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Evaluation of the clinical, functional and radiological outcomes in patients with distal tibia fractures with simple intra-articular extension treated with intramedullary multidirectional locking nail: a prospective study

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ABSTRACT

Background: Distal tibia fractures with extension into the ankle joint (AO/OTA type 43C) poses challenge for an orthopedic surgeon, due to its subcutaneous nature and precarious blood supply. Literature has described various treatment modalities; most commonly used being locking compression pates, external fixators and intramedullary multidirectional locking nails.
Methods: This prospective study included 60 patients with distal tibia fracture AO type 43C1 and 43C2, managed with intramedullary multidirectional locking nails in a close manner, with intra-articular fragment fixation preceding the nail insertion. The aim of this study was to evaluate the clinical, functional and radiological outcomes as well as the complications in these patients.
Results: Patients' mean age was 48.7±16.6 years; most had type 43C1 fractures (51 patients). The mean surgery time was 88.4±17.5 minutes, performed within 5.6±2.01 days post-injury. The 30 patients had fibula fracture with syndesmotic injury which was fixed with TENS nail. The functional assessment with Johner and Wruh's criteria; 45 patients (75%) had excellent, 12 patients (20%) had good and 3 patients (5%) had fair outcomes. The fracture union averaged 16.7±1.63 weeks (14-20 weeks). 6 patients had superficial wound complication, while 3 patients had valgus malalignment; all managed without further surgery.
Conclusions: Intramedullary nailing following specific surgical technique, and potential percutaneous screws; is a safe, effective and successful treatment option for AO/OTA types 43C1 and 43C2 fractures with high fracture union rates, high functional results, and low complication rates.

Keywords: Intramedullary multidirectional locking nail, Syndesmotic injury, Johner and Wruh's criteria, Valgus

INTRODUCTION

Distal tibial fractures account to around 7% of all the tibial fractures and around 10% of all the lower extremity fractures.[1-4] It is more common in the age group of 30-50 years with the male preponderance.[5] These injuries may be either low or high energy injuries. The low energy distal tibia fractures are mainly seen in older age group which occurs mainly due to the rotational forces after trivial fall or slip.[6] The spiral fracture with or without intra articular extension is often encountered in this type of mechanism of injury. In high energy distal tibia fractures occurring due to road traffic accident or fall from height; the younger age groups are usually involved.[7] Axial loading, compression and torsional forces are involved in this type of injury leading to comminution and extension of the fracture into

the ankle joint.[8-10] As tibia being a subcutaneous bone and having precarious vasculature in nature; fractures involving the ankle joint are difficult to manage. Internal fixation devices like locking compression plates and intramedullary nails are often used for the fracture fixation of distal tibia.

It is very important to have a clear identification of the fracture pattern using various radiographic tools; so as to plan the implants accordingly to have better results. It was in 1969 the treatment of distal tibia fractures got revolutionized by the study done by Reudi and Allgower where 74% of patients after surgery were pain free with good functional outcome at 4 years follow-up.[8] Therefore in 1970's and 80's widespread use of internal fixation for distal tibia fractures became popular. However, this was accompanied by a high rate of major complications like malunion (42%), superficial infections (20%), non-union (18%) and osteomyelitis (17%). These high rates of complications emphasized the importance in handling soft tissues during fracture management. But all these fractures in Reudi and Allgower's series were low energy injuries. They later published another series in 1979 which consisted of high energy injuries and inferred that overall results were not good using traditional fixation methods.[11] This led to new methods which caused less soft tissue damage and yielded better results. The new techniques used were intra medullary nailing (IM nailing), hybrid fixators and biological minimally invasive plate osteosynthesis (MIPO).

However, the optimal treatment of intra-articular distal tibial fractures still remains controversial. Conservative treatment, IM nailing, external fixators and biological MIPO have been described and each of them has their own advantages and disadvantages.[12-14] The foremost important contributions to intramedullary fixation, however, came from Gerhard Küntscher (1900-1972) who performed a variety of animal experiments and explained not only the nailing technique but also the implant design and shape. He suggested a tight fit between nail and bone to gain a better stability. To increase the surface area of contact within the medullary cavity, he began to ream the canal so as to insert longer, thicker, and cloverleaf nails. In 1950, Herzog et al introduced the tibia nail with a proximal bend and lateral slots at the distal end to just accept anti-rotational wires. Klemm and Schnellmann in Germany and Kempf et al in France further developed and were precursors to today's interlocking nails. In 1958, the AO/ASIF (Association for the study of internal fixation) formulated the four basic principles which have become the rules for the internal fixation.[15] AO principles of fracture fixation are: Fracture reduction and fixation to restore anatomical relationships; Fracture fixation providing absolute or relative stability according to the "personality" of the fracture, the patient, and the injury as required; Preservation of the blood supply to soft tissues and bone by gentle reduction techniques and careful handling; and Early and safe mobilization and rehabilitation of the injured part and therefore the patient as a whole.

The role of the intramedullary nailing in the treatment of simple intra- articular distal tibia fractures (AO/OTA type 43 C1 and C2) has not been well defined. Various authors have published their studies on the treatment of the non-articular metaphyseal tibial fractures with the intramedullary nailing technique.[16-18] However, little evidence exists regarding the management of distal tibia fractures with intra articular extension into the joint, with the intramedullary nailing technique.[19-21]

Aims and objectives

The aim and objectives of this prospective study was to evaluate the functional and radiological outcomes of distal tibia fractures with simple intra articular extension managed with close reduction and internal fixation with newer generation IM nails. The study also aimed at evaluating the rehabilitation and the mobilization protocols; as well as evaluating the complications associated with the surgery.

METHODS

The present study was a prospective study conducted in the department of orthopaedics in Bharat Ratna doctor Babasaheb Ambedkar municipal hospital, Mumbai from July 2021 to July 2023, with prior approval taken from the institutional ethical committee. The study population consisted of patients coming with the fracture of distal fourth tibia-fibula with simple extension into the joint (AO type 43C1 and 43C2).

Inclusion criteria

Skeletally mature patients (age >18 years) with the fracture of distal fourth tibia-fibula with simple extension into the ankle joint (type C1 and C2), as confirmed radiographically with standard x rays of ankle joint and CT scans; either closed injury or grade 1 compound, without distal neurovascular deficits were included in study.

Exclusion criteria

Skeletally immature patients (age <18 years); extra articular fractures of the distal fourth tibia-fibula; completely intra articular fractures (type C3); grade 2 or 3 compound fractures; comminuted fractures; pathological fractures; and fractures with distal neurovascular compromise were excluded from the study.

The study included a total of 60 patients with distal tibia fracture with simple intra articular extension; who were managed surgically with close reduction and internal fixation with expert IM nailing. In all the cases expert nail was used which allowed us to have distal locking in multi direction to have better stability in the small distal fragment. All the patients were thoroughly investigated

radiographically and were then classified as per the AO/OTA classification system. On admission the fracture was initially stabilized temporarily with above knee slab; and proper care was taken to reduce the swelling by RICE protocol (Rest, immobilization, cold fomentation, limb elevation). After full anesthetist work up and once the swelling got reduced; the patients were then posted for the surgery.

All the surgeries were done in supine position with the knee frame to have flexion at the knee joint while reaming. Intra articular fracture was initially fixed with lag screws under the c arm guidance; before proceeding with the nailing procedure. In cases where fibula was fractured simultaneously, it was fixed with the tens nail before fixing tibia; provided the fibula fracture was within 5 cm proximal to the syndesmotic joint. In all the cases reamed expert tibia nailing was used done with distal locking done in 2 planes to have rotational stability.

Post operatively, on day 1 the knee mobilization with hamstrings, quadriceps and ankle pumps were started with nil weight bearing walking on the other leg. Partial weight bearing was begun after radiological union of the fracture was seen. Full weight bearing was initiated after complete consolidation of the fracture as seen on the x rays. Patients were followed up at 2nd and 6th week, 3rd, 6th and 12th month post operatively. The functional and radiological outcomes were assessed at the last follow up with the help of Johner and Wruh's criteria.[22]

RESULTS

The study included a total of 60 patients, with the mean age of the population being 48.7±16.6 years with the range being 19-68 years. The study had 35% of the patients above 60 years of age, with 20% each in 21-30- and 41-50-years age groups. The age distribution of the study population is depicted in Figure 1. There were 33 males (55%) and 27 females (45%) in the study. The right limb was fractured in 45 (75%) patients, with left limb injured in 15 (25%) patients. No patient had bilateral injuries. Domestic fall was responsible for 15 (25%) fractures, while road traffic accidents RTA's accounted for 45 (75%) fractures. According to the AO/OTA classification system, 51 patients had type 43C1 fracture pattern, while 9 patients had type 43C2 fracture pattern; as classified using standard radiographs and CT scans with 3D reconstruction. There were 3 patients with diabetes mellitus, 21 patients with hypertension, 3 patients with combined Diabetes and Hypertension. 33 patients in the study had no co morbidities. The distribution of the study patients according to the co morbidities is depicted in Figure 2.

The mean time from injury to surgery was 5.6±2.01 days with range being 2-9 days. The mean duration of surgery was 88.4±17.5 minutes with the range being 63-121 minutes. The 36 patients had associated fibula fracture, of which 6 patients had fracture above 5 cm from the syndesmotic joint, and thus were not fixed. However, remaining 30 patients had fibula fracture within 5 cm from the syndesmotic joint or below it, and thus were fixed with IM TENS nail. Plate fixation for the fibula was not done in any of the case so as to prevent the rigidity of the fixation.

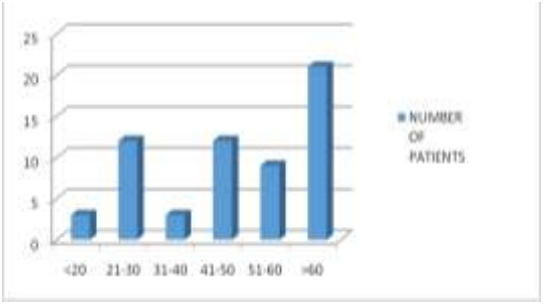

Figure 1: Age wise distribution of the study patients.

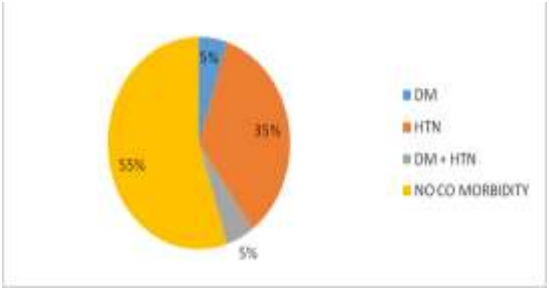

Figure 2: Distribution of the study patients according to the comorbidities.

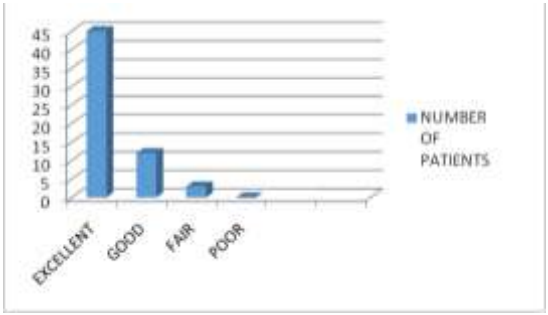

Figure 3: Distribution of the patients according to the functional outcomes on the final follow-up.

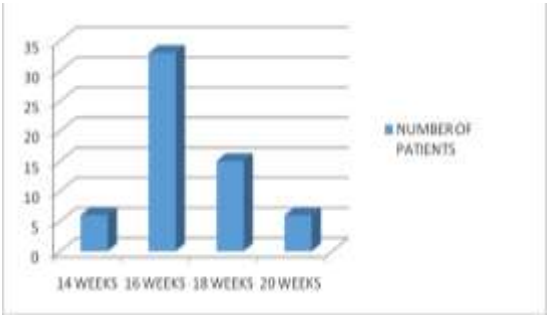

Figure 4: Distribution of the patients according to the time to fracture union in weeks.

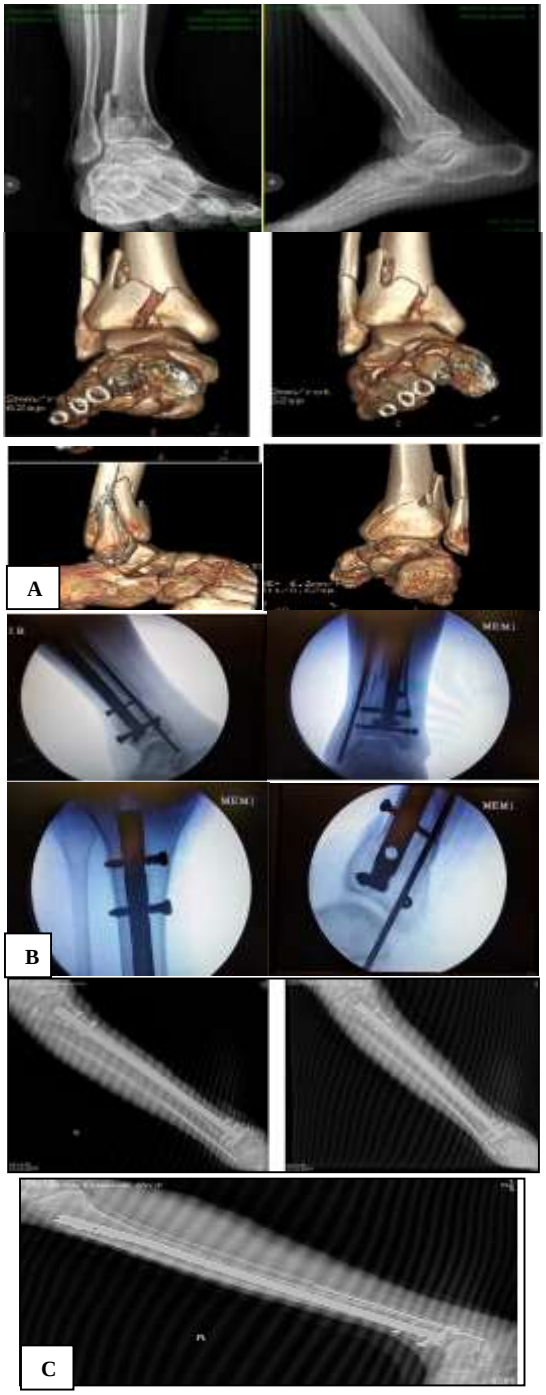

Figure 5 (A-C): Pre operative radiographs and 3D CT scans of ankle joint along with distal tibia fibula along with intra operative c arm images and immediate post operative radiographs.

The functional outcome on the final follow up was assessed with Johner and Wruh's criteria. According to this criterion, 45 patients (75%) had excellent outcomes, 12 patients (20%) had good outcomes and 3 patients (5%) had fair outcomes as depicted in Figure 3. The mean time for fracture union as seen on standard anteroposterior and lateral radiographs was 16.7±1.63 weeks' post-surgery, with range being 14-20 weeks. 6 patients (10%) had union as early as at 14 weeks; 33 patients (55%) had union at 16 weeks; 15 patients (25%) had union at 18 weeks; while 6 patients (10%) showed union as late as at 20 weeks post-surgery as depicted in Figure 4. In the current study, no patients had non-union as a complication post operatively. Post operatively 6 patients had superficial wound complications in the form of wound dehiscence and infection, which was treated conservatively with regular dressings and antibiotics; while 3 patients had valgus malalignment. No patient needed re surgery for the same.

Figure 6 (A and B): 1 month and 4 months post operative radiograph showing good maintenance of reduction and alignment.

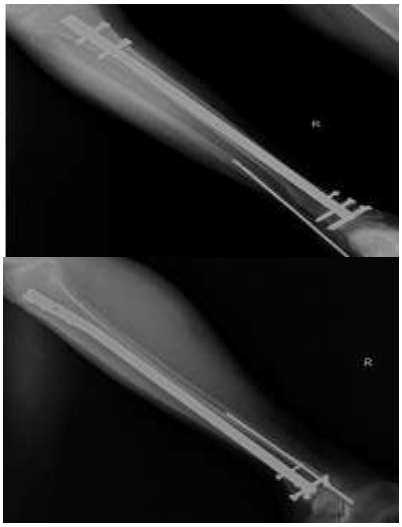

Figure 7: The twelve months post operative radiograph showing good maintenance of reduction and the alignment with complete consolidation of the fracture.

Figure 8 (A and B): Pre operative radiographs and CT scans of the ankle joint along with distal tibia fibula along with immediate post operative radiographs.

Figure 9 (A and B): 1 month and 4 months post operative radiograph showing good maintenance of reduction and alignment.

Figure 10: 12 months post operative radiograph showing good maintenance of reduction and alignment with complete consolidation of the fracture.

DISCUSSION

The management of unstable distal tibial fracture with articular involvement remains challenging and controversial. A variety of treatment methods have been suggested for distal tibial fractures. The intramedullary nailing and plate fixation represent two viable approaches to internal fixation of intra-articular fractures of the distal tibia. It is still a matter of debate whether the fractures should be treated by plate or nail. The open reduction and plating results in extensive soft tissue dissection and may be associated with wound complications. Distal tibia has less vascular and less muscular and soft tissue support than any other part of the tibia therefore infection, delayed union or non-union have been a more common complication after open reduction and internal plate fixation.[23]

The success of the interlocking intramedullary nailing for the treatment of the tibia shaft fractures has led many orthopaedic surgeons to expand the indications to address the proximal and distal tibia metaphyseal fractures.[4,24,25] However, the technical limitations of the intramedullary devices along with the special characteristics of these fractures jeopardize the final outcome and leads to a high rate of intraoperative and postoperative complications such as expansion of the fracture, nonunion, malalignment, implant failure, and fracture propagation into the joint. The tight fit of intramedullary nails provides a good fixation of shaft fractures. However, biomechanical support of intramedullary nails is reduced in the distal metaphyseal region where the medulla widens.

The mean age of the patients in our study was 48.7 years with range being 19-68 years with male preponderance of 55%; which was comparable with the other similar studies conducted by Beytemür et al where the mean age of the study population was 40 years with range being 19-82 years with male preponderance of 74%; Katsenis et al where the mean age of the study population was 35.5 years with range being 20-71 years with male preponderance of 64%; and McLauchlan et al where the mean age of the study population was 46 years with range being 15-92 years with male preponderance of 61.9%.[9,21,26] However with respect to the mode of injury, our results of 75% patients sustaining high energy trauma were comparable with the study conducted by Katsenis et al who reported 72% high energy trauma fractures.[21] While the studies conducted by Beytemür et al reported 29% of high energy trauma fractures and McLauchlan et al[9] reported as low as 17% of high energy trauma fractures; with both these studies including vast majority of the patients sustaining low energy trauma fractures. Also, our results with respect to the fracture classification of the patients in the study showed 85% belonging to AO/OTA type 43C1; while those in the studies conducted by Beytemür et al and Katsenis et al had 57% and 56% respectively of the patients belonging to AO/OTA type 43C1. This difference was due to exclusion of simple distal tibial metaphyseal fractures (AO/OTA type 43A and 43B) in our study; while these being included in the other studies. Our study showed the average time to fracture union being 16.7 weeks; which was comparable with the studies conducted by Beytemür et al and Katsenis et al who had average time to fracture union as 16.5 weeks and 16.3 weeks respectively.

Fixation of the fibula in distal tibial fractures is a controversial topic.[27] Prior studies have shown a higher malunion rate if the fibula is not fixed in distal tibia-fibula fractures that are nailed, with a worsening in the malunion rate as time progressed.[27] Egol et al found a late malalignment rate of 4% in distal tibial fractures treated with fibular fixation and of 13% in distal tibial fractures treated without fibular fixation.[28] In contrast, Vallier et al found a higher rate of non-union with fibular fixation. The most important indication for fibular fixation is syndesmotic injury. If the fibula fracture is located proximal to the syndesmotic joint by 5cms, its fixation is not necessary. However, if the syndesmotic injury is diagnosed, fixation is absolutely necessary.[28,29] In our study the main indication to fix the fibula fracture was; a major fracture displacement with the disturbance of the ankle mortise. In any such a case, the fibula fracture was anatomically reduced and fixed to secure the tibiotalar joint, the tibia leg length, the alignment, and the tibial rotation. Contrary with the Tampa series, we had no case with late tibia malalignment or delayed union. In view of our results, we recommend primary fixation of the fibula fracture up to the distal third of the fibula. We resorted to fibular fixation with TENS nailing in 30 cases out of 36 associated fibular fractures cases encountered, which we thought that the stability of the distal tibial fragment was questionable. Fixation of the fibular fracture helped us to correct alignment of the tibia. The procedure can be carried out mostly by close method.

The articular component of the fracture has to be addressed before the intramedullary nailing with periarticular lag screws. This prerequisite eliminates the potential for additional articular displacement during the insertion of the nail. In our series, anatomic reduction of the articular extension of the fracture was achieved and retained postoperatively in all cases. Unlike the situation with diaphyseal fractures, nail insertion in distal tibial fractures does not result in fracture reduction. In a systematic review of 1125 distal tibia fractures treated with 3 different methods, Zelle et al recorded an extremely high rate of malunion or unacceptable shortening ranging from 16.2% to 30.1% in the fracture population treated with intramedullary nailing.[29] Eccentric reaming followed with incomplete fracture apposition and failure of center to center placement of the nail, along with inability to control the small distal fragment with adequate distal static locking have been emphasized by other authors as the main reasons of intraoperative tibia malreduction.[28,30]

On the other hand, the discrepancy between the nail diameter and the diameter of the distal tibial medullary canal along with the reduced interface between the cortex

of the tibia and the nail may lead to late tibia deformity and malalignment. So, the selection of the nail size in length and width and the multiplane fixation of the distal fragment should not be underestimated. Accurate reduction of the metaphysio-diaphyseal fracture has to be achieved before the reaming and the placement of the nail. To overcome the intra-operative reduction difficulties, a lot of alternative reduction methods have been proposed.[31,32] Skeletal traction through the calcaneum, provisional reduction with a percutaneous clamp, blocking screws, and femoral distractor may facilitate the distal fragment manipulation. C-arm visualization in both planes during the nail insertion is mandatory for the central placement of the nail in both the anteroposterior and the lateral planes, the maintenance of the reduction through the nail passage and to avoid further fragmentation or deformity. In 60 fractures, we had only 3 cases with 4 degrees of valgus deformity. No case with secondary postoperative loss of reduction was recorded.

The inability to interlock distally with multiple screws in 2 planes and as close as possible to the epiphyseal line of the tibia reduces the stability of the fixation intra-articular fractures. The union rate for distal tibial fractures treated with reamed or un reamed intramedullary nailing without the need of an additional intervention ranges from 58% to 100%.[10,33] Duda et al confirmed that biomechanical conditions in un-reamed intramedullary nailing of distal tibial fractures are unfavorable, because of a large axial to shear strain ratio between the bone fragments. Unreamed nailing of distal tibial fractures is associated with a rather high rate of bone healing complications and locking screw failure.[34,35] As long as we had reamed 1.5-2.0 mm greater than the nail diameter, a few millimeters proximal migration of the nail with a subsequent telescoping sliding of the bone through the nail is allowed and the beneficial compressive micromotion at the fracture site may promote the healing of the fracture. We advocate isthmus reaming for nailing in distal tibia. The isthmus reaming minimizes the violation of medullary canal and provides effective bone dust for early union. Limited reaming spares cortical perfusion compared with standard reaming at the time of nail insertion.[36,37] IM nailing can be considered the "gold standard" for the treatment of tibial midshaft fractures, but there are concerns about their use in distal tibia fractures.[38] This is because of technical difficulties with distal nail fixation, and the discrepancy between the diaphyseal and metaphyseal diameter of the IM canal and risk of nail propagation into the ankle joint. In recent years, intramedullary nailing has become widely accepted as the operative treatment of choice for tibial diaphyseal fractures. There use have been extended to fractures closer to the ankle joint. Bonnevialle et al unreservedly propose nailing for distal tibia fractures presenting 2-6 cm of cancellous bone above the subchondral bone.[39]

Intramedullary nailing is an effective alternative for the treatment of distal metaphyseal tibial fractures. Simple articular extension of the fracture is not a contraindication to intramedullary fixation. Functional outcomes improve with time.[19,40,41] The intramedullary canal at distal tibia prevents intimate contact between the nail and endosteum, insertion of two distal locking screws becomes therefore more necessary. There is consensus in the literature on the need for double distal screw fixation so as to obtain better control of sagittal and frontal as well as horizontal movements by distributing stresses. It is also well documented that the placement of two distal screws increases the stiffness and strength of the bone- implant construct, thus leading to enhanced mechanical stability of the fixed fracture.[16,42]

In our study, distal tibial fractures were treated with a reamed intramedullary nailing system that increases distal fixation by two distal interlocking screws passing through the distal 0.5 cm to 1.5 cm from the tip of the nail. The design of the nail allows one mediolateral and one anteroposterior screw for better stabilization of the distal fragment. The 5% patients had a malalignment of the tibia but after union it was within acceptable range. They attained the full function of ankle and knee. The results were satisfactory even when two locking bolts were used. No cases had gross malalignment (angulation of >10˚ valgus) or restricted movements of ankle. In no cases there was breakage of the screws.

Although the clinical benefit of dynamization in fresh tibial fractures is debated, the technique is generally accepted as an essential method of stimulating fracture healing in delayed and non-unions. Mosheiff et al reported that 22 of 52 patients with distal tibial metaphyseal fractures treated with unreamed nailing required secondary procedures (e.g. dynamization, autogenous bone grafting, fibulectomy) to progress to union.[43] Dynamic locking allows intermittent compression of the fracture site during early weight-bearing therefore incidence of screw breakage is very low as compared in the literature. Incidence of delayed union and nonunion rate is very low as compared to reported series as we used the single interlocking bolt in dynamic mode especially in upper part and 2 locking bolts in lower end to secure the distal fragment. We believe that dynamization of long bone fractures has been shown to accelerate periosteal callus formation during early stages of bone healing. In addition, a more uniform callus formation is seen as a result of this controlled reduction of the fracture gap. Toe touch weight-bearing after removal of cast allows early osseous healing without fatigue, and failure of locking bolts. Fear of shortening because of dynamization and early weight-bearing has not been sustained. The anterior knee pain remains a problem with IM nailing regardless of the surgical approach relative to the patellar tendon.

Katsenis et al recently reported 50 intra articular distal tibia fractures. Fixation of the articular fracture extension was performed in 37 of 50 fractures before nail placement with 4-mm cancellous screws.[21] Immediate partial weight bearing (up to 50%) and routine dynamization were performed in all cases. Final coronal and sagittal plane deformity was reported to be less than 4 degrees in all

cases and average less than 1 degree. Functional outcome scores and range of motion were measured in all patients with minimum 3-year follow-up. The authors reported outcome scores similar to reported lower extremity injury norms and return to work/previous level of activity in almost all patients. Dogra, Ruiz, and Marsh reviewed 83 patients with isolated fractures of the tibial diaphysis treated primarily with closed, reamed intramedullary nailing. Twenty-nine patients experienced pain around the knee when resting. The cause of this symptom is still unclear.[44,45] In our study, incidence of anterior knee pain is very less as compared in the literature because of minimum trauma at insertion site and nail buried nicely in upper part of tibia. Autogenous bone grafting is the most common secondary procedure to promote the bone healing. In our series, all fractures united uneventfully without a secondary procedure. No significant limitation of the daily activities recorded in this series. Ninety-two percent of the patients were able to participate in all the sport activities they used to do before the injury.

The main limitations of our study are inherent in its lack of comparison group. One weakness of this study is that the follow-up has not been clinically and biomechanically proven to be the end point of the final result for this type of fracture.

The interlocking nail provides sufficient stability by three-point fixation at either ends and also in the diaphysis by its bony contact. We believe that to achieve uneventful union with minimum morbidity, due attention should be focused on avoiding damage to the periosteum of small bone fragments in comminuted fractures. The minimal surgical trauma and flexible fixation allow prompt healing when the blood supply to bone is maintained. The mechanically incompetent and biologically viable fragments heal around the nail to promote union and early recovery. It is our observation based upon the analysis of the patients in our series we strongly advise that the nail provides an effective implant providing stability and allowing union in simple and complex distal tibial fractures.

The present study represents the first attempt to evaluate the long-term clinical, functional, and radiological result of intra-articular distal tibial plateau fractures treated with intramedullary nailing. It provides solid clinical and radiographic evidence that once all the parameters of the injury have been well managed and the complications eliminated, these fractures treated with nail have a good chance of obtaining a satisfactory long-term functional result.

CONCLUSION

Intramedullary nailing is not contraindicated for distal tibial fractures with un-displaced, intra-articular fragments, as reported in the literature. Intramedullary nailing in accordance with the surgical technique, with additional percutaneous screws, if necessary, is a successful treatment option for AO/OTA types 43C1 and C2 fractures with high fracture union rates, high functional results, and low complication rates. Dynamic osteosynthesis is a minimally invasive technique based on principles of limited exposure and indirect reduction methods, which avoids major soft tissue complications and shortens the length of the patient's stay in the hospital. We conclude that intramedullary nailing is a safe and effective technique for treatment of distal metaphyseal tibial fractures with simple intra-articular extension. One drawback of this prospective study is that it is a limited patient study with only 2 years post operative follow up.

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