Realignment Surgery for Anterior Translation of Talus after Malunited Ankle Fracture

CURRENT STATUS: POSTED

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DOI: 10.21203/rs.2.12098/v1

SUBJECT AREAS
Orthopedics

KEYWORDS
Malunited ankle fracture, Anterior translation of talus, Distal tibial plafond osteotomy, Joint preserving surgery
Abstract

Background: It is challenging for the clinical management of malunited ankle fracture. The aim of this study is to evaluate the clinical outcome of realignment surgery for anterior translation of talus after malunited ankle fracture and to analyze its. Methods: A total of 11 patients with anterior translation of talus after malunited ankle fractures underwent corrective osteotomy in our institute were retrospectively reviewed. All patients were evaluated with radiological parameters and clinical functional scores. There were 4 patients with Weber type A fracture, 4 patients with Pilon type B fracture and 3 patients with Weber type C fracture. 8/11 patients had impaction on the anterior distal tibial plafond, intra-articular distal tibial osteotomy was performed in these patients, additional bony correction and soft tissue surgery were also performed to achieve congruent ankle joint. Results: The mean age at surgery was 32.8 ± 10.8 (range,16-48) years. The mean follow-up time was 50.5 ± 23.6 (range, 16-80) months. The mean AOFAS-AH score increased from 28.2 ± 19.1 preoperatively to 72.5 ± 8.1 points postoperatively( p<0.05), the mean lateral talar station(LTS) improved from 9.2 ± 3.7 preoperatively to 1.5 ± 1.4 mm postoperatively( p<0.05). 10/11 patients had improvement or no worsening ankle osteoarthritis on sagittal plane, while 1 patient had advanced ankle osteoarthritis. Conclusion: A congruent ankle joint in sagittal plane could be achieved by corrective osteotomies with additional soft tissue procedures. The realignment surgery was a valuable treatment option for the salvage of anterior translation of talus after malunited ankle fracture.

Background

Ankle fracture is the most common fracture around foot and ankle. Open reduction and internal fixation provides encouraging clinical outcomes for displaced ankle fractures.[1,
However, failure to achieve an anatomical reduction of the fragments may lead to malunion of fracture, which is associated with poor clinical results.[3] The reasons for ankle malunion can be related to failure of internal implants, surgeon’s experience and loss of reduction etc.

In review of the literature, supramalleolar osteotomy is recognized as an effective corrective procedure to address malalignment of the hindfoot.[4–9] The philosophy of supramalleolar osteotomy is to shift the loads and redistribute stress within the ankle joint by rearranging the alignment of the hindfoot. However, there is limited information about the deformity in the sagittal plane and their treatment strategy.

In this retrospective study, we have included a cohort of malunited ankle fracture characterized with anterior translation of talus in sagittal plane. According to biomechanical study, a reduction in contact area of the tibiotalar joint might be resulted as the ankle joint was anteriorly subluxated.[10] The purpose of this retrospective study is to investigate the clinical outcome of the realignment surgery for anterior translation of talus after malunited ankle fracture, to analyze the pathology for the development of anterior translation of talus in malunited ankle joint and to advocate a modified grade system for anterior translation-type ankle osteoarthritis in sagittal plane.

Methods

Inclusion and Exclusion Criteria

A retrospective cohort of consecutive patients with malunited ankle fracture between March 2011 and October 2017 were evaluated. This study was approved by the ethics committee of our hospital. Informed consent was obtained from all individual participants included in this study. The study was carried out in accordance with the Declaration of Helsinki. Patient inclusion criteria was (1)malunited ankle fracture with anterior
translation of talus in lateral view. (2) limited early and mid-staged ankle osteoarthritis. 
We excluded patients with (1) diffused end-staged ankle osteoarthritis. (2) bad soft tissue 
envelope. (3) bad health condition. (4) acute and chronic infection. (5) osteoporosis, age, 
diabetes, peripheral vascular disease etc.
A total of 11 consecutive patients met our criteria. There were six males and five females, 
left ankle were involved in six patients while the remaining five were on the right. Their 
average age at the time of reconstruction surgery was 32.8±10.8 (range, 16–48) years. 
The average body mass index (BMI) was 23.0±4.8 (range, 17.0–31.5) kg/m². The average 
interval between primary treatment and reconstruction operation was 8.4±2.7 (range, 4–12) months. There were 3 open fractures and 8 closed fractures. Initially, 10 patients were 
treated operatively while the remaining 1 patient was managed conservatively.

Clinical and Radiographic Assessment

A detailed review of both preoperative and postoperative functional outcome and 
radiological variables was performed. Functional outcome was evaluated using the The 
American Orthopedic Foot and Ankle Society-Ankle and Hindfoot (AOFAS-AH) score. Pain 
was also measured by a Visual Analogue Scale (VAS). The range of motion of the ankle 
joint was recorded including the maximum dorsiflexion and maximum plantarflexion angle. 
The weightbearing anterioposterior (AP) and lateral views of the affected ankle joint were 
obtained for evaluation preoperatively and postoperatively. The lateral talar station (LTS) 
was defined as the distance of the center of rotation of a circle fitting the talar dome to 
the tibial axis line on weightbearing lateral view of the ankle joint.[11] The tibial lateral 
surface (TLS) angle was formed by the angle between the mechanical axis of the tibia and 
a line connecting the most anterior and posterior margin of the tibial plafond. The distal
tibial ankle surface (TAS) angle was formed by the angle between the mechanical axis of
the tibia and the tibial plafond on the AP view. The talocrural angle was constructed by
drawing a perpendicular line downward from the tibial plafond surface, which was crossed
by a line drawn connecting the tips of both malleoli. It was measured in the superomedial
quadrant with the average of $83\pm 4$ degrees.[12]

The modified Kellgren and Lawrence score was utilized to evaluate ankle osteoarthritis on
tagittal plane.[13] In addition, we found it difficult to evaluate this cohort of patients
using the Takakura classification, as this grade system paid much more attention on
coronal plane. Thus we advocated a modified grade system for anterior translation-type
ankle osteoarthritis based on Takakura-Tanaka classification for varus-type osteoarthritis.
[4, 7, 14] This was the grade system on sagittal plane: Stage 0, normal ankle, congruent
joint without translation of talus. Stage 1, degeneration of ankle cartilage, without
anterior translation of talus. Stage 2, anterior translation of talus without impaction of the
distal tibial plafond. Stage 3, anterior translation of talus, with impaction of the distal
tibial plafond, narrowing of the joint space without subchondral bone contact. Stage 4,
anterior translation of talus, impaction of the distal tibial plafond with subchondral bone
contact. Stage 5, anterior translation of talus with complete subchondral bone contact
(Figure 1).

In addition to the evaluation of preoperative and postoperative weightbearing radiological
variables, the X-rays on initial fracture and after primary treatments were also essential.
Radiological variables including fracture type, with or without subluxation on initial
fracture, with or without anterior distal tibia plafond fracture, subluxation latency time(0
referred to subluxation immediately after primary treatment) and time of anterior distal
tibial plafond impaction(0 referred to impaction immediately after primary treatment)
were also documented. In review of X-rays on fracture, of the 11 consecutive patients
included in this study, 4 patients with Weber type A fracture were classified into Group A, 4 patients with Pilon type B fracture were classified into Group B and the remaining 3 patients with Weber type C fracture were classified into Group C.

Surgical Technique

The aim of realignment surgery was preserving the ankle joint, while the principles for surgery were to anatomically reduce the ankle joint, to reconstruct the articular surface of the ankle joint and to provide stability of ankle joint as well. These could be achieved by corrective osteotomies including intra-articular distal tibial plafond osteotomy and fibular osteotomy, soft tissue procedures including medial and posterior release, medial and lateral ligament reconstruction.

For patients with prolonged anterior translation of talus, soft tissue release of the ankle joint was often mandatory in order to achieve anatomical reduction of the ankle joint. Malunion of the fibular, separation of distal syndesmosis, malunion of medial malleolus and widening of medial malleolus space were characterized for patients with Weber type C fracture (Group C). Extensive contracture or scar tissue formation was often anticipated between the distal syndesmosis and the medial gutter. An adequate debridement and release of the scar tissue would facilitate anatomical reduction of the ankle joint.

For patients with anterior distal tibial plafond impaction, the outline of the impacted anterior distal tibial plafond could be easily noticed after reduction of the talus in lateral view intra-operatively. A Kirschner wire was used to mark the direction of the osteotomy from the anterior to the posterior edge of the impacted area. The osteotomy of the distal tibia was performed with an oscillating saw in the same plane as the Kirschner wire, ending at the subchondral bone. Then wide osteotome was used to very gradually bend the plafond until a congruent ankle joint was achieved. Then followed by the inserting of
an allograft bone graft into the defect. Cannulated screws or plates were utilized to secure the osteotomy (Figure 2).

2 patients had a concomitant impaction of the medial tibial plafond, intra-articular osteotomy combined with supramalleolar osteotomy was often indicated, so a medial approach with medial malleolar osteotomy was utilized. [15] The impacted distal tibial plafond was visualized after oblique medial malleolar osteotomy. A horizontal cut was performed about 1cm above the ankle joint, this cut was supposed to correct the impacted medial tibial plafond. Then followed by a vertical cut made to the posterior edge of the impacted area, then an osteotome was used to bend the plafond until a congruent ankle joint was achieved. Allograft bone grafts were inserted into the defect. Plates and screws were utilized to secure the osteotomy (Figure 3).

Malunion of the fibular was the most common scenario, often involved shortening or rotation of the fragment. [16, 17] CT was usually used to evaluate rotational deformity of the fibular. Horizontal fibular osteotomy was usually used because it was the easiest way to correct both shortening and rotational deformity of the fibular. [3] In this study, fibular osteotomy was performed in 2 patients in Group A and 2 patients in Group C. Lateral and medial ligament reconstruction was performed if patient had ankle instability after bony correction. Ligament reconstruction would provide extra-stability of the ankle joint, preventing recurrence of the deformity.

**Postoperative rehabilitation**

The ankle was stabilized in neutral position with a well-padded short let splint. The wound was inspected on the second day after operation and a walking boot was applied. Nonweightbearing range of motion exercise was initiated at one or two weeks after operation. Partial weightbearing with the protection of the walking boot was encouraged
at six weeks after operation and gradually progress to full weightbearing at 3 months after operation.

Statistical analysis

The statistical analyses were performed using IBM SPSS Statistics version 23 statistical software. The normality of data including the preoperative and postoperative radiological parameters and clinical outcomes was tested using the K-S test. For data met normality, the Student’s t test was performed. For those did not met the normality, the Wilcoxon signed rank test was used. Difference with a p value of <0.05 was considered significant.

Results

In review of the X-rays on fracture and after primary treatment, 9 patients suffered subluxation of ankle joint initially on fracture (3/4 in Weber type A fracture, 3/4 in Pilon type B fracture, 3/3 in Weber type C fracture). 7 patients had anterior distal tibial plafond fracture (2/4 in Weber type A fracture, 4/4 in Pilon type B fracture, 1/3 in Weber type C fracture). 8 patients revealed subluxation of ankle joint immediately after primary treatment (2/4 in Weber type A fracture, 3/4 in Pilon type B fracture, 3/3 in Weber type C fracture), 2 patients had subluxation at 4 and 5 months after initial treatment respectively, while we missed information for the remaining one patient, the only thing we knew was that he had subluxation at 7 months after initial surgery, but we could not determine whether he had subluxation immediately after initial surgery. 8 patients had impaction on the anterior distal tibial plafond impaction at the time when they come to our clinic (2/4 in Weber type A fracture, 4/4 in Pilon type B fracture, 2/3 in Weber type C fracture), the average impaction latency time after initial treatment was 3.1±2.9 months. Intra-articular distal tibial plafond osteotomy was performed in 8 patients with the impaction. 2 patients with the Weber type A fracture was performed through medial
approach. Both of the patients had impaction on the medial tibial plafond, so supramalleolar osteotomy was added in these 2 patients. Anterior approach was performed in the remaining 6 patients. Fibular osteotomy was performed in 4 patients, the medial and/or lateral ligament reconstruction was performed in 5 patients.

Interestingly, displaced talar dome fragment was identified in 1 patient who had a Weber Type A fracture, the fragment was located at the posterior which blocked the anatomical reduction of the ankle joint, the fragment was placed in site and fixed with 2 cannulated screws after debridement. In another case, the patient had a Weber type C fracture. During the revision surgery, we found the tibialis posterior tendon was dislocated to the anterior surface of the distal tibia through the distal tibiofibular syndesmosis. After reduction of the tendon, we were able to anatomically reduce the ankle joint (Table 1).

The AOFAS-AH score increased from an average of 28.2 ± 19.1 points to 72.5 ± 8.1 points ($p = .003$). The VAS pain score improved from an average of 7.0 ± 1.3 points to 2.8 ± 1.0 points ($p < 0.001$). Significant difference was not found for dorsiflexion ($p = .391$) and plantarflexion ($p = .429$) preoperatively and postoperatively (Table 2). The LTS improved from an average of 9.2 ± 3.7 mm to 1.5 ± 1.4 mm ($p = .003$). The TLS angle improved from an average of 74.7 ± 6.2 degrees to 80.6 ± 3.6 degrees ($p = .011$). Significance difference was not found for the TAS angle and the talocrural angle. The mean TAS angle was 83.3 ± 10.1 degrees preoperatively and 86.5 ± 3.3 degrees postoperatively ($p = .248$), the mean talocrural angle was 74.7 ± 6.0 degrees preoperatively and 77.3 ± 2.9 degrees postoperatively ($p = .072$) (Table 3).

There were 3 patients in grade 2 and 8 patients in grade 3 preoperatively, 1 patient in grade 1, 8 patients in grade 2, 1 patients in grade 3 and 1 patient in grade 4 postoperatively according to the modified Kellgren and Lawrence score ($p = .034$).

According to our anterior translation-type ankle osteoarthritis scoring system, there were
2 patients in stage 2, 3 patients in stage 3, 6 patients in stage 4 preoperatively, and 2 patients in stage 1, 5 patients in stage 2, 3 patients in stage 3, and 1 patient in stage 5 postoperatively \((p = .008)\) (Figure 4). Both of these two grade systems showed improvement or no worsening ankle osteoarthritis on sagittal plane in 10/11 patients, while 1 patient had advanced ankle osteoarthritis.

**Discussion**

It was challenging for the management of malunited ankle fracture. For patients with end-staged ankle osteoarthritis, ankle fusion or total ankle arthroplasty could effectively relief pain and improve function.\(^{[18, 19]}\) However, for patients with mild to moderate ankle osteoarthritis, corrective osteotomies with additional bony and soft tissue procedures could be used as an alternative for the salvage of ankle joint. In review of the literature, most of the interest was focused on the deformity correction in frontal view, the supramalleolar osteotomy, which was recognized as an effective corrective procedure to address malalignment of the hindfoot.\(^{[4–9]}\)

However, limited studies could be found about the management of deformity in sagittal plane,\(^{[20]}\) despite the fact that most of the studied mentioned about the TLS angle. It was known that deformity in sagittal plane could change the ankle joint mechanics to a greater degree than coronal plane deformity.\(^{[11, 21]}\) Scheidegger P\(^{[22]}\) reported a retrospective study about a flexion osteotomy for a total of 39 patients with distal tibial recurvatum deformity. Despite the fact that this technique could effectively improve the congruency of ankle joint, it was an extra-articular osteotomy. In 2012, Mann HA\(^{[23]}\) reported an intra-articular opening medial tibial wedge osteotomy technique for the management of intra-articular various ankle arthritis. This was an intra-articular osteotomy in frontal plane and their clinical results was encouraging.

8/11 patients in our cohort revealed intra-articular deformity in sagittal plane as the result
of impaction of the anterior distal tibial plafond. Therefore, we felt that an intra-articular opening wedge osteotomy was indicated in order to achieve a congruent ankle joint in sagittal plane (Figure 5). 2 of the 8 patients had a concomitant malunion of medial malleolus, so we felt that a medial approach with medial malleolar osteotomy would be a better solution. The anterior approach with anterior distal tibial plafond osteotomy was utilized for the remaining 6 patients. The bony correction of the distal tibial plafond would provide anterior stability of the ankle joint. 5/11 patients underwent lateral or/and medial ankle ligament reconstruction to provide extra-stability of the ankle joint, preventing recurrence of the deformity.

The aim of the realignment surgery was preserving the ankle joint. Anatomical reduction of the ankle joint was critical during the operation. Surgeons should pay attention to both the intra-operative AP and lateral views of the ankle joint until an anatomical reduction was achieved. When the reduction was unacceptable or difficult, the most common reason was the shortening or rotational deformity of the fibular. Surgeons should evaluate the intact Shenton line of the ankle and the unbroken curve between the lateral talus and the peroneal groove of the fibular intra-operatively.[17, 24] Soft tissue release was essential before reduction of the ankle joint, especially for cases with prolonged anterior translation of talus. Besides, even though it was rare, in this study, 1 patient with a Weber type A fracture, a talar fragment was identified at the posterior of the ankle joint. Another patient with Weber type C fracture, the tibialis posterior tendon was identified to be dislocated to the anterior surface of the distal tibia through the syndesmosis. So it was also important for the surgeons to keep in mind that displaced bony fragments or soft tissue could block anatomical reduction of the ankle joint.[25, 26]

In order to understand the reason why talus was anterior translated after malunited ankle fracture, it was essential to investigate the X-rays on fracture and immediately after initial
treatment. Patients included in this cohort could be divided into 3 different groups, Group A(4/11) with Weber type A fracture, Group B(4/11) with Pilon type B fracture and Group C(3/11) with Weber type C fracture. We assumed that the intact distal tibia plafond as well as the medial and lateral ankle ligaments provides stability of the ankle joint in sagittal plane. Pilon type B fracture could cause impaction of anterior distal tibial plafond, loss of reduction of these fragments after operation or failure to restore these fragments intra-operatively might result in anterior distal tibial plafond impaction, and anterior translation of talus might follow subsequently. 3/4 patients in Group B demonstrated anterior translation of talus immediately after operation, this could be the result of inadequate reduction of the impacted fragments. While for the remaining 1 patient, despite a congruent ankle joint was achieved after operation, he still lost reduction of anterior distal tibial plafond fragments 5 months after operation and anterior subluxation followed. Patient in Group C might sustain a complete rupture of distal tibiofibular syndesmosis, medial ankle ligament and acute anterior ankle subluxation. Failure to restore a congruent and stable ankle joint might result in the recurrence of anterior ankle subluxation. 3/3 patients in Group C demonstrated subluxation of the ankle joint on fracture and all of the 3 patients still had anterior subluxation immediately after operation. 2/3 patients did not have distal tibial plafond fracture initially, while 1 patient developed impaction of anterior distal tibial plafond because of the prolonged anterior translation of talus. The lateral ankle ligaments played an important role in maintaining the stability of the ankle joint. In some case with lateral ankle instability or lateral osteophytes after fracture, the talus could be in varus, internally rotated and anteriorly translated relatively to the distal tibial plafond.[27, 28] The prolonged internal rotation and varus inclination of the talus would initiate or hasten the impaction of the anterior distal tibial plafond, the anterior translation of talus would
follow subsequently.[29] 2/4 patients in Group A sustained initial fracture of the anterior and medial distal tibial plafond and medial malleolar fracture. Inadequate or loss of reduction of the anterior and medial distal tibial plafond would subsequently cause the varus inclination and internal rotation of the talus within the mortise, resulting anterior translation of talus after operation.

So based on the understanding of pathology of anterior translation of talus, we advocated the anterior translation-type ankle osteoarthritis scoring system. It was a 5 staged classification, this system was based on the progression of anterior translation of talus after ankle fracture. However, as the limited cases were analyzed and only included patients with ankle fracture, more evidence based studies were needed to determine the repeatability, reliability and the clinical significance of this classification.

1 patient developed staged 5 ankle osteoarthritis, however, this patients was still satisfied with the operation and did not need any further surgical intervention. Most of the patients benefit from the realignment surgery, or at least did not developed worsening osteoarthritis. This could be the result of anatomical reduction of the ankle joint after corrective osteotomies, the pressure within the ankle joint had been redistributed. Marti RK[30] recommended that it can be considered up to 7 years after injury even when there are degenerative changes. There should be more evidence-based studies to support this notion. It was obvious that once the malalignment was approved on X-rays, the earlier the revision surgery was performed the less ankle joint would be destroyed, the more patient would benefit from the realignment surgery.[3]

There were several limitations in this study. The first was the retrospective nature and no control group was included. The second was the limited patients were included in this study, we were also trying to subdivide the patients into 3 groups according to the X-rays on fracture, this made the number of patients in each subgroups even more small. The
third was the variation of the follow up duration, the arthritis might develop over time, so it might be too early to determine the clinical outcome. Studies with larger population and long term follow up was needed to evaluate the clinical efficacy.

Conclusion
A congruent ankle joint in sagittal plane could be achieved by corrective osteotomies with additional soft tissue procedures. The X-rays on fracture and immediately after treatment were essential in order to analyze the fracture type and make the plan for realignment surgery. The realignment surgery was a valuable treatment option for the salvage of anterior translation of talus after malunited ankle fracture.

Abbreviations
BMI, body mass index; AOFAS-AH, American Orthopaedic Foot and Ankle Society-Ankle and Hindfoot; VAS, Visual Analogue Scale; AP, anterioposterior; LTS, lateral talar station; TLS angle, tibial lateral surface angle; TAS angle, distal tibial ankle surface angle;

Declarations

Ethics approval and consent to participate
This study was approved by the ethics committee of Ruijin Hospital North, Shanghai JiaoTong University School of Medicine. Written consent to participate was provided by participants included in the study.

Consent to publish
Written consent to publish the related images or clinical details of participants was provided by participants included in the study. Proof of consent to publish can be requested at any time.

Competing interests
The authors have no conflict of interest.
Funding
This study was supported by a research grants from National Natural Science Foundation of China, Grand Number: 81772372. The authors disclosed receipt of financial support from this research grant for the research and publication of this article.

Authors’ contributions
XL drafted the manuscript. RK and YX carried out patients follow up and performed the data collections. YZ helped with the data analysis, XX designed the study and helped to draft the manuscript. All authors read and approved the final manuscript.

Availability of data and materials
All the data supporting our findings was contained within the manuscript. And all data in this study was freely available to any researcher for noncommercial purposes.

Acknowledgements
None

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Tables

Table 1: Case Data
| Case | Sex | Age | Side | Operation interval<sup>1</sup> Months | Followup<sup>2</sup> (Months) | Fracture type | Impaction<sup>2</sup> | Subluxation latency<sup>3</sup> (Months) |
|------|-----|-----|------|---------------------------------|-----------------------------|----------------|---------------- |-------------------|
| 1    | F   | 26  | L    | 7                               | 29                          | Weber type A   | Without       | Y                 | 0                 |
| 2    | F   | 32  | L    | 4                               | 32                          | Weber type A   | With          | Y                 | 4                 |
| 3    | F   | 48  | R    | 10                              | 80                          | Weber type A   | With          | N                 | 0                 |
| 4    | M   | 31  | R    | 12                              | 44                          | Weber type A   | Without       | Y                 | N/A               |
| 5    | M   | 23  | L    | 6                               | 58                          | Pilon type B   | With          | Y                 | 0                 |
| 6    | M   | 36  | R    | 12                              | 16                          | Pilon type B   | With          | N                 | 5                 |
| 7    | M   | 16  | R    | 6                               | 58                          | Pilon type B   | With          | Y                 | 0                 |
| 8    | M   | 22  | L    | 7                               | 70                          | Pilon type B   | With          | Y                 | 0                 |
| 9    | M   | 34  | L    | 11                              | 19                          | Weber type C   | Without       | Y                 | 0                 |
| 10   | F   | 45  | L    | 9                               | 72                          | Weber type C   | Without       | Y                 | 0                 |
| 11   | F   | 48  | R    | 8                               | 77                          | Weber type C   | With          | Y                 | 0                 |

1. Operation interval: Time interval between primary treatment and realignment surgery;  
2. Impaction: Anterior distal tibial plafond impaction on fracture;  
3. Subluxation latency: “0” refers to ankle subluxation immediately after primary treatment;  
4. Impaction latency: “0” refers to impaction immediately after primary treatment;
Table 2. Clinical outcome

| Parameter                  | Preoperative | Postoperative | P Value |
|----------------------------|--------------|---------------|---------|
| AOFAS-AH                   | 28.2 ± 19.1  | 72.5 ± 8.1    | .003    |
| VAS                        | 7.0 ± 1.3    | 2.8 ± 1.0     | <.001   |
| Plantarflexion(degrees)    | 23.2 ±8.4    | 24.5 ±5.2     | 0.429   |
| Dorsiflexion(degrees)      | 5.5 ±9.3     | 7.3±5.6       | 0.391   |

Table 3. Radiological outcome

| Parameter                  | Preoperative | Postoperative | P Value |
|----------------------------|--------------|---------------|---------|
| The LTS(mm)                | 9.2 ± 3.7    | 1.5 ± 1.4     | 0.003*  |
| The TLS angle(degrees)     | 74.7 ± 6.2   | 80.6 ± 3.6    | 0.011*  |
| The TAS angle(degrees)     | 83.3 ± 10.1  | 86.5 ± 3.3    | 0.248   |
| The talocrural angle(degrees) | 74.7 ± 6.0   | 77.3± 2.9     | 0.072   |

Figures
Figure 1

The anterior translation-type ankle osteoarthritis.
Figure 2

The anterior approach for intra-articular distal tibial plafond osteotomy. a) the impacted anterior distal tibial plafond after anatomical reduction of talus. b) a congruent ankle joint was achieved after intra-articular distal tibial plafond osteotomy.
The medial approach for intra-articular distal tibial plafond osteotomy. a) supramalleolar osteotomy was performed after medial malleolus osteotomy, note the impacted anterior distal tibial plafond. b) the vertical cut was made at the posterior edge of the impacted area. c) bone grafts were inserted after the correction. d) intra-operative radiograph showed a congruent joint was achieved after correction.

The changes of the preoperative and postoperative sagittal osteoarthritis score using two scoring system. Each one dot represents one patient. a) the modified Kellgren and Lawrence sagittal osteoarthritis score. b) the anterior translation-type ankle osteoarthritis score.
Figure 5

A 36-year-old man with Pilon type B fracture. a) 12 months X-ray after primary treatment. b) 16 months X-ray after realignment surgery.