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# Adult rigid flatfoot

## Triple arthrodesis and osteotomy

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**Abstract**

To analyze the efficacy of arthrodesis combined with osteotomy applied to subtalar, calcaneocuboid, and talonavicular joints for the treatment of adult rigid flatfoot.

This retrospective study included 29 adult patients with rigid flatfoot who underwent triple arthrodesis combined with osteotomy from January 2015 to December 2017. All patients suffered from stage III of adult acquired flatfoot. Patients returned for a clinical and radiologic follow-up evaluation at an average of 19.5 (range, 15–27) months postoperatively. Outcomes were assessed by comparing pre- and postoperative AOFAS scores, VAS pain scores, and Karlsson scores, and the radiographic assessment including Meary, Pitch, and Kite angles.

Twenty six patients returned for final evaluation. Twenty four patients had an excellent or good outcome on patient subjective self-assessment. All the VAS scores, AOFAS scores, and Karlsson scores at final follow-up showed different extents of improvement. The mean Meary angle significantly decreased from 25.8±5.4 degrees preoperatively to 6.9±7.7 degrees at final follow-up, and the mean Pitch angle improved markedly from 12.5±3.7 points preoperatively to 23.2±4.1 points at final follow-up ($P < .001$).

Arthrodesis combined with osteotomy can effectively correct calcaneal valgus deformity, restore arch structure, and relieve foot pain in adult rigid flatfoot.

**Abbreviations:** AAFF = adult acquired flatfoot, AOFAS = American Orthopaedic Foot and Ankle Society, NSAIDs = non-steroidal anti-inflammatory drugs, PRP = platelet-rich plasma, VAS = Visual Analog Scale pain scores.

**Keywords:** adult rigid flatfoot, arthrodesis, osteotomy, treatment

## 1. Introduction

Flatfoot refers to the deformity of the medial arch of the foot with or without any symptoms when standing. However, flatfoot disease usually involves the symptoms of foot pain, weakness, and restricted mobility which are caused by the lesions of foot joints and soft tissue in patients with flatfoot. Flatfoot disease is mainly divided into adolescent flatfoot and adult acquired flatfoot (AAFF).[1,2]

Adolescent flatfoot disease is largely solved by corrective shoes, soft tissue surgery, and orthopedic procedures. If the scaphoid resection is performed, the insertion site reconstruction of the tendon is a necessity. Bone surgery basically does not require fusion, while calcaneus osteotomy is commonly performed to correct the calcaneus valgus deformity in adolescent.[3]

Adult acquired flatfoot disease refers to a-secondary flat foot disease in adults with symptoms. The incidence of flatfoot in China, the United States and the UK is approximately 3.7% to 8%, 2.7% and 3% respectively; and it is common in female patients over 40 years old.[4] Main causes of adult acquired flatfoot are bone and ligament injuries, pathological changes of the foot joints, neuromuscular lesions, and posterior tibial tendon dysfunction.[5] Although there are various pathogenic factors o, posterior tibial tendon dysfunction remains the most common etiology.

The posterior tibial muscle is a semi-plum muscle, which is located deep in the triceps of the calf, between the long flexor of the toe and the long flexor of the thumb. Originated from the 2/3 of the calf interosseous membrane and the posterior tibia, descending on the long tendon, its tendon passes posterior to the ankle's axis of rotation, immediately behind the medial malleolus in a groove supported by the flexor retinaculum, and medial to the subtalar axis, making it a plantar flexor and inverter of the hindfoot. It also produces supination of the forefoot. When the tendon is under tension, it inverts the subtalar joint and locks the transverse tarsal joints preventing the medial arch from collapsing. The tibial nerves innervate the muscles..[6] Tendons mostly degenerate in the watershed area behind the medial malleolus. It is speculated that this may be due to a sharp change in tendon orientation, which occurs at the proximal insertion of 2 to 4 cm.[7]

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So when the posterior tibial tendon has functional impairment, it can hardly play the role of dynamic stabilizer in the middle foot, which leads to transverse tarsal joint collapse and forefoot abduction. The spring ligament as a static stabilizer of the medial foot will also lead to dysfunction. Maybe this can result in a peritalar subluxation of the transverse tarsal joints. With the development of foot deformity, the role of deltoid ligament will also weaken, leading to changes in joint position, which in turn causes joint degeneration of the midfoot and hindfoot.[8]

Myerson has a pathological classification of posterior tibial tendon dysfunction, mainly divided into 4 stages: Stage I refers to the inflammatory phase, characterized by tenosynovitis, periorbital inflammation, or tendonitis with no change in tendon length. There is swelling and pain in the internal ankle, but the hindfoot activity is normal with no obvious deformity. In stage II, the tibialis posterior tendon is elongated, the swelling and pain of medial malleolus are aggravated, the medial arch of foot is reduced, the hind foot has valgus deformity, varus weakness is obvious, and heel test is positive (Fig. 1). There is anterior and inferior lateral malleolus pain. The arch of the foot is flat when it is loaded, and the hind foot can still move normally when it is not loaded. Stage III presents with rigid deformity in the hind foot, calcaneus valgus, forefoot abduction, and arch disappearance. Stage IV is characterized by talus valgus, deltoid ligament tear, and ankle joint lesion. Breibart divided the stage II into A stage (early stage) and B stage (late stage). In Stage IIa, there is heel valgus, with arch of foot slightly or moderately flat; Over 35% of the talonavicular joints are uncovered. Stage IIb shows the arch of foot collapsed obviously, with mid-talus-navicular joint abduction, and over 35% talus-navicular joint uncovered.[6,9]

Patients with stage I posterior tibial tendon dysfunction underwent soft tissue surgery mainly when conservative treatments such as braces, plaster, or oral NSAIDs were ineffective.[10] On the premise that the purpose of stage II surgery is to keep the function to the maximum, the common surgical methods include open wedge osteotomy of medial wedge (Cotton osteotomy) and lateral calcaneal detention lengthening (Evans operation).[9,11] The main operative methods for patients at stage III were triple-joint arthrodesis (subtalar joint, calcaneocuboid joint, and talonavicular joint).[6] Stage IV patients usually involve ankle joint lesions. The operation is thorough ankle and subtalar joint fusion.[12,13]

**Figure 1.** Heel lifting experiment positive.

Lee[14] points out that stage III patients are with rigid flat foot, fixed hind foot deformity, stiffness, accompanied by a certain degree of osteoarthritis. Triple arthrodesis is effective in stabilizing joints and relieving pain. However, Tang[15] has found that triple arthrodesis has some defects in remodeling the arch of foot and improving the force line of hind foot. So combined with the domestic and foreign references, we performed the triple arthrodesis plus subtalar joint, calcaneocuboid joint and medial wedge osteotomy to improve the foot force line, relieve pain, and remodel the shape of the arch of the foot. We also evaluated the effect of the operation according to the symptoms, imaging, scores, and satisfaction of the patients before and after the operation.[16,17]

## 2. Methods

This retrospective study included 29 adult patients with rigid flatfoot who underwent triple arthrodesis combined with osteotomy from January 2015 to December 2017. The institutional review board approved the study, and all patients provided informed consent for study inclusion.

Inclusion criteria: Adult; Flatfoot Stage III: Calcaneal valgus, stiffness deformity of hind foot, and forefoot abduction occurred; Repeated swelling and pain on the medial and lateral sides of the ankle joint; Heel lifting experiment positive; Radiological examination of Meary angle, Kite angle and Pitch angle were less than normal angle; no history of foot and ankle injuries, no other foot deformities.

Exclusion criteria: Adolescent flatfoot; chronic lateral ankle instability; medial deltoid ligament tear; acute foot injury; local infection of foot and ankle; and patients with serious medical disease such as heart disease or hypertension (http://links.lww.com/MD/D637).

Twenty nine adult patients with rigid flatfoot underwent triple arthrodesis combined with osteotomy. Ten of the 29 patients were male, and 19 patients were female. Their average age at the time of surgery was 45.8 (range, 38–57) years. The left foot was involved in 12 cases (41.4%), and the right in 17 cases (58.6%). Average follow-up duration was 19.5 (range, 15–27) months.

Preoperative detailed medical history and strict physical examination were performed. Routine X-ray included the antero-posterior and lateral films of the affected foot, assessing the severity of flat foot, and osteoarthropathy, checking for other deformities and abnormalities, long axis of calcaneus, and full length of lower limbs, and assessing the patient's calcaneal valgus condition. MRI examination was performed to understand the condition of posterior tibial tendon. CT or three-dimensional CT reconstruction was used to determine the bone displacement and tarsal fusion, and to evaluate the degree of arch depression and the angle of heel valgus and valgus strictly.

### *2.1. Operative procedures*

After anesthesia, the patient's foot strength was examined and the foot would be determined to be stiff and flat again. A thigh tourniquet was applied and regular iodine alcohol disinfection was used. A 5 cm curved incision was made from the tip of the external malleolus to the base of the fifth metatarsus to protect the long and short tendon of the fibula. The subtalar joint was then exposed. The oscillating saw was used to remove the subtalar articular cartilage surface and the soft tissue of the achilles tendon was separated. The cartilage surface of the

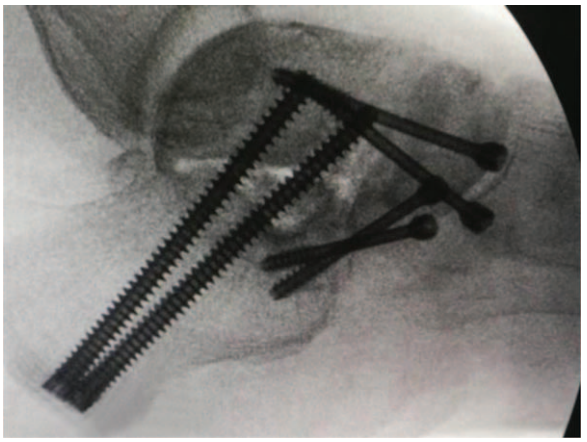

**Figure 2.** Postoperative: triple arthrodesis and osteotomy.

Achilles tendon was removed. A 4 cm incision was made in the talar neck to the scaphoid joint while paying attention to protect the blood vessels and peripheral nerves. The joint surface of the scaphoid was fully exposed and the cartilage removed. Intraoperatively, bone retraction was employed to clean the residual cartilage surface again. After cleaning, the joint surface was rinsed with bone marrow. After the articular cartilage is cleaned, the osteotomy is performed. The oscillating saw is used to make a wedge-shaped osteotomy at the subtalar joint (to correct the calcaneus valgus deformity). Similarly, the wedge-shaped osteotomy was performed to calcaneocuboid joint and the talonavicular joint to reshape the arch of the foot; the use of 2.5 mm Kirschner wire for perforation at the osteotomy and joint surface is beneficial to bone healing, remodeling the lateral arch after osteotomy, and correcting calcaneus valgus. Kirschner wire was temporarily entered to fix the osteotomy, and the C-arm was used as a perspective to see if the mean angle and the calcaneus tilt angle have returned to normal angle. After satisfaction is ensured, the cannulated nail was fixed. Before closing the incision, we filled the gap between the bones with cancellous bone. A drainage tube was placed, and the wound was wrapped. (Fig. 2)

Cefazolin Sodium Pentahydrate was routinely used to prevent infection of surgical incision 30 minutes before the procedure. The wound healing was observed by intermittent dressing change after operation. Three days postoperatively, the patient was required to move the toes and lower limbs actively to strengthen the muscle function and prevent venous thrombosis of lower limbs. Two weeks later, the suture of surgical incision was removed, and 1 month later, the foot was cruised to the ground to bear weight and reinforce foot movement once a X-ray indicated satisfactory outcomes.

The patients were prescribed to take X-rays at 1, 3, and 6 months after surgery to evaluate the wound healing and bone fusion, and rule out assess complications such as infection and nonunion.

At the final follow-up, subjective patient satisfaction was recorded. Whether the ankle was painful during daily work or activity was noted. In addition, the patients were asked if the same surgery would be recommended to the patients with the same disease or when pain and swelling occurs on the contralateral ankle. The data was analyzed by comparing the pre- and postoperative American Orthopaedic Foot and Ankle Society (AOFAS) scores, visual analog scale (VAS) pain scores, and Karlsson scores. All the patients underwent pre- and postoperative radiographic assessment including Meary, Kite, Pitch.

### 2.2. Statistical analysis

Pre- and postoperative values (AOFAS ankle-hindfoot scores, VAS scores, Karlsson ankle scores, and radiologic measurement included Meary, Kite, Pitch) were recorded. Firstly, Shapiro–Wilk test is used to determine whether the data is normal distribution. Whitney U-test was used for non-normally distributed continuous variables and t-test was for normally distributed variables. Statistical significance was accepted for $P$ values $<.05$. The statistical analysis was performed using SPSS Statistics version 16.0 software (SPSS Inc., Chicago, Illinois, USA).

## 3. Results

Six months after surgery, all the patients were followed up. The deformities of calcaneus valgus and flat arch of foot were corrected. All the patients had relief of pain in the medial and lateral ankle joints and were able to engage in general work and life without any obstacles. No patients had complications of local infection and delayed or non-union of bone although foot swelling happened to some cases.

Twenty six patients (26 ankles) (89.7%) returned for a final evaluation. Overall patient satisfaction was rated as excellent by 22 (84.6%) patients, good by 2 (7.7%) patients, fair by 2 (7.7%) patients, and poor by no patient. (Table 1).[18]

Among the 3 missing interviewees, ones family moved to another city due to work, 1 person changed the contact information, and the other 1 died in a sudden traffic accident 13 months after the surgery.

At the final follow-up, 2 patients stated that the effect of operation was fair. One of them was a 57-year-old female patient who had no cardiocerebrovascular disease before the operation. Postoperatively, however, she presented with elevated blood pressure and rapid heart rate and was reluctant to ambulate. Consequently, her ankle joints were noted to be stiff when she was re-examined 3 months after the operation. After physical therapy in the rehabilitation department of our hospital, the ankle joint activity improved. The other patient was a young female with preoperative AOFAS score of 62.7, VAS score of 6.3, Meary angle of 26.2 degrees, Kite angle of 23 degrees, and Pitch of 11 degrees. One day after the operation, X-ray showed that the Meary angle was 8 degrees, Kite angle of 45 degrees, and Pitch angle of 23 degrees. At 3 months after operation, patient became pregnancy and gained weight. As a result, she expressed

**Table 1**

**Clinical rating scale for postoperative foot and ankle[18].**

| Rating | Description |
|---|---|
| Excellent | Full range of motion equal to the contralateral ankle without pain. Unrestricted work or sports activity |
| Good | Functional range of motion and stable ankle. With minimal pain with work or sport activity. |
| Fair | Functional range of motion, good stability, moderate level of pain, and/or stiffness with activities of daily living and sports activity. |
| Poor | Persistent pain, the same or worse than before surgery. |

**Table 2**

**Preoperative and final follow-up values of the assessed variables (n = 26).**

| Index | Preoperative | Last follow-up | Test statistic | *P* value |
|---|---|---|---|---|
| Meary (° $\bar{x} \pm s$) | 25.8 ± 5.4 | 6.9 ± 7.7 | 18.356 | .00035 |
| Pitch (° $\bar{x} \pm s$) | 12.5 ± 3.7 | 23.2 ± 4.1 | 12.652 | .00056 |
| Kite (° $\bar{x} \pm s$) | 26.1 ± 2.9 | 41.7 ± 6.2 | −9.328 | .00098 |
| AOFAS (points $\bar{x} \pm s$) | 60.2 ± 7.1 | 89.7 ± 5.5 | −19.163 | .02804 |
| Karlsson (points $\bar{x} \pm s$) | 59.7 ± 6.2 | 87.1 ± 6.2 | −18.552 | .02096 |
| VAS (points $\bar{x} \pm s$) | 6.4 ± 1.3 | 2.3 ± 0.8 | 9.112 | .01714 |

discomfort during the rehabilitation exercise. But the patient's pain was significantly less than before the operation.

At the time of final follow-up, 24 patients (24 feet) were pain-free and 2 cases presented mildly painful with stiffness after exercises. No patients had difficulty walking on even ground. The VAS pain score was markedly reduced from 6.4 ± 1.3 points preoperatively to 2.3 ± 0.8 points at the last follow-up. The mean preoperative AOFAS score (6.2 ± 7.1) improved significantly to a mean postoperative score of 89.7 ± 5.5. The Karlsson score remarkably improved from 59.7 ± 6.2 points preoperatively to 87.1 ± 6.2 points at final follow-up. The mean Meary angle significantly decreased from 25.8 ± 5.4 degrees preoperatively to 6.9 ± 7.7 degrees at final follow-up, and the mean Pitch angle significantly improved from 12.5 ± 3.7 points preoperatively to 23.2 ± 4.1 points at final follow-up. (Table 2. Fig. 3).

## 4. Discussion

Triple-joint arthrodesis is a traditional operation which refers to the simultaneous arthrodesis of subtalar joint, calcaneocuboid joint, and talus-navicular joint. It is mainly suitable for adult stiff flatfoot (stage III) with hind foot deformity, muscle weakness, or paralysis. The purpose of treatment is to relieve pain of the subtalar joint and the lateral ankle joint and restore ankle function. However, in addition to the traditional fusion surgery, we also performed appropriate wedge-shaped osteotomy of the subtalar joint, cuboid bone and medial wedge bone to restore the arch of the foot to the maximum extent and improve the force line of the hind foot. In order to prevent bone nonunion after operation, a 2.5 mm Kirschner wire was used to drill holes in the osteotomy surface and fusion joint surface to promote bone healing; cancellous bone was taken from the osteotomy block and mostly filled in the residual space between the osteotomy surfaces of the subtalar joint, especially in the joint area for fusion, to ensure the close contact of fusion surface.

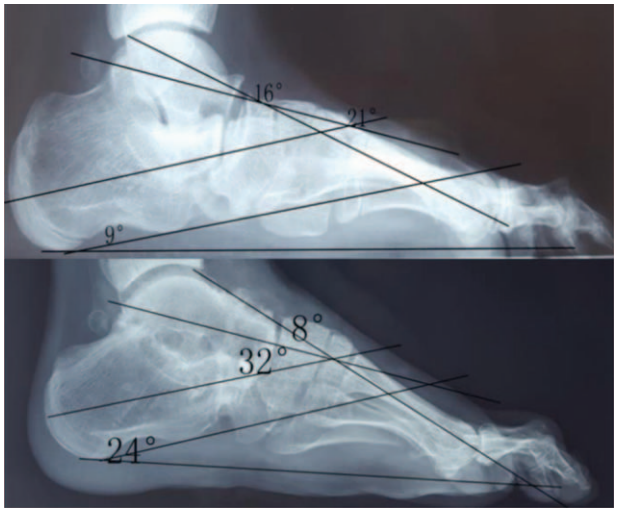


**Figure 3.** Preoperative: Meary: -16°, Kite: 21°, Pitch:9 °. Postoperative: Meary: +8°, Kite: 32°, Pitch: 28 °.

It is worth noting that after the screw fixation at the osteotomy site, the patient's "weight-bearing" state can be restored during the operation, and the weight-bearing degree of the first metatarsal bone can be estimated by using the tray to hold the foot. If the first metatarsal head was shown to be too high, then it should be lowered to increase the weight of the first metatarsal head.

We believe that wedge-shaped osteotomy is the key to restoring force lines and arches after successful fusion of the joints. Prior to the wedge osteotomy, all the joint surfaces should be clearly exposed and the bleeding should be completely controlled. In this way, the foot bones can be arranged neatly and tightly without leaving a dead space. We summarize the experience of fusion and osteotomy as followed:

1. the center axis of the foot is perpendicular to the calf;
2. the first metatarsal, the fifth metatarsal, and the calcaneus nodules are on the same level after the weight; restore the arch height.

At present, there is some controversy about the triple-joint arthrodesis. Walling[19] et al performed triple-joint arthrodesis on 25 patients with flatfoot. One patient (4%) had bone nonunion after operation; 2 patients (8%) had calcaneal varus deformity due to the inappropriate correction in flatfoot patients; 1 patient (4%) had no significant improvement in pain after operation, and the arch of foot failed return to normal height. Mann[20] et al performed 3-joint fusion on 18 cases of adult flatfoot. At the last follow-up, the AOFAS score increased significantly, but 3 patients developed bone nonunion. Brilhault[21] et al evaluated 14 patients with arthrodesis. The average follow-up time was less than 21.5 months. All deformities were well corrected. None of them had bone nonunion. Jackson[22] followed up 8 patients with 100% of the fusion rate and whose average fusion time was 5.25 months. After joint fusion and osteotomy, 26 patients were followed up for the last time. Calcaneal valgus deformity and flat arch deformity were corrected. After the surgery, ankle pain in both sides of ankle joint was significantly alleviated and they could completely engage in normal working. No patients had complications of local infection and delayed or nonunion of bone although foot swelling happened to some cases. As multiple factors affects the operation, we should correctly select the surgical indications. The choice of fusion position and the

effective recovery of osteotomy force line are the priorities for the procedure.

The common complications of triple arthrodesis were nonunion of bone, varus deformity of hind foot, secondary arthritis of middle foot, and ankle joint, infection of surgical site, failure of internal fixation, and so on. Bone nonunion is the main cause of persistent pain and dissatisfaction after operation. The common nonunion site is the talus-scaphoid joint. We believe that good results and less complications can be achieved if the surgical team pays attention to the relevant factors such as correct judgment and maintenance of intraoperative line of gravity of lower limb, strict aseptic techniques, soft tissue protection, correct choice of incision, and other details. In addition, this study is a retrospective study. There are relatively few cases with a lack of randomized controlled study and long-term follow-up. Future research should be gradually improved.

## 5. Conclusion

Triple-joint arthrodesis combined with osteotomy is a new attempt to treat adult rigid flatfoot. From our follow-up observation, this surgical method can obviously relieve the pain of the foot, correct the force line, and obtain good clinical results. However, there is still no unified treatment for adult acquired flatfoot. We suggest that patients with symptomatic flatfoot should receive intervention as soon as possible.

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