observed in pediatric patients, and few reports involving only adult case series exist. The aim of this study was to evaluate the outcome of the Ilizarov technique combined with additional procedures for equinocavovarus deformities in adults.

Methods: Total 28 adult patients (33 feet) who underwent equinocavovarus foot deformities correction using the Ilizarov technique combined with additional procedures between February 2013 and December 2017 were included. Clinical outcomes were assessed preoperatively and at final follow-up using the Visual Analog Scale (VAS), the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hind foot score, the Foot Ankle Ability Measure (FAAM) score, and the Short Form-36 (SF-36) questionnaire. The radiographic outcomes were measured using weight-bearing ankle and foot radiographs taken preoperatively and at the last follow-up visit.

Results: The mean VAS, AOFAS ankle-hind foot scores, FAAM scores were significantly improved (P < 0.0001 for each) at a mean follow-up of 37.30 ±10.94 months. SF-36 scores increased postoperatively in terms of physical function, role-physical, body pain, general health, vitality, social function, role-emotional, mental health, and health transition (P < 0.0001 for each). Early complications were found in 19 feet (57.6%) and late complications were found in 7 feet (21.2%). Radiographs showed that the tibio-talar angle (p < 0.0001), tibial-sole angle (p < 0.0001), talus-first metatarsal angle (p = 0.0004), talo-calcaneal angle (p = 0.0002), and hindfoot alignment view angle (p < 0.0001) were significantly improved. Twenty-seven (97%) patients were satisfied with their outcomes and reported that they would undergo the same procedure if they had the same preoperative deformities.

Conclusion: The combination of the Ilizarov technique and additional procedures provides an effective and reliable means of correcting equinocavovarus foot deformity, yielding high levels of patient satisfaction and a low incidence of recurrence. Studies with more cases are needed to assess the results because there are many different etiological mechanisms.

Background

The correction of complex equinocavovarus deformities in adults continues to be a difficult surgery to perform because of the multidirectional components of the deformity and numerous different etiologies, including trauma, congenital anomalies, neglected or relapsed clubfoot, neuromuscular disease, poliomyelitis, spina bifida, osteomyelitis, trauma and burn injuries [1–2].

The goals of treatment for equinocavovarus deformities are to convert a deformed, rigid structure into a stable, pain-free, plantigrade foot and to allow patients to experience good function [2]. Surgical treatments involving soft tissue procedures, bone procedures or a combination of both types of procedures, with either internal or external fixation for stabilization have been shown to be more effective than conservative treatment [3]. Conventional surgery involving acute correction using soft tissue release,
tendon transfer, osteotomy, and arthrodesis can lead to satisfactory results in many cases, but relapse of the deformity is a common problem [4, 5]. These procedures are technically challenging, even for an experienced surgeon, and the risk of complications is high, particularly in patients with secondary severe joint stiffness and soft-tissue contracture [6]. Therefore, one-step operative corrections are considered high risk procedures.

The Ilizarov technique based on the concept of distraction osteogenesis and histogenesis, gradually lengthens the blood vessels, nerves, and muscles, reducing the risk of neurovascular damage, skin necrosis, and infection; with this technique the gradual correction of severe deformities is possible [1]. This technique has been recommended for very rigid feet with recurrent clubfeet by many researchers in recent decades [7]. However, these results were mostly observed in pediatric patients, and few reports involving only adult case series exist [6, 8, 9]. Therefore, the aim of this study was to evaluate the outcome of the Ilizarov technique combined with additional procedures for equinocavovarus foot deformities in adults.

**Patients And Methods**

After we obtained institutional review board approval, we reviewed the data of 63 patients who underwent foot deformity correction using external fixation between February 2013 and December 2017. All surgeries were performed by a fellowship-trained foot and ankle surgeon (BLB). The inclusion criteria for this study were patients (age ≥ 17 years) with equinocavovarus deformities treated by Ilizarov technique. We excluded 18 patients who were younger than 17 years old and 17 patients with equinocavovarus deformities corrected by a one stage procedure or treated by composite external fixation. All medical records, radiographs and clinical photographs that were available were reviewed, and passive ankle range of motion (ROM) was recorded preoperatively and postoperatively by two authors (BLB, LPT).

A total of 28 patients (33 feet) participated in the study (Fig. 1). The clinical characteristics of the patients and demographic data including age, sex, affected side, body mass index (BMI) and mechanism of deformity are summarized in Table 1. There were 17 males and 11 females with a mean age of 36.52 ± 11.85 years (range, 18 to 60 years). The mean duration of deformity prior to the procedure was 17.45 ± 15.60 years (range, 1 to 50 years). The mean follow-up time was 37.30 ± 10.94 months (range, 28 to 87 months). Five patients had bilateral involvement, and both feet were treated. Three patients (5 feet) had previously undergone surgical intervention related deformity correction (triple arthrodesis in 2 feet, open Achilles lengthening in 2, anterior tibialis transfer in 1). Twenty patients walked with crutches. Foot callus was present in most of the patients and skin ulceration was found in 7 patients (10 feet).

All the combinations of operative procedures performed are summarized in Table 2. The most commonly performed bone procedures were first metatarsal dorsal wedge osteotomy, which was performed in 9 feet, and subtalar arthrodesis, which was performed in 9 feet. The most commonly performed soft tissue procedures were plantar fasciotomy, which was performed in 27 feet, and Achilles tendon lengthening, which was performed in 26 feet, specifically, percutaneous Achilles tendon lengthening was performed in
20 feet, and open Achilles tendon lengthening was performed in 6 feet. Ilizarov external fixators were applied in all patients and temporary fixation of the metatarsophalangeal (MTP) joint with K-wire was performed in 12 feet.

**Clinical Outcome Assessment**

Clinical outcomes were assessed preoperatively and at final follow-up using the Visual Analog Scale (VAS), the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hind foot score [10], the Foot Ankle Ability Measure (FAAM) score [11], and the Short Form-36 (SF-36) questionnaire [12]. The AOFAS scoring system considers a score of ≥ 90 points as excellent, a score of 80 to 89 points as good, a score of 70 to 79 points as fair, and a score of ≤ 69 points as poor. The SF-36, a general quality-of-life assessment tool, was used to evaluate the patients’ physical function, role-physical, body pain, general health, vitality, social function, role-emotional, mental health, and health transition.

The results were evaluated based on the clinical criteria established by Ferreira et al. [13]. For the treatment of neglected clubfoot using the Ilizarov method, the criteria were as follows: a absence of pain in foot and ankle, the capacity to walk on a plantigrade foot, the capacity to wear conventional shoes, the absence of significant recurrence of the original deformity after a follow up period of at least 2 years, and patient satisfaction with the final appearance of the foot. When all the criteria were met, the result was considered good; when only one of the above criteria was not met, the result was considered fair; and when two or more of the criteria were not met, the result was considered poor. The patients’ overall satisfaction was also investigated. Patient satisfaction was determined by a questionnaire which patients were asked whether they were satisfied with the outcomes and whether they would undergo the operation again if they had the same preoperative deformities. Patients were considered satisfied when they replied they were satisfied and that they would undergo the operation again.

**Radiographic Review**

Radiographs are obtained to assess the bone deformity, joint incongruity, arthritis, bony spurs, deformity recurrence, and tibiotalar joint compression. The radiographic outcomes, including tibial-sole angle, tibiotalar angle, talo-calcaneal angle, talus-first metatarsal angle, and hindfoot alignment view angle, were measured using weight-bearing ankle and foot radiographs taken preoperatively and at the last follow-up visit (Fig. 2).

**Statistical Analysis**

The results are presented as the means and standard deviations, and 95% confidence intervals (CIs) were calculated. Paired Student's t test was used to compare the clinical scores and radiographic angles before operation and at the last follow-up. Statistical analyses were carried out using SPSS software version 16.0 (SPSS Inc, Chicago, IL), and the level of statistical significance was set to be P < 0.05.

**Operative Technique**
All operations were performed under regional or general anesthesia by one surgeon (BLB). The limb was prepared and draped under all aseptic precautions. The patient was remained in a supine position and a tourniquet was applied.

We first performed a combination of soft tissue procedures, including plantar fasciotomy, abductor halluces fasciotomy, and percutaneous/open lengthening of the tight tendon, depending on the severity and rigidity of the subcomponents of the deformities. In patients who needed tendon transfer, the tendon was transferred to the fixed position, and the tendon was fixed after external fixation was applied. Then, bone procedures, including calcaneal lateral sliding/closing wedge osteotomy, first metatarsal dorsal wedge osteotomy, tibial osteotomy, subtalar arthrodesis, and triple arthrodesis, were performed. A tibial osteotomy was performed to derotate or lengthened the limb. In general, Steinmann pins and Kirschner wires were used for fixation in the osteotomies and arthrodesis. In patients with toe plantar flexion, the corrected toes were temporally fixed with intramedullary Kirschner wires attached to the forefoot half ring for 2-3 weeks.

The Ilizarov external fixator generally consisted of two full rings around the tibia, and two half rings around calcaneus and forefoot (Fig. 3). Two rings were fixed perpendicular to the axis of the tibia by one crossed wire and two half pins for each ring. The calcaneus was fixed with crossed wire and two half pins connected to a posterior half ring. The forefoot half ring was fixed with two crossed wires. The rings and half rings were connected to each other by rods and universal hinges to allow individual movement of the distal tibia, hindfoot, and forefoot. Hinges and threaded rods were then assembled to allow the concomitant correction of forefoot adduction, midfoot cavus, hindfoot equines and varus deformities. Equinus was corrected by shortening the anterior rod between the metatarsal half ring and the tibial ring.

**Postoperative Care**

Correction of the deformity began immediately after the relief of pain and edema on the foot and ankle healed (after a latent period of 6 to 7 days), and doctors taught the patients how to adjust the device on their own (gradual correction at a rate of 1 mm per day). Manipulation of the Ilizarov apparatus was controlled by gradual distraction as tolerated until slight overcorrection of the deformity to 5 to 10 degrees of dorsiflexion at the ankle was achieved. Then, the patients were allowed to gradually bear weight with support on the operated limb (Fig. 4). The aim of the next phase was to consolidate the correction already achieved.

The decision to remove the fixator was made on the basis of clinical absence of tenderness, satisfactory stress tests results after the removal of connecting rods, and radiological evidence of consolidation indicating regenerate or complete fusion of the joints without joint subluxation. After the removal of the fixator, the patients used an ankle-foot orthosis continuously for 3 to 6 months, were encouraged to walk with full weight-bearing on the operated limb, and continued to perform supervised gait training and strengthening exercises to achieve the best results. Then, the patients were allowed to walk in a normal shoe. The duration of external fixation was 14.88 ± 4.53 weeks, which included the mean time required to
correct the deformity, which was $4.18 \pm 1.81$ weeks, and the mean time of stabilization in the apparatus, which was $10.7 \pm 3.17$ weeks. The mean duration of hospitalization was $23.09 \pm 8.43$ days.

Results

Clinical Outcomes

Overall outcomes for the entire cohort are highlighted in Table 3. The mean ankle dorsiflexion angle improved $29.50 \pm 18.66$ degrees, the mean plantar flexion angle decreased $19.80 \pm 17.47$ degrees, and mean ankle ROM improved $11.55 \pm 10.55$ degrees. The mean AOFAS score improved $40.64 \pm 7.85$. This difference was statistically significant in the pain score, functional score and alignment score ($p < 0.0001$). The activity daily living subscale score for the FAAM improved $31.12 \pm 11.10$, and the sports subscale score for the FAAM was improved $27.42 \pm 10.41$. The patients could perform daily life activities with the foot and ankle, but they generally experienced difficulty during sports activities. The SF-36 scores increased postoperatively in terms of physical function, role-physical, body pain, general health, vitality, social function, role-emotional, mental health, and health transition. The magnitude of improvement was statistically significant ($p < 0.0001$).

Of the 28 patients (33 feet), according to the clinical criteria established by Ferreira et al., good results were found in 27 feet (82%), fair results were found in 5 feet (15%) and poor results were found in 1 foot (3%). AOFAS Overall, the AOFAS scores were excellent in 5 (15%) patients, good in 9 (27%), fair in 13 (39%), and poor in 6 (18%), yielding a 42% excellent or good rate. Twenty-seven (97%) patients were satisfied with their outcomes and reported that they would undergo the same procedure if they had the same preoperative deformities.

Radiographic Results

Lateral weight-bearing radiographs showed that the tibio-talar angle changed from $132.70 \pm 21.43$ degrees preoperatively to $101.50 \pm 7.05$ degrees postoperatively ($p < 0.0001$), the tibial-sole angle changed from $120.10 \pm 21.05$ degrees to $91.85 \pm 4.71$ degrees ($p < 0.0001$), the talus-first metatarsal angle changed from $27.81 \pm 14.02$ degrees to $12.73 \pm 7.15$ degrees ($p = 0.0004$), and the talo-calcaneal angle changed from $37.06 \pm 7.65$ degrees to $31.61 \pm 6.74$ degrees ($p = 0.0002$). The hindfoot alignment view angle changed from $32.45 \pm 12.20$ degrees preoperatively to $4.82 \pm 2.68$ degrees postoperatively in the hindfoot alignment view ($p < 0.0001$). Of the 3 patients who underwent tibial lengthening, the tibia was lengthened by a mean of 6 cm (3 cm, 5 cm, 9 cm), and the tibia achieved complete healing. No nonunion occurred in the patients who underwent osteotomy or arthrodesis.

Complications

Early complications were found in 19 feet (57.6%) including: slight pin track infection in 15 feet treated locally, deep pin site infection in 2 feet treated by the removal of the pin, and limited ischemia on the posteromedial aspect of 2 feet and ankles treated with local dressings and by reducing the speed of
correction. To reduce the risk of early complications, we strictly controlled the traction speed. During distraction periodic radiographs were taken to check for joint subluxation. Late complications were encountered in 7 feet (21.2%), and 3 feet (9.1%) required additional surgeries. Subluxation of the MTP joint of the hallux was observed in 1 foot, which was treated with arthrodesis of the MTP joint. Clawing of the lesser toe in 1 foot was corrected by percutaneous tenotomy of the flexor tendon with temporally fixed intramedullary Kirschner wires for 4 weeks period. Mild recurrent varus deformity of the hindfoot in 2 feet; one foot was treated nonoperatively, and one foot was treated with calcaneal lateral sliding osteotomy because of persistent pain. Preoperative anterior subluxation of the talus was observed in 7 feet on lateral radiographs and corrected by the Ilizarov technique. Three feet had mild recurrence at the last follow-up, in which compression of the tibiotalar joint was found. However, these patients did not undergo an additional surgery because the mild pain was tolerated. For these findings, a longer follow-up period is necessary to determine whether further surgical treatment is needed.

Discussion

The Ilizarov technique has been used to treat complex deformities of the foot and ankle in adults and has shown good results [6, 8, 9, 14, 15]. This technique is advantage because it is a minimally invasive technique involving minimal dissection and a low risk of neurovascular and soft tissue injury and infection. However, the recurrence of deformity is also a common problem in adults [16]. Recurrence is possibly related to occurrence of stiffness in the feet and soft tissue contracture after previous surgeries, the occurrence of soft tissues contracture and the inability for remodeling to occur in adults, and the development of progressive neuromuscular imbalance caused by lower motor neuron disease [9]. Lee and colleagues achieved satisfactory results in patients younger than 10 years, but most adult patients with severe cavovarus deformity required secondary triple arthrodesis [9]. Furthermore, in other reports, a secondary procedure, such as arthrodesis or tendon transfer, was performed for many cases of recurrence [13, 17]. Hence, complete correction of all components through either osteotomy or arthrodesis, and/or tendon transfer or even overcorrection of the deformity is suggested [16].

The role of procedures performed in addition to Ilizarov external fixation is still under discussion [7]. Some surgeons have stated that it is possible to correct cavovarus deformities using an Ilizarov external fixator without additional procedures in certain cases [6, 8, 14]; in contrast, other authors have reported a high rate of recurrence at the follow-up [17–19]. A nonosteotomy technique with gradual soft-tissue stretching is appropriate for young patients less than 8 years of age with only mild bony deformities [2]. Song and colleagues [20] reported the correction of severe equinovarus deformities with limb lengthening in 14 patients (13 adults) with post-poliomyelitis feet. More complications were observed in patients who performed soft-tissue distraction and good results were observed in patients who performed triple arthrodesis. Several studies showed that osteotomies performed in combination with the Ilizarov technique showed better results than the Ilizarov technique alone regarding recurrence [9, 17, 20]. Lee and colleagues [16] believe that performing osteotomy through one of the triple joints first is more appropriate for adults, than is disrupting the midfoot and later performing triple arthrodesis. The present study included a total of 33 feet in which 41 bone procedures and 88 soft tissue procedures were performed for
the initial correction of deformities. All 17 patients with neurologic problems underwent a combination of procedures involving soft tissue release, tendon transfers, osteotomies or arthrodesis. We also showed good clinical outcomes with a low rate of recurrence cases requiring secondary surgery. Of course, the combination of procedures should be selected on the basis of the etiology and type of deformity. In patients who previously underwent an operation or have severely rigid neuromuscular foot deformities, the soft tissues are contracted, and there may be bony deformity and joint involvement; furthermore, they may have an initial imbalance of bone and soft tissue. In these patients, we agreed with Lee DY et al. [16] that to reduce the risk of recurrence, it is essential to correct all components of the deformity completely and to eliminate neuromuscular imbalance by performing arthrodesis with or without a tendon transfer, although external fixation alone can achieve satisfactory correction at first.

After complete correction of the deformities is achieved, effective ankle ROM is important to restore so that patients walk well, and it can be achieved by the following procedures: Functional tendon transfer can improve dorsiflexion and maintain the balance of the foot and ankle [21]. The Ilizarov technique can yield 3 to 5 mm of distraction of the ankle joint, leading to realignment and the joint space being maintained, without compression of the cartilage or bones, so this technique is effective improving ankle ROM over time [17, 22, 23, 25]. Early weight-bearing ambulation and early ankle motion exercises facilitate recovery of contractures, reduce disuse muscle atrophy and degeneration of articular cartilage, prevent stiffness of the foot and ankle, help counteract prolonged joint immobilization, and improve ankle ROM. Overcorrection is also effective at improving ankle ROM. Ferreira RC et al. reported that all feet were stiff and severely deformed before surgery and remained stiff after surgery, but most of the feet were plantigrade and asymptomatic [13]. In the present study, for these cases, functional tendon transfer was performed at the same time that the Ilizarov fixator was applied, and ankle ROM improved postoperatively, which is helpful for patients to walk well.

The most common complication is pin tract infection, and it is reported to some extent in nearly every patient during the course of treatment [7, 13, 26, 27]. Most of the cases of pin tract infection are minor and do not alter or affect the course of treatment or the final results, although they may sometimes lead to deep infection. To reduce the risk of pin tract infection, several authors have mentioned that strictly controlling the speed of drilling and sawing to minimize the risk of thermal necrosis and periosteal damage during pin insertion or an osteotomy, immediately releases tented skin around the pin; Many half pins were used to increase the stability of the external fixator (loosening and deformation may increase the risk of complications) [26]. In the present study, we found mild cases of pin track infection in 15 feet treated locally and deep pin site infection in 2 feet treated by the removal of the pin. Most of these cases occurred early and then occurred less frequently after we learned from this experience and more carefully treated the wounds. Moreover, we suggest that the pin of the fixed forefoot is positioned so that it penetrates three metatarsals so that it is stable, and correction can be achieved by pulling the bone instead of overpulling the skin soft tissue and causing skin infection and necrosis, which lead to pin tract infections.
In general, according to the results of the present study, 97% of the patients were satisfied with their outcomes because achieved satisfactory cosmetic improvement and a plantigrade foot; thus, they could wear normal shoes, which ultimately improved the patients’ quality of life and ability to walk. Pain was relieved after the removal of the external fixator, but persistent mild pain remained in some patients. The patients who had neuroticism rarely complained of pain and were satisfied with the correction of their severe deformities, even if some foot stiffness remained. All patients showed improvement in quality of life, and their confidence in participating in social activities increased, for example, their mental state improved, and they wore increasingly fashionable clothes every time they visit the clinic. Some females even began to wear makeup, which they had never done before. The patients were satisfied with their ability to perform activities of daily living, and expressed difficulty performing sports activities.

**Conclusion**

The combination of the Ilizarov technique and additional procedures provides an effective and reliable means of correcting equinocavovarus foot deformity, yielding high levels of patient satisfaction and a low incidence of recurrence. Studies with more cases are needed to assess the results because there are many different etiological mechanisms.

**Abbreviations**

AOFAS: American Orthopaedic Foot and Ankle Society; VAS: Visual Analog Scale; FAAM: Foot Ankle Ability Measure; SF-36: Short Form-36; MTP: metatarsophalangeal

**Declarations**

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**Availability of data and materials**

The data of this study were real and were performed in the SPSS 16.0 software (SPSS Inc., Chicago, IL). The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Authors’ contributions**
BLB and LPT participated in the data collection and evaluation. BLB participated in the data analysis. BLB and QSH participated in the study design. BLB and WZT participated in the manuscript revision. All authors participated in the manuscript preparation and approved the final manuscript.

Ethics approval and consent to participate

This study has been approved by the ethical committee of Shandong Provincial Hospital affiliated to Shandong First Medical University. We have obtained the consent to participate from the participants.

Consent for publication

Not applicable.

Competing interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

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Tables

Table 1  Characteristics of patients

| Variable                                                                                | Data          |
|----------------------------------------------------------------------------------------|---------------|
| Age, mean± SD (range), (years)                                                         | 36.52 ± 11.85 |
| BMI, mean± SD (range), (kg/m²)                                                          | 23.55 ± 3.70  |
| Sex (patients, percentage)                                                              |               |
| Male                                                                                   | 17 (60.7%)    |
| Female                                                                                  | 11 (39.3%)    |
| Related extremity (patients, percentage)                                                |               |
| Right                                                                                   | 10 (35.7%)    |
| Left                                                                                    | 13 (46.4%)    |
| Bilateral                                                                               | 5 (17.9%)     |
| Previous surgery* (feet, percentage)                                                    | 5 (15.2%)     |
| Foot skin ulceration (feet, percentage)                                                 | 10 (30.3%)    |
| Walking with crutches (patients, percentage)                                            | 20 (71.4%)    |
| Etiologies (feet, percentage)                                                           |               |
| Spina bifida                                                                            | 8 (24.2%)     |
| Trauma                                                                                  | 8 (24.2%)     |
| Poliomyelitis                                                                           | 5 (15.1%)     |
| Cerebral palsy                                                                          | 4 (12.1%)     |
| Burn injuries                                                                           | 4 (12.1%)     |
| Congenital anomalies                                                                    | 3 (10.1%)     |
| Tumor                                                                                   | 1 (3.0%)      |

BMI body mass index, *previous surgery means previous surgery for deformity correction.

Table 2  Ilizarov technique combined with additional procedures

| Variable procedures                                      | combined procedures |
|----------------------------------------------------------|--------------------|
| Bone procedures*                                         |                    |
| First metatarsal dorsal wedge osteotomy                   | 9                  |
| Subtalar arthrodesis                                     | 9                  |
| Triple arthrodesis                                       | 7                  |
| Calcaneal lateral closing wedge osteotomy                 | 5                  |
| Tibia osteotomy                                          | 4                  |
| Tibia lengthening                                        | 3                  |
| V-osteotomy                                              | 2                  |
| U-osteotomy                                              | 2                  |
| Soft tissue procedures*                                   |                    |
| Plantar fasciotomy                                       | 27                 |
| Percutaneous Achilles lengthening                        | 20                 |
| Posterior tibial tendon transfer                         | 16                 |
| Abductor hallucis fasciotomy                             | 7                  |
| Open Achilles lengthening                                | 6                  |
| Posterior tibial tendon lengthening                       | 5                  |
| Tibialis anterior tendon transfer                        | 5                  |
| Jones procedure                                           | 1                  |
| Peroneal longus tendon transfer                          | 1                  |

*The bone procedures included osteotomy and arthrodesis and the soft tissue procedures included soft tissue release and tendon transfer.

Table 3  Clinical outcomes of the patients
| Variable           | Preoperative | Postoperative | P-value |
|--------------------|--------------|---------------|---------|
| Ankle ROM          | 10.45 ± 10.26| 23.00 ± 9.86  | <.0001  |
| Dorsiflexion       | -27.94 ± 18.00| 3.55 ± 5.21   | <.0001  |
| Plantarflexion     | 38.70 ± 12.17| 19.55 ± 8.55  | <.0001  |
| VAS score          | 5.97 ± 1.24  | 1.09 ± 1.01   | <.0001  |
| AOFAS score        |              |               |         |
| Pain score         | 22.12 ± 4.15 | 36.06 ± 4.96  | <.0001  |
| Functional score   | 11.61 ± 7.11 | 31.64 ± 5.43  | <.0001  |
| Alignment score    | 2.42 ± 2.54  | 9.55 ± 1.46   | <.0001  |
| Total score        | 36.45 ± 11.08| 77.09 ± 8.88  | <.0001  |
| FAAM score         |              |               |         |
| Daily activity     | 27.97 ± 11.25| 59.09 ± 12.64 | <.0001  |
| Sports activity    | 17.73 ± 11.15| 45.15 ± 13.36 | <.0001  |
| SF-36 score        |              |               |         |
| Physical function  | 32.12 ± 16.91| 64.70 ± 9.60  | <.0001  |
| Role-physical      | 21.21 ± 21.76| 56.06 ± 16.57 | <.0001  |
| Body pain          | 49.85 ± 15.04| 72.81 ± 14.10 | <.0001  |
| General health     | 43.94 ± 12.42| 60.00 ± 10.53 | <.0001  |
| Vitality           | 47.58 ± 9.77 | 64.55 ± 8.04  | <.0001  |
| Social function    | 42.05 ± 18.17| 60.23 ± 11.03 | <.0001  |
| Role-emotional     | 40.40 ± 23.23| 64.66 ± 18.53 | <.0001  |
| Mental health      | 50.06 ± 5.67 | 67.88 ± 6.89  | <.0001  |
| Health transition  | 36.36 ± 12.64| 61.21 ± 13.98 | <.0001  |

ROM ankle range of motion, VAS Visual Analogue Scale, AOFAS American Orthopaedic Foot and Ankle Society. FAAM Foot and Ankle Ability Measure, SF-36 the Short Form-36 questionnaire, ns nonsignificant difference. The values are expressed as the mean ± standard deviation.

**Figures**
(A and B) Preoperative photo showing a 28-year-old woman with both equinovarus feet deformity caused by spina bifida, (C and D) postoperative 31-month photo showing complete correction of the deformities.
Figure 2

(A) Lateral weight-bearing radiograph showing the measurements of the tibio-talar angle, tibial-sole angle, talo-calcaneal angle, and talus-first metatarsal angle. (B) Hindfoot alignment view showing the measurement of the hindfoot alignment angle.

Figure 3

(A) Interoperative photo showing the application of the Ilizarov external fixator. The forefoot, hindfoot and tibial frames are connected by hinges. (B) Postoperative photo showing the application of two telescopic rods to prevent anterior subluxation of the talus, these rods can be applied during the peri-Ilizarov fixator application period.
Figure 4

Postoperative photo showing a patient who was allowed to gradually bear weight with support on the operated limb when full correction was achieved.