Clinics in Surgery

Research Article
Published: 28 Aug, 2018

Closed Reduction Treatment and Outcome of Triplane Fracture of the Distal Tibia: Retrospective Study of 46 Cases

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Abstract

Objectives: We designed a prospective study to confirm the hypothesis that acute triplane fracture of distal tibia can be treated conservatively with good range of motion and daily mobility without pain.

Methods: Forty-six patients participated and completed the study, including 35 male and 11 female. Inclusion criteria was, patients with acute triplane fractures (≤ 3 days) who received closed reduction and cast immobilization. Clinical investigation and the foot and ankle outcome score (FAOS) survey were done. X-rays and computed tomography scan of the ankles were obtained at follow-up.

Results: Fractures were 2-parts in 33 and 3-parts in 13 patients, fracture displacement were <2 mm in 21 patients and ≥ 2 mm in 25 patients, and 18 patients had concomitant fibular fractures. All patients were treated conservatively (cast immobilization with closed reduction). The mean period of cast was 4.3 ± 0.6 weeks; non-weight-bearing in a boot for 3 days, and follow-up period was 63.0 ± 5.4 months. All patients had good outcome, no one has ankle osteoarthritis on X-rays and CT scans at final follow-up. Mean FAOS score was 97.89 ± 6.15, with FAOS pain 38.70 ± 4.00, FAOS function 49.20 ± 2.29, alignment 10.00 ± 0.00. Patients had full range of motion, good daily mobility and no pain during walking.

Conclusion: Results confirm the benefit of conservative treatment in acute triplane fracture of distal tibia that conservative treatment was sufficient to reestablish ankle stability, allowing complete recovery of ankle Range of motion (ROM) and reducing the risk of early degenerative joint disease, and it is also cost-effective.

Keywords: Triplane fracture; Ankle; Closed reduction; Outcome

Abbreviations

FAOS: Foot and Ankle Outcome Score; ROM: Range of Motion

Introduction

Distal tibial epiphysis is the second most common site of epiphyseal fracture in the pediatric population, only second to the distal radius [1]. Triplane ankle fractures represents 6% to 10% of distal epihpyseal fracture [2], and typically occur in children aged 12 to 15 years, with more commonly in boys than girls [3]. Primary mechanism of triplane fracture is supination and external rotation of the foot, with plantar flexion [4]. Although many patients sustain triplane fracture during athletic activity, it has also been reported as a consequence of fall or twisting injury while walking [5]. Clinically, swelling and local tenderness over the injured joints are common presentations, and deformity is variable. AP, lateral, and mortise radiographs are essential for initial diagnosis of transitional fracture. Cast immobilization is usually used for minimally displaced (<2 mm) and non-displaced fractures, while closed or open reduction for fractures with >2 mm intra-articular step-off [6]. In recent years, authors advocated reduction with operative stabilization to get adequate reduction and prevent ankle osteoarthritis. However, if closed reduction is successful, open reduction is not required [7]. So, we designed a retrospective project to test the hypothesis that acute triplane fracture of the distal tibia can be treated conservatively with good Range of Motion (ROM) and daily mobility without pain.

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Received Date: *13 Aug 2018*
Accepted Date: *27 Aug 2018*
Published Date: *28 Aug 2018*

Citation:
Zhang C, Huang C, Hong J, Li Y, Hu J, Yu W, et al. Closed Reduction Treatment and Outcome of Triplane Fracture of the Distal Tibia: Retrospective Study of 46 Cases. Clin Surg. 2018; 3: 2088.

Table 1: Characteristics of cohort.

Case	Gender/Age	Mechanism	Fracture parts/ Side	Displacement	Treatment	Cast duration	Follow up	Outcome
1	M/12y	Football	2/R	2 mm	closed reduction	4 Weeks	17 months	Excellent
2	M/14y	Basketball	3/R	5 mm	closed reduction	6 Weeks	44 months	Excellent
3	M/13y	Scooter	3/R	6 mm	closed reduction	6 Weeks	52 months	Excellent
4	M/13y	Broad jump	3/L	5mm	closed reduction	5 Weeks	36 months	Excellent
5	M/10y	Running	2/R	3mm	closed reduction	5 Weeks	60 months	Excellent
6	M/12y	Fall down stairs	2/R	2mm	closed reduction	4 Weeks	26 months	Excellent
7	M/12y	Skateboarding	2/L	1mm	closed reduction	4 Weeks	39 months	Excellent
8	M/15y	Fall from height	2/R	1mm	closed reduction	4 Weeks	52 months	Excellent
9	M/13y	Football	3/R	2mm	closed reduction	5 Weeks	34 months	Excellent
10	M/12y	Skateboarding	2/L	5mm	closed reduction	5 Weeks	57months	Excellent
11	M/14y	Fall down stairs	3/R	1mm	closed reduction	4Weeks	47 months	Excellent
12	M/12y	Fall from height	2/L	1mm	closed reduction	4 Weeks	51 months	Excellent
13	M/14	Running	2/R	4mm	closed reduction	5 Weeks	68 months	Excellent
14	M/11y	Fall from height	3/L	6mm	closed reduction	6 Weeks	63 months	Excellent
15	F/10y	Fall down stairs	3/R	1mm	closed reduction	4 Weeks	58 months	Excellent
16	M/13y	Football	3/R	2mm	closed reduction	4 Weeks	27 months	Excellent
17	F/12y	Biking	2/R	1mm	closed reduction	4 Weeks	61 months	Excellent
18	M/12y	Running	2/R	1mm	closed reduction	4 Weeks	51 months	Excellent
19	F/12y	Skateboarding	2/L	2mm	closed reduction	4 Weeks	62 months	Excellent
20	M/15y	Fall from height	2/R	2mm	closed reduction	4 Weeks	47 months	Excellent
21	F/10y	Running	3/L	3mm	closed reduction	5 Weeks	58 months	Excellent
22	M/13y	Skating	2/L	2mm	closed reduction	4 Weeks	68 months	Excellent
23	M/14y	Football	3/R	2mm	closed reduction	4 Weeks	69 months	Excellent
24	M/15y	Traffic accident	2/L	2mm	closed reduction	4 Weeks	71 months	Excellent
25	M/16y	Running	3/L	2mm	closed reduction	4 Weeks	65 months	Excellent
26	M/15y	Traffic accident	2/L	1mm	closed reduction	4 Weeks	48 months	Excellent
27	M/13y	Walking	2/L	1mm	closed reduction	4 Weeks	52 months	Excellent
28	M/13y	Skateboarding	2/R	1mm	closed reduction	4 Weeks	67 months	Excellent
29	F/11y	Fall down stairs	2/R	1mm	closed reduction	4 Weeks	56 months	Excellent
30	F/12y	Running	2/L	1mm	closed reduction	4 Weeks	71 months	Excellent
31	M/13	Traffic accident	2/L	1mm	closed reduction	4 Weeks	54 months	Excellent
32	F/11y	Running	2/R	1mm	closed reduction	4 Weeks	63 months	Excellent
33	M/12y	Fall from height	2/L	2mm	closed reduction	4 Weeks	54 months	Excellent
34	M/14y	Football	3/R	2mm	closed reduction	4 Weeks	68 months	Excellent
35	M/11y	Fall down stairs	2/L	1mm	closed reduction	4 Weeks	50 months	Excellent
36	F/16y	Skating	2/R	1mm	closed reduction	4 Weeks	68 months	Excellent
37	F/11y	Fall down stairs	2/L	2mm	closed reduction	4 Weeks	51 months	Excellent
38	F/12y	Skating	2/R	1mm	closed reduction	4 Weeks	68 months	Excellent
39	F/12y	Skateboarding	2/R	2mm	closed reduction	4 Weeks	53 months	Excellent
40	M/11y	Skating	2/R	0mm	closed reduction	4 Weeks	57 months	Excellent
41	M/15y	Walking	2/L	1mm	closed reduction	4 Weeks	58months	Excellent
42	M/11y	Walking	2/L	1mm	closed reduction	4 Weeks	68 months	Excellent
43	M/14y	Traffic accident	2/R	1mm	closed reduction	4 Weeks	62 months	Excellent
44	M/15y	Fall from height	3/L	2mm	closed reduction	4 Weeks	50 months	Excellent
45	M/11y	Basketball	2/L	2mm	closed reduction	4 Weeks	27 months	Excellent
46	F/13y	Fall down stairs	2/L	3mm	closed reduction	5 Weeks	54 months	Excellent

Figure 1: Case-1 AP (A-1) and lateral (A-2) radiographs of the left ankle demonstrating triplane fracture. (B-1/2) Frontal and lateral radiographs of the left ankle after close reduction and cast immobilization. (C-1/2) One month after treatment, frontal and lateral radiographs showed that fracture line nearly disappeared. (D-1/2) One year after treatment, the fracture line disappeared. (E-1/2) Four years after treatment, epiphyseal plate closure and no sign of traumatic ankle arthritis.

Figure 2: Case-1 Computed tomographic scans of the left ankle demonstrating in better detail morphologic complexity of the triplane fracture. Sagittal reformation (A-1) demonstrates both physeal (arrow) and posterior metaphyseal (arrow) fracture extension of Salter-Harris type II fracture, in addition to a cortical fracture fragment interposed along the posterior metaphyseal cortical fracture fragments. Cornoal reformation (A-2) demonstrates the distal fibular shaft is noted. Axial image at the level of the distal tibial epiphysis (A-3) show epiphyseal widening and displacement in the sagittal plane (arrow). Three-dimensionally shaded surface reformation (A-4) show antero-medial displacement of the epiphysis and physeal fracture extension of a Salter-Harris type III fracture of the tibia (arrow), in addition to a distal fibular oblique fracture. (B1-B4) CT scans after close reduction and cast immobilization, fracture displacement was <2 mm. (C1-C4) One year after treatment, the fracture line disappeared, bone healing was satisfactory.

Materials and Methods

From Sep 2010 to March 2015, records of 34 boys and 12 girls with triplane fractures were retrospectively reviewed. Inclusion criteria was, patients with acute triplane fractures (≤ 3 days), who received closed reduction and cast immobilization. An exclusion criterion was patients with history of ankle fracture. Approval of the study was granted by ethics committee of Guangzhou Orthopedic Hospital. Informed consent was obtained from either the patient or a family member. Patients' age, gender, mechanism of injury, diagnosis, displacement and number of fragments, management, and duration of cast, treatment outcome, and complications (pain, restricted range of motion or functional deficits) were recorded. Standard AP and lateral radiographs were taken. CT scans were used to determine the number and position of fragments [8]. Forty-six patients with acute triplane fractures received closed reduction and cast immobilization at the emergency department. An assistant stabilized the knee at 90° during this forceful manipulation. Lateral fracture segments was pushed onto the tibia before traction, then the fractures and/or dislocations were reduced by applying longitudinal traction to the involved digits with pressure over base of the tibia, which last for three to five minutes, then pushed the lateral fracture segments again to make its reduction. Foot positioned in external rotation for medial fractures, and internal rotation for lateral fractures. Reduction procedure was performed under C-arm fluoroscopy. After reduction, non-weight-bearing thermoplastic orthoses immobilizations were used initially to help control secondary dislocation. Thermoplastic orthoses placing the foot in internal rotation may help reduce the displaced fracture and maintain alignment [6]. X-rays were taken immediately after application of the thermoplastic orthoses to confirm reduction. To assure anatomical alignment and secondary dislocation, frequent control radiographs were taken. Thermoplastic orthoses were

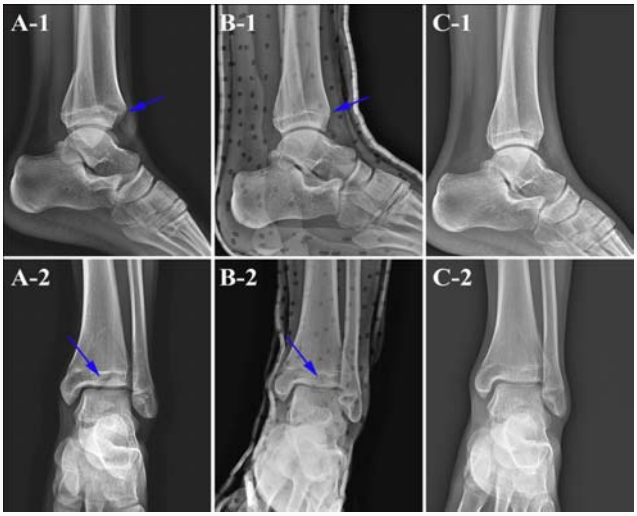

Figure 3: Case-2 AP (A-1) and lateral (A-2) radiographs of the left ankle demonstrating a triplane fracture. (B-1/2) Frontal and lateral radiographs of the left ankle after close reduction and cast immobilization. (C-1/2) Three month after treatment, frontal and lateral radiographs showed nearly disappeared fracture line.

Figure 4: Case-2 Computed tomographic scans of the left ankle demonstrating better morphologic complexity of the triplane fracture. Sagittal reformation (A-5) demonstrates triplane fracture, temporary cast fixation was used to relieve pain. (B1-B5) CT scans after close reduction and cast immobilization, fracture displacement was <2 mm. (C1-C5) Three months after treatment, the fracture line disappeared, bone healing was satisfactory.

replaced when swelling of the ankle decreased, generally 5-7 days after reduction. The injured ankle was immobilized for 4.28 ± 0.58 weeks, after that the thermoplastic orthoses were removed, and X-ray was taken. Followed by non-weight-bearing in a boot for 3 days and commencement of range-of-motion exercises, then weight bearing in the boot for next 2 weeks [9].

Radiographs and medical records of the patients were collected (Table 1). Fracture healing, presence of deformity, premature closure of the growth plate, and post-traumatic arthritis were assessed on radiographs. Treatment outcome (pain, activity, function of ankle joint, walking ability and radiographs) was evaluated using the Foot and Ankle Outcome Score (FAOS) by a clinical investigator [10] at one year post-treatment and final follow-up.

Statistical analysis

Descriptive statistics were evaluated on all baseline variables. Results are presented as the mean ± SD. Differences between groups were assessed by analysis of variance. *P* values less than 0.05 was considered statistically significant.

Results

Forty-six patients aged 10-16 years (12.7 ± 1.6) with triplane fractures of the left (n=22) and right (n=24) ankles were treated in our hospital, with follow-up until 54.0 ± 13.0 months (17-71 Months). Injury mechanism included low-energy trauma (n=10) such as walking, and falling off stairs or chairs. Moderate-energy trauma (n=32), such as football injuries (n=5), basketball injuries (n=2), falling from a height of >1 m (n=6), skateboarding (n=5), running (n=7), scooter (n=1), skating (n=4), bicycling (n=1) and broad jump (n=1). High-energy trauma (n=4), as road traffic accidents (n=4) [Table 1]. All patients had good outcome, with no sign of ankle osteoarthritis on X-rays and CT scans at final follow-up. The mean FAOS score was 97.89 ± 6.15, with FAOS pain 38.70 ± 4.00, FAOS function 49.20 ± 2.29 and FAOS alignment 10.00 ± 0.00. At final follow-up, patients had full range of motion and good daily mobility, without pain during walking. There were no major complaints mentioned after conservative treatment, and no degenerative arthritis developed in any patients at final follow-up.

Discussion

Pediatrics triplane fracture of distal tibia is multiplanar injury with 3 possible fracture configurations in three planes, transverse (growth plate), sagittal (epiphysis), and coronal (distal tibial metaphysis) anatomic planes, disrupting the tibial articular surface of the ankle. It is a rare condition and typically occurs in adolescents who is transitioning to skeletal maturity, represents 5% to 10% of paediatric intra-articular ankle injuries [11].

Mechanism and diagnosis

Primary mechanism of triplane fracture injury is supination, isolated external rotation of the ankle, isolated plantar flexion of the foot, or combination of both mechanisms [4]. Triplane fracture has been reported as the consequence of fall or twisting injury while walking, traffic accident, fall down from stairs, sports injury etc [12,13]. The number of fragments depends on which part of the physis is closed at the time of injury. In this study, fractures were 2-parts in 33 patients, and 3-parts in 13 patients.

Clinically, swelling and local tenderness over the injured joints are common presentations, and deformity is variable. AP, lateral and mortise radiographs are essential for initial diagnosis. However, number of fracture fragments not always seen in plain radiographs; therefore CT scans are necessary to identify the number and position of fragments [14]. CT scan are especially important in cases of closed reduction and cast immobilization, in which the fragments are not directly visualized [8] and also used to diagnose the rare medial triplane variant that was not clearly delineated on plain radiographs [15].

Treatment

Treatment selection of triplane fractures depends mostly on the grade of displacement visualized on CT. Previous studies showed that fractures with >2 mm intra-articular step-off require reduction, and long-term results are correlated with the accuracy of anatomic reduction [6,16]. A displacement of >2 mm on plain X-ray can lead to Post-traumatic osteoarthritis, hence an attempt for close reduction is indicated, and residual gap or step-off of <2 mm is acceptable [17]. Although rapariz et al. [18] reported ORIF is the traditional surgical option for triplane fractures with >2 mm displacement [19]. However, Crawford [17] reported that closed reduction can be performed in the emergency room first, if there is residual step-off of >2 to 3 mm, operative treatment is indicated. In this study we treated the triplane fractures with closed reduction and cast immobilization under fluoroscopy to achieve nearly anatomical reduction and prevent the secondary displacement. As CT will accurately measure residual displacement of the fragments, X-ray and CT scans were used to confirm the reduction, which showed that all the reduction reached satisfactory alignment. It was strongly advocated that CT/MRI scans are superior to plain x-ray in determining triplane and tillaux fracture fragments and alignment after closed reduction [17]. So post-reduction CT scans and serial radiographs were used to assess adequacy of reduction and to guard against loss of reduction while the foot was in cast, with acceptable residual gap or step-off of <2 mm.

Comparison with previous findings

Secondary dislocation after closed reduction and splint immobilization can occur within 2 weeks after reduction [20]. To avoid secondary dislocation some authors have suggested early operative stabilization with K-wires after reduction [17]. However, none of our patients had secondary displacement or functional impairment after conservative treatment. The reason may be that first we performed complete reduction under fluoroscopy, second we applied anterior and posterior thermoplastic orthoses, which could be easily moulded according to the shape of the injured ankle [21,22], third we change the cast immediately after swelling subsided.

Landin et al. [23] found no correlation between residual fracture displacement and long-term results. Painless varus deformity not affecting function are the most common complication [24]. Most studies reported minimal symptoms in patients 5 years after triplane fractures [25]. Patients with >2 mm of residual displacement or step-off may present with arthritic changes on X-rays 6 to 9 years after injury but are often asymptomatic [26]. Most patients have good mid-term results and generally returned to pre-injury activity levels without any symptom or complication.

Long term complications of triplane fractures also include growth retardation of lower limb due to epiphyseal injury and traumatic ankle osteoarthritis. Post-traumatic ankle osteoarthritis was not rare, trauma is the primary cause of osteoarthritis in ankle joint [27], especially in malleolar fractures, with 37–53% of malleolar fractures patients developed into ankle osteoarthritis [28,29]. It has been reported that risk factors for development of ankle osteoarthritis are the type of ankle fracture, medial malleolar fracture, fracture-dislocation, increasing body mass index, age 30 years or more and duration of treatment [30]. However, none of our patients developed into ankle osteoarthritis according to ankle osteoarthritis scale surveys. This is similar with previous reports, van et al. [31] treated 20 patients with triplane fractures with the follow-up from 25 to 175 months, and all patients were free of symptoms, no restriction in daily and sports activities, and no sign of incongruity, growth disturbance, and ankle osteoarthritis. The reason may be the ages of these patients were too young.

People may worry about whether triplane fractures by conservative treatment will affect the growth of lower limb. In our study, we also get AP radiography of bilateral tibia and fibula, which showed the length of bilateral tibia and fibula is almost same, which may due to these injuries typically occur near skeletal maturity [32]. Mizuta et al. [33] described two triplane ankle fracture patients with premature physeal closure, no growth retardation was found because the patients were nearing skeletal maturity.

Strengths and weaknesses of the study

Strength of the present study is follow-up rate of our patients were 97.8%, only one patient had 17 months follow-up. We used AP and lateral radiographs for initial diagnosis, and CT scans were used to confirm. Treatment outcome (pain, activity, function of ankle joint and walking ability) was evaluated using FAOS surveys and radiographs during follow-up.

Our current studies also have several limitations. First, the follow-up period is not long enough, the follow-up period are 54.0 ± 13.0 months. Rapariz et al. [18] treated 35 patients with triplane fractures, and found ankle joint degenerative changes were seen at >5 years when good reduction (<2 mm) could not be achieved. Long-term studies (follow-up greater than ten years) can better evaluate the development of ankle osteoarthritis [30]. Second, close reduction depends on the surgeon's experience, results diversity exists among different surgeons. That is easy to understand, the outcome of other treatment also depends on the operator's demonstrated skill [34,35]. Third, because our hospital is the traditional Chinese medical

orthopaedic institute for trauma and injury, so majority of traumatic fracture patients in Guangzhou city come to our hospital for conservative treatment. We just have the records of treated patients in ER that is 46 patients from Sep 2010 to March 2015. Although we got nearly all of the treated patients for follow-up investigation, but patients who preferred surgical treatment went to other hospital. This may have biased our results. Fourth, the numbers of subjects available for analysis are small, and lacking long time follow–up to detect the occurrence of traumatic arthritis of ankle joint. Moreover, most of the patient population was teenager and under the age of 30 years at final follow-up, an age group in which OA rarely occurs, and up to 90% of arthritic change in the ankle are post-traumatic in nature [27]. Crawford [17] also suggested although most studies report minimal symptoms in patients 5 years after triplane fractures, but these patients are only in their teens. So maybe it's not obvious to get conclusion of ankle osteoarthritis, and even long-term follow-up investigation is needed in the future.

Conclusion

Our study showed that conservative treatment of triplane fractures by early closed reduction and thermoplastic orthotic immobilization achieved better mid-term outcomes, with good ROM, mobility and FAOS scores without secondary dislocation.

Declarations

Ethics approval and consent to participate: Approval of the study was granted by ethics committee of Guang Zhou Orthopedic Hospital. Informed consent was obtained from either the patient or a family member.

Authors' contributions: Chi Zhang and Hua Wang designed the project; Chongxia Huang and Hua Wang wrote this paper; Chi Zhang, Jinsong Hong, Yunfeng Li and Jianwei H collect the data; Chongbo Huang conducted SPSS analysis; Chongbo Huang and Chongxia Huang revised the paper. Consent for publication: I hereby authorize and give full consent to Journal of Foot and Ankle Research to publish and copyright all photographs and outcome.

Competing interests: Chi Zhang, Hua Wang, Jinsong Hong, Yunfeng Li, Jianwei H, Chongbo Huang and Chongxia Huang declare that they have no conflict of interest.

Acknowledgement

This work was supported by grants from the National Natural Science Foundation of China (Grant No.81401840) and Sun Yat-sen University Starting Funds for Young Teachers (Grant No.16ykpy31).

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