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Functional outcome of hybrid external fixator for fractures of metaphyseal distal tibia

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Abstract
Introduction: The difficulty in treating the fracture of distal tibial metaphysis is exemplified by orthopaedists, who in the first half of 20th century, believed the injuries were so severe and operative repair was fraught with so many complications that the fracture was deemed not amenable for surgical reconstruction. Since there was no definitive protocol for the treatment of such fractures, the Hybrid External Fixator seemed suitable for such fractures as they combine the advantages of monolateral and circular fixation. Tensioned wires provide improved fixation in small fragments and osteoporotic bone. It allows early weight bearing and movement of ankle at all times.
Materials and Methods: Twenty five patients with distal tibial metaphyseal fractures were studied from June 2016 to July 2018 in our institution and followed up for a period of 6-10 months.
Results: All the fractures consolidated with average of 13 and weeks the fixators were removed. All the studied fractures resulted in good union. 1 of the 3 compound fractures and 2 of the 10 simple fractures developed pin tract infections which were suppressed using antibiotics. 6 patients had ankle stiffness from 20-90% of total ankle movement. This was probably due to the patient incompliance to the physiotherapy regimen. 1 case had a malunion with an anterior angulation of 5 degrees but had a good ankle function. At 6 months, results were based on objective and subjective parameters by Ovadia and Beals. 6 (48%) patients had excellent outcome 3 (23%) had good, 3 (23%) had fair and 1 (6%) patient had a poor outcome.
Conclusion: Hybrid external fixator is simple, rapid and straightforward application, reduced surgical time, minimally invasive and adjustable. It has negligible complications and resulted in excellent results for this type of fractures.

Keywords: Articular, external fixators, follow up studies, prognosis, range of motion, tibial fractures/surgery, treatment outcome

Introduction
The difficulty in treating the fractures of distal tibial end is exemplified by orthopaedists, who in the first half of twentieth century, believed these injuries were so severe and fraught with so many complications, that the fracture was deemed not amenable for surgical reconstruction [1].
Distal tibial fractures represent a significant challenge to most of the surgeons even today. They are only 1-10% of all lower extremity fractures [2]. The low energy type of fractures often get dramatic results with open reduction and internal fixation. But high energy fractures are documented to show a high amount of complications due to soft tissue coverage, skin necrosis, infections and also the usually comminuted nature of the fractures [3].
Conservative treatment by cast application lead to prolonged immobilization, leading to ankle and knee stiffness affecting quality of life of the patient.[4] Introduction of the external fixator was a revolution in the evolution of management of fractures. It has undergone a sea of change from a simple frame to a more complex frame and various pin arrangements.
The Hybrid External Fixator combines the advantages of the monolateral pin fixators and the circular Ilizarov wire fixators. The tensioned wires provide improved fixation in the small distal cancellous fragment, whereas the pin fixators give adequate stability to the proximal fragment. It is simple, has a rapid and straight forward application, reduced surgical time and is minimally invasive. It is adjustable, hence fracture reduction can be easily attained after frame assembly [5]. Along with rigid fixation, it allows immediate mobilization of the knee and ankle joints and early weight bearing. "Early motion has been touted as the functional savior of major intra articular injuries" [6]

Aims and Objectives

- To study and establish the results and functional outcome in surgical treatment of distal metaphyseal fractures of Tibia using a Hybrid External Fixator.
- To study the merits and demerits of surgical procedure

Materials and Methods

Between June 2016 and july 2018, 13 consecutive adult patients with fresh fractures of the distal tibial metaphysis were treated with the Hybrid External Fixator at Tertiary care hospital, Surat

Inclusion criteria

1. Age above 21 years
2. Fresh closed and open fractures of distal tibial metaphysis.
3. Intraarticular and extra articular fractures of the distal tibia.

Exclusion criteria

1. Age below 21 years.
2. Massively comminuted intraarticular fractures, Type C3 (AO/OTA) of distal tibia.

Pre-op Management

On admission of the patient, a careful history was elicited from the patient and/or attenders to reveal the mechanism of injury and the severity of the trauma. The patients were then assessed clinically to evaluate their general condition and the local injury. General condition was assessed with the vital signs and systemic examination. Methodical examination was done to rule out fractures at other sites.

Management of closed fractures

Local examination of the injured extremity revealed swelling, deformity and loss of function. Palpation revealed abnormal mobility and crepitus at the fracture site. Distal neurovascular status was assessed by the posterior tibial artery and dorsalis pedis artery pulsations, capillary filling, local temperature, pallor and paraesthesia.

Antero-posterior and lateral radiographs of the affected leg along with ankle were taken and the fracture patterns were classified based on the AO/OTA classification of fractures of distal tibia.

The limb was then immobilized in an above knee Plaster of Paris slab till definitive fixation with Hybrid External Fixatorwas done.

Management of Open Fractures

Patients with open fractures were graded using the Gustilo Anderson classification for open fractures. Antibiotics were started immediately for all patients. Injection cefotaxime 1-gram intravenous twice daily along with injection Amikacin 500mg intravenous twice daily were the antibiotics. Injection Tetglob (Tetanus immunoglobulin) 500 IU IM and single dose of tetanus toxoid was given.

After obtaining the necessary radiographs, Type I and II open fractures were treated by cleaning of the wound with copious amount of normal saline, and Hydrogen peroxide, followed by painting of the skin around the wound with Povodine iodine and surgical spirit. This was followed by primary wound closure. The limb was then immobilized in an above knee Plaster of Paris slab till definite fixation was done.

In the Type III fracture, patient was taken for emergency wound debridement and Hybrid External Fixatorwas applied.

Pre-operative Planning

All the patients were explained and motivated about the cosmetic problems and difficulties in daily routines by the application of an external fixator. Appropriate and valid written consent was taken. The patient was taken for surgery after routine investigation and after obtaining fitness towards surgery. The investigations done were, Hemoglobin percentage, Fasting blood sugar, Blood urea, Serum creatinine, HIV, HBSAg and ECG.

A dose of tetanus toxoid and antibiotic was given pre-operatively. Preparation of the part was done before a day of the surgery. Instruments were checked and sterilized before hand.

Operative Procedure

Type of Anesthesia- Spinal

- Position-supine with affected leg elevated on a pillow/sand bag.
- Pneumatic/Esmarchs tourniquet applied and time noted

Securing the distal fragment

- After reduction of the distal fragment, it was secured using three Ilizarov wires.
- The wires were pushed manually till it hit the cortex, then drilled across both the cortices and hammered out through the opposite soft tissue.
- Nerves and vessels were avoided by the awareness of the anatomy, based on the safe corridor for pin insertion in the lower leg by Fred Behrens and Kate Searls [35].
- Two olive wires were placed at $40\text{-}70^0$ to each other, one from posterolateral to anteromedial and posteromedial to anterolateral under fluoroscopic control.
- Minimal incisions were used to accommodate the beads in the olive wires.
- A third plain Ilizarov wire was placed in between the earlier two wires, parallel to the operating table.
- Appropriate size Ilizarov half ring was selected, so as to leave a gap of 2 cms between the leg and the ring on all sides.
- The wires were fixed to the rings using cannulated/slotted wire connecting bolts and tensioned using Russian free hand technique with two 10/11 wrenches.
- Skin traction by the wires, if any were released using minimal incisions on the side of the skin stretching.

Securing the proximal fragment

- The regular tibial external pin fixator was used for the proximal fracture fragment Three 4.5mm Shanz pins were placed 3-4cms apart on the antero-medial surface of tibia perpendicular to the operating table.
- Generous (1.0-1.5cms) incisions were put and skin and fascia was cut.
- Drill holes were made using 3.2/3.5mm drill bit in the same saggital plane.
- The Shanz pins were driven into the drill hole using a T-Handle to the extent that the proximal end of the threads of the pin were well buried in the proximal cortex.
- All the pins were placed in the same saggital plane.
- The pins were connected to the connecting rods with the pin clamps.

Fracture reduction and frame assembly

- Fracture reduction was obtained using longitudinal traction (Ligamentotaxis), confirmed using the image intensifier.

- The pin fixator assembly was connected to the ring assembly using a twisted connecting plate.
- All the nuts and bolts were tightened.
- A diagonal strut was connected from the proximal Shanz pin or the connecting rod to the lateral most hole of the half ring for extra stability.
- The compound fractures were treated with primary or secondary flap reconstructions or split thickness skin grafting as deemed suitable by the plastic surgeon.

Post-operative regimen
Active mobilization of the ankle, knee and non-weight bearing of the patient using standard walking frame was done from the first post-operative day under the supervision of a physiotherapist.
Intravenous antibiotic regimen was continued for 5-7 days (12-14 days in compound fractures) after the surgery. Another 5 days of oral antibiotics were advised. Regular cleansing of the pin exit points was done. Compound fractures were dressed as per instructions from the plastic surgeon.

Follow up
The patients were followed up at intervals of three weeks for up to 6-10 months to assess the radiological union and to check the stability of the construct.
The fracture was designated as united, when there was periosteal bridging callus at the fracture site at least in three cortices in the antero-posterior and lateral views. Trabeculations extending across the fracture site was also taken into consideration. Partial and full weight bearing were allowed based on the radiological union and consolidation of the fractures. Uncomplicated fixators were removed after complete fracture union. Fixators with pin tract infections were removed earlier and a patellar tendon bearing cast was applied which were removed after radiological union of the fracture. Ovadia and Beals [10] based results on objective and subjective evaluation. This scoring system was used in this study to assess the results.

Results
The present study consists of 13 cases of fracture of the distal metaphyseal end of tibia. All the cases were fixed using the hybrid external fixator. The study period was from June 2016 to July 2018. The age of the patients ranged from 24-62 years with the fracture being most common in the 4th and 6th decade and an average age of 41.16 years. Out of 13 patients, 11 (84%) patients were males and 2 (16%) patients were females showing male preponderance because of traveling and working in fields and factories.

Side affected
There were 8 (64%) patients with right distal tibia fractures 5(36%) patients with left distal tibial fractures.

Mode of injury
In our study, 9 (72%) of patients sustained injury following road traffic accident and 4 (28%) patient sustained injury following fall.

Fracture Characteristics
Clinical: Out of the 25 cases, 10 (80%) cases were closed fractures and 3(20%) cases were open fractures.
Classification of the 3 cases of open fractures classified based on Gustillo Anderson classification of open fractures, 1 (33%) was type I compound 1 (33%) was of type II compound and 1(33%) was of type III B compound.

Fracture Pattern
The fracture pattern was classified based on AO/OTA classification for fractures of distal tibia of the 13 cases studied, 3 (20%) cases were A1, 3(24%) were A2, 5(40%) were A3 and 2 (16%) cases were C1 type of fracture.

Associated Injuries
All but one of 13 cases studied had an associated fracture of the lower third of fibula. The one case with intact fibula had to be osteotomized to give adequate compression at the tibial fracture site. One patient had a fracture lower end of radius on the ipsilateral side of the injury which was treated by closed reduction and below elbow Plaster of Paris cast application.

Statistics of Surgery
All the 13 cases were operated under Spinal anesthesia. All the cases studied under went closed reduction under fluoroscopic control. Follow up ranged from 6 months to 10 months.

Duration of Surgery
Of the 13 cases treated with Hybrid External Fixator 8 (64%) cases took 31-50 minutes, 2 (16%) took 51-60 minutes, 2(12%) took 61-70 minutes 1(8%) took 71-80 minutes. The surgical time averaged 52 minutes.

Minimal internal fixation: In 2 of the patients, we had stabilized the coronal fracture of the distal tibia using anteroposterior compression screws percutaneously. In 1 of the patient, the fibular fracture was fixed using a 6 holed 1/3rd semi tubular plate and screws.

Duration of fracture union: All the fractures united with an average of 13.16 weeks (12-15weeks). There was no delayed union or non-union.

Table 1: Showing duration of fracture union

Duration (in weeks)	No. of Patients
12	4
13	5
14	2
15	2
Total	13

Fractures of 4 (28%) patients united in 12 weeks, 5(40%) patients united in 13 weeks, 2 (16%) fractures united in 14 weeks and in 2 (16%) patients the fractures united in 15 weeks.

Removal of fixator
The fixators were removed at an average of 13 weeks. In 2 patients, the fixators were removed earlier (10-12 weeks) as they had pin tract infections.

Table 2: Showing time of removal of fixator

Duration (in weeks)	No. of Patients	Percentage
10	1	8
11	1	8
12	1	4
13	3	28
14	7	52

Results: The results were based on the objective and subjective parameters as described by Ovadia DN and Beals RK [10].

Present study: At the end of 6 months of the 13 patients treated, 6 (48%) patients had excellent outcome, 4 (28%) had good results, 2 (20%) had fair outcome and 1 (4%) patient had a poor result.

Objective

Table 3: Showing objective results

Results	No. of cases	Percentage
Excellent	6	48
Good	4	28
Fair	2	20
Poor	1	1

Subjective

Table 4: Showing subjective results

Results	No. of cases	Percentage
Excellent	6	48
Good	5	36
Fair	2	16
Poor	0	0

Complications

Intra operative complications: There were no cases of intraoperative complications.

Post-operative complications

1. Pin tract infections

2 of the patients developed superficial pin tract infections, which were treated with daily dressings and appropriate antibiotics after pus culture and sensitivity. All these infections subsided on the above said treatment. However, as a precautionary measure, the fixators were removed earlier (8-10) weeks and a patellar tendon bearing cast was applied in these patients, which were removed after radiological union of the fracture.

Table 5: Showing Complications

Complications	No. of patients
Pin tract infection Ankle movement restriction	2
> 75%	1
51-75%	1
25-50%	3
< 25%	1
Anterior angulation 5^0	1

2. Ankle stiffness

We had 6 patients with ankle stiffness. This was probably due to the incompliance of the patient to the advised physiotherapy regimen, as there was no means to monitor the physiotherapy of the ankle joint after discharge of the patient. Ankle stiffness ranged from restriction of ankle movement from 20%-90%. The patient who had 90% restriction had an equinus deformity.

3. Anterior angulations

1 patient developed an anterior angulation of 5^0. This however did not grossly hinder with the mobility of the joints or daily activities of the patients.

Discussion

Fractures of distal tibia are among the most difficult fractures to treat effectively. The status of the soft tissues, the degree of comminution and articular damage sustained at the time of injury affect the long term clinical results. The goal of operative treatment is to obtain anatomic realignment of the joint surface while providing enough stability to allow early motion. This should be accomplished using techniques that minimize osseous and soft tissue devascularization in the hopes of decreasing the complications resulting from treatment.

The present study was under taken to determine the efficacy of the Hybrid External Fixator in treatment of the fractures of the distal tibial metaphysis. We evaluated our results and compared them with those obtained by various other studies utilizing different modalities of treatment, our analysis is as follows:

Age distribution

Our study revealed the average age of patients with such injuries to be 41 years (24-62). It is comparable with a study on similar fractures conducted by RF Gaudinez, Arati R. Mallik and Monroe Szporn [19] whose average age was 35, and also study by R. Barbieri, Richard Schenk, Kenneth Koval *et al.* [18] where average age was 39 years.

Sex Distribution

In our study, the male preponderance for such kind of injuries were high 84% compared to the study by Barbieri *et al*. [18], which was 59% possibly due to the fact of male dominance over the female in traveling, occupational injures etc., in India. However, the study by Ovadia and Beals. [10] were comparable in the fact that they had 67% male patients.

Mechanism of Injury

Gaudinez [19] *et al* observed 93% high energy fractures in his study. Ovadia and Beals [10] could attribute only 46% of such injuries to be of high energy. However, our present study correlates with the study conducted by Barbieri *et al*. [18] similar fractures in which they noted 75% high energy trauma. Our study showed 75% high energy trauma.

Clinical type

Our study had 20% open injuries. This was comparable on the studies conducted by Gaudinez *et al*. [19] who has 21% open fractures, Ovadia and Beals [10] who reported 20% open injuries. Barbieri *et al*. [18] however had 30% of open injuries.

Fracture Patterns

The present study could not be compared with the other studies because our primary aim was to study the distal metaphyseal fractures (with/without intra articular extension). We had also excluded the type C3 (AO/OTA) fractures. However, study by Barbieri *et al*. [18] showed 9% A1, 9% A2, 10% A3, 16% C1, 32% C2 and 24% C3. Kevin J, Philip R Wolinsky, Mark P *et al*. [21] also had fractures types comparable to study by Barbieri *et al*. [18]. We had a higher percentage of type A fracture due to the selection process based on the aim of the study.

Duration of surgery

The average surgical time was 52 minutes (40-80 minutes). It is comparable with the average of 62 minutes taken by Gaudinez *et al*. [19] in their study.

The length of the operative time reflects a significant learning curve. The first few fixators took 70-80 minutes in this study, whereas the most recent ones look 40-50 minutes.

Duration of fracture union

The average time for fracture union in various studies conducted using various methods was 13-16 weeks. Our study had an average fracture union of 13 weeks which were comparable with studies conducted using the hybrid external fixator. Barbieri *et al*. [18] had an average fracture union of 14 weeks and Gaudinez *et al*. [19] had an average of 13 weeks.

Table 6: Comparison of Duration of fracture Union between different studies

Study	Method	Average fracture union
Herfet *et al*[13]	ORIF/EX FIX	16 weeks
Wrysch *et al*[12]	EX FIX (Spanning)	15 weeks
Bone *et al*[14]	EX FIX (Spanning)	14 weeks
Barbieri *et al*[18]	Hybrid EX FIX	14 weeks
Gaudinez *et al*[19]	Hybrid EX FIX	13 weeks
Present study	Hybrid EX FIX	13 weeks

Removal of fixation

Table 7: Comparision of removal of fixator between different studies

Study	Method	Average fixator removal time
Wrysch *et al*. [12]	EX FIX (Spanning)	10 weeks
Bone *et al*. [14]	EX FIX (Spanning)	10 weeks
Gaudinez *et al*. [19]	Hybrid EX FIX	14.5 weeks
Present study	Hybrid EX FIX	13 weeks

In our study, we had removed the fixator at an average of 13 weeks. It is however lower than the 14.5 weeks in a similar study by Gaudinez *et al* [29], probably due to the fact that fixators with pin tract infections were removed earlier (10-12 weeks) and PTB cast was applied for 2-3 weeks. Barring the 5 patients with pin tract infection, the average fixator removal time was 14 weeks, which is comparable to the similar study.

The ankle spanning fixators must have been removed earlier to prevent the ankle stiffness.

Results and Complications

In a study that established open reduction with plate and screw fixation as the standard. Ruedi and Allgower[7] achieved 74% acceptable results in 84 patients. These results did not deteriorate for 9 years. Mast *et al*. [35] reported 78% satisfactory results in 37 patients with a minimum follow up interval of 6 months. Less dramatic results were reported by a variety of authors when the plafond fractures studied included larger numbers of high energy injuries. Bourne and colleagues [9] studied 42 patients with tibial plafond fractures, 62% of whom were victims of high-energy trauma. Of the 16 Ruedi type III fractures treated by open reduction and internal fixation, only 44% had a satisfactory result. The majority of these fractures were complicated by nonunion (25%), infection (13%), and Arthrodesis (32%). Ovadia and Beals [10] reviewed 34 fractures equivalent to Ruedi Type III treated with traditional open reduction and plate fixation. Good to excellent results were achieved in only 47%. Complications were numerous and, although not sub classified according to fracture type, superficial infections or skin loss developed in 9 patients (11%), osteomyelitis developed in 5 patients (6%), 17 patients (12%) required either ankle Arthrodesis or Arthoplasty. Teeny and Wiss [27] studied 60 tibial plafond fractures. 60% of those were secondary to high-energy trauma. They reported 50% poor results when open reduction and plate fixation was used. When the subset of 30 Ruedi Type III fractures was analyzed there were 12(40%) acceptable outcomes with 37% of these fractures complicated by a skin slough or deep infection. Mc Ferran *et al*. [28] reported on 52 tibial plafond fractures treated with open reduction and internal fixation. Forty percent of these were Ruedi Type III injuries. Overall, 40% of the patients suffered some complication, with a deep infection or osteomyelitis occurring in 43% of fractures, and a wound breakdown requiring soft tissue coverage in 62% of fractures.

Table 8: Comparision of acceptability of fixation between different studies

Study	Methods	Acceptable	Not acceptable
Ruedi and Allgower [7]	Open Reduction and internal fixation	74	26
Mast *et al*. [35]		78	22
Bourne *et al*. [9]		44	56
Ovadia and Beals. [27]		47	53
Teeny and Wiss. [11]		50	50
Bone *et al* [14]	Ankle spanning external fixators	90	10
Bonar and Marsh [15]	Hinged ankle spanning fixators	70	30
Tornetta *et al* [16]	Ankle sparing hybrid external fixators	69	31
Gaudinez *et al* [19]		64	36
Barbieri *et al* [18]		61	39
Present study		76	24

NB: The excellent and good results have been tabulated as acceptable and the fair and poor results as not acceptable for easier comprehension.

Bone *et al*. [14] reported on a series of 20 high-energy tibial plafond fractures treated using limited open reduction and internal fixation of the articular surface followed by neutralization of the fracture with an external fixator placed across the ankle joint. All the fractures healed, and only 2 patients (10%) had a poor clinical result. There were minimal complications with 2 pin tract infections (20%), no deep infections, and no skin sloughs occurring.

Bonar and Marsh [15] reported on use of hinged transarticular external fixator to treat pilon fractures. Post-operative complications were minimal with no cases of superficial or deep wound dehiscence. There were 5 cases of pin tract infection. Two required oral antibiotics, two required intravenous antibiotics, one required external fixator removal and subsequent deformity. There was no late surgery or osteomyelitis. The results were described as good in 69%, fair in 20% and poor in 11%.

Using the technique of hybrid external fixator, Tornetta *et al*. [16], accomplished 69% good results in the high energy injuries and major complications were avoided. There was

one deep infection, one superficial infection, one malunion and three pin tract infections. Barbieri *et al*. [18] achieved 67% good results using the hybrid external fixator. There were three cases of osteomyelitis, one skin sloughing and five pin tract infections. Three patients had a loss of reduction and required frame revision. Gaudinez *et al*. [19] based their study on the scale by Ovadia and Beals [10] with 64% patients having good to excellent subjective results, and 71% patients had Good to excellent objective results. Complications included superficial pin tract infections in 3 patients, all of which resolved with local pin care and a short course of orally administered antibiotics. There were no deep infections.

It is extremely difficult to make true comparisons between these studies because the method of fracture classification, number of high energy injuries, and functional scoring system all differ. However, when critically analyzing the outcomes of this study with respect to earlier studies, the comparison is favorable.

In our study, we had 6 (48%) patients with excellent, 4 (28%) patient with good, 2 (20%) patients with fair and 1 (4%) patient with a poor outcome. However, we had excluded the C3 (AO/OTA) fractures, which formed a significant part of the other similar studies. The 76% good to excellent result is better than or equal to most of the series.

There 2 five superficial pin tract infections, which resolved on meticulous pin care and oral antibiotics. 6 of our patients had ankle stiffness of varying degrees. This was probably due to the incompliance of the patients to the physiotherapy regimen advised. We had 1 malunion with anterior angulation of 5^0. Barring the 6 patients with ankle stiffness, the 28% rate of complications in comparable with the other studies.

Clinically (subjective) results showed 84% good to excellent results and 16% fair results. Patients who had an excellent or good result on the objective evaluation invariably had an excellent or good final subjective evaluation result. Some patients who only had a fair or poor result in the objective evaluation also had a satisfactory final subjective result. This indicated that minimum limitation of motion, malalignment and shortening did not preclude a good clinical result.

Conclusion

Hybrid external fixator technique has resulted in the effective stabilization of distal tibia fractures. It does provide adequate stability and allows early motion. The closed reduction not only helps in achieving reduction in difficult situations, but also in rapid union, because it facilitates preservation of the blood supply to the fragment. This method limits further damage to the already compromised soft tissue. Its greatest advantage is in open fractures where wounds can be left open. It is also effective in extraarticular fractures occurring within 5cm of the joint because, Intramedullary nails often do not provide enough stability and plates would require extensive soft tissue dissection.

It is a simple, has a rapid and straight forward application and has a reduced surgical time. Tensioned wires provided improved fixation in small and osteoporotic fragments.

When encountered with the unreconstructable distal tibial fracture, those with comminution or poor bone stock, rather than a primary Arthrodesis, closed reduction and Hybrid External Fixator satisfies the goals of plantigrade foot and soft tissue healing, without obviating any other means of further treatment.

Although, a larger sample of patients and longer follow up are required to fully evaluate this method of treatment, we strongly encourage its consideration in the treatment of such complex fractures.

References

1. Martin JS, Marsh JL, Bonar SK, De Coster TA. Found EM. Assessment of the AO/ASIF fracture classification for the distal tibia. J Orthop Trauma. 1997; 11:477- 483.
2. Michael Sirkin, Roy Sanders. The treatment of pilon fractures. Clinic Orthop. 2001; 32(1):91-102.
3. French B, Tornetta P. Hybrid external fixation of tibial pilon fractures. Foot Ankle Clin. 2000; 5(4):2000.
4. John Charnley. The closed treatment of common fractures. Cambridge. Colt Books Ltd. 1999.
5. Yang L, Saleh M, Nayagam. The effect of different wire and screw combinations on the stiffness of hybrid external fixator. Proc Inst Mech Eng (H). 2000; 214(6):669-76.
6. Salter RB, Simmonds DF, Malcolm BW, Rumble EJ, MacMichael D, Clements ND. The biological effect of continuous passive motion on the healing of full thickness defects in articular cartilage. J Bone Joint Surg. 1980; 62A:1232-1251.
7. Ruedi TP, Allgower M. The operative treatment of intra articular fractures of the lower end of tibia. Clin Orthop. 1979; 138:105-110.
8. Kellam J, Waddell JP. Fractures of the distal tibial metaphysic with intra-articular extension – the distal tibial explosion fracture. J Trauma. 1979; 19:593-601.
9. Bourne R, Rorabeck C, Macnab J. Intra-articular fractures of the distal tibia: The pilon fracture. J Trauma 1983; 23:591-596. Ovadia DN, Beals RK. Fractures of the tibial plafond. J Bone Joint Surg Am. 1986; 68:543-551.
10. Dillin L, Slabaugh P. Delayed wound healing, infection, and non union following open reduction and internal fixation of tibial plafond fractures. J Trauma. 1986; 26:1116-1119.
11. Wyrsch B, McFerran MA, McAndrews M, Limbird TJ, Harper MC, Johnson KP *et al*. Operative treatment of fractures of the tibia plafond: A randomized, prospective study. J Bone Joint Surg Am. 1996; 78:1646-1657.
12. Helfet DL, Koval K, Pappas J, Sanders RW, Dipasquale T. Intraarticular "pilon" fracture of the tibia. Clin Orthop 1994; 298:221-228.
13. Bone LB, Stegemann P, McNamara K. External fixation of severely comminuted and open tibial pilon fractures. Clin Orthop. 1993; 292:101-107.
14. Bonar SK, Marsh JL. Unilateral external fixation for severe pilon fractures. Foot Ankle Int. 1993; 14:57-64.
15. Tornetta PI, Weiner L, Bergman M. Pilon fractures: Treatment with combined internal and external fixation. J Orthop Trauma. 1993; 7:489-496.
16. Saleh M, Shanahan, Fern ED. Intraarticular fractures of the distal tibia. Surgical management by limited internal fixation and articulated distraction. Injury. 1993; 24(1):37-40.
17. Barbieri R, Schenk R, Koval K, Aurori K, Aurori B. Hybrid external fixation in the treatment of tibial plafond fractures. Clin Orthop. 1996; 332:16-22.
18. Gaudinez RF, Mallikar, Szporn M. Hybrid external fixation in tibial plafond fractures. Clin Orthop. 1996; 329:223-32.
19. Anglen JO. Early outcome of Hybrid External Fixator for the fractures of distal tibia. J Orthop trauma. 1999; 13(2):92-97.

20. Kevin J Pugh, Philip R Wolinsky, Mark P McAndrew. Tibial pilon fractures: A comparison of treatment methods. J Trauma. 1999; 47(7):937-41.
21. Yang M, Nayagam S, Saleh M. Stiffness characteristics and interfragmentary displacement with different hybrid external fixators. Clin Biomech (Bristol, Avon). 2003; 18(2):166-72.
22. Piper KJ, Won HY, Ellis AM. Hybrid external fixation in complex tibial plateau and plafond fractures: an Australian audit of outcome. Injury. 2005; 36(1):178-84.
23. Salmons Stanley. "Muscles". Williams L Peter *et al* in Gray's Anatomy, 38th edition, Edinburg; Churchill Livingstone, 1995, 2092.
24. Marsh JL, Charles L Saltzman. "Ankle fractures". Robert W. Bucholz, James D Heckman in Rockwood and Green's fractures in Adults, 5th edition, Philadelphia, Lippincott, Williams and Wilkins, 2001, 2051.
25. Swiontkowski MF, Sands AK, Agel J, Diab M, Schwappach JR, Kreader HJ. Interobserver variation in the AO/OTA fracture classification system for pilon fractures: is there a problem? J Orthop Trauma. 1997; 11:467-470.
26. Teeny S, Wiss DA, Hathaway R. Tibial plafond fractures, errors, complication and pitfalls in operative treatment. Orthop Trans. 1990; 14:265.
27. McFerran MA, Smith SW, Bonlas HJ. Complications encountered in the treatment of pilon fractures. J Orthop Trauma. 1992; 6:195-200.
28. George W Wood II. "General Principles of Fracture Treatment". Terry Canale in Campbell's Operation Orthopaedics, 10th edition, St. Louis, Mosby, 2000, 2671.
29. Griffiths GP, Thoradson DB. Tibial plafond fractures limited internal fixation and a hybrid external fixator. Foot Ankle Int. 1996; 17:444-448.
30. Court Brown CM, Walker C, Garg A. Half ring external fixation in the management of tibial plafond fractures. J Orthop Trauma. 1999; 13(3):200-206.
31. Steven A Olson, Christopher G, Finkemeier, David H Moehring. "Open fractures" Robert W. Bucholz, James D. Hechman in Rockwood and Gray's Fractures in Adults, 5th edition, Philadelphia, Lippincott, Williams and Wilkins. 2001, 293.
32. Madhav A Karunakar, Michael J Bosse. "Principles of external fixation". Robert W Bucholz, James D. Heekman in Rockwood and Green's Fractures in Adults, 5th edition, Philadelphia, Lippincott, Williams and Wilkins, 2001, 233.
33. Fred Behrens, Kate Searls. External fixation of tibia: Basic concepts and prospective evaluation. J Bone Joint Surg (British). 1986; 68(B):246-54.
34. Mast JW, Spiegel PG, Pappas JN. Fractures of tibial pilon. Clin Orthop. 1988; 230:68-82.