Outcomes of Treating Tibial Shaft Fractures Using Intramedullary Nailing (IMN) versus Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO)

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ABSTRACT

Background: Tibia shaft fractures are one of the most common long-bone fractures, second most common open sport-related injuries and they are estimated to occur in 4 percent of the senior population. Objective: Management of tibial fractures has been updating to achieve the best outcomes and avoid complications especially when talking about most common long bone fractures. Less invasive fixation techniques are the preferred ones to reduce surrounding soft tissue injury, improve healing process and decrease complications. Minimally invasive percutaneous plate osteosynthesis (MIPPO) and Intramedullary nailing (IMN) are the least invasive and most popular modalities used nowadays. This study compares outcomes and complications of both modalities. Methods: This is a retrospective cohort study conducted in orthopedics department at KAUH-Jordan. Patients were followed up for a mean of 15.3 months. Only MIPPO and IMN were used, and exclusively tibial shaft fractures were included. Open fractures were classified according to the Gustilo-Anderson classification. Results: Ninety patients with a mean age of 36.9 years (range, 9-79) were observed. Fifty nine of them were treated with IMN; nine of them had complications. Thirty one patients were treated with MIPPO and only three developed complications. Three patients treated with IMN had non-union, whereas none of MIPPO patients developed non-union. Only perioperative blood loss was more when MIPPO was used taking into consideration the amount in the suction tube, amount of fluid irrigation and soaked gauze. Conclusion: In treating tibial shaft fractures, MIPPO appears to cause fewer complications and provides better healing environment therefore attributes to lower non-union rates than IMN. Larger sample size might be needed to provide better results. Keywords: Tibia shaft fracture, IMN, MIPPO, Open fracture.

1. BACKGROUND

Tibia shaft fractures are one of the most common long-bone fractures, second most common open sport-related injuries and they are estimated to occur in 4 percent of the senior population (1, 2). The tibia is vulnerable to injury by both low energy and high energy mechanisms. Low energy impacts usually resulted from transitional forces and indirect trauma resulting in spiral fractures at different levels with minimal soft tissue injury. While high energy mechanism is a result of direct impact and resulting in short oblique or wedge fractures with significant comminution and can be associated with soft-tissue injury, compartment syndrome, ipsilateral skeletal muscle injury and bone loss (3, 4). Several options for managing tibial fractures are available including casting, plate fixation, Intramedullary nailing, and external Fixation (5). High complications were reported in tibial fractures with high rates of nonunion due to the lower blood supply of the tibia in comparison with other long bones (6). Although many studies had been conducted to obtain the best management of tibial fractures, it remains debatable (7). For instance, nailing is preferred in the management of most displaced tibial fractures. However, it has a significant rate of malalignment (5% to 58%) when dealing with distal and proximal tibial fractures because it can be difficult to control by the intramedullary device (8, 9). Therefore, minimally invasive...
plating is preferred by some surgeons when dealing with peripheral fractures. The use of this technique has the advantage of maintaining a more favorable biomechanical environment for fracture healing and reducing surgical trauma (8, 10-13). In addition, this controversy is augmented by the plentiful factors which affect the outcomes such as age, gender, comorbidities, type of fracture, classification according to Gustilo-Anderson, Tscherne and Gotzen classification (5, 30, 31). Despite the successful use of minimally invasive plating and its favorable results with lower rates of infection and malunion, the optimal approach is still controversial with few studies comparing minimally invasive plating and IMN (8, 10-29).

Management of tibial fractures has been updating to achieve the best outcomes and avoid complications especially when talking about most common long bone fractures. Less invasive fixation techniques are the preferred ones to reduce surrounding soft tissue injury, improve healing process and decrease complications. Minimally invasive percutaneous plate osteosynthesis (MIPPO) and Intramedullary nailing (IMN) are the least invasive and most popular modalities used nowadays.

2. OBJECTIVE

Therefore, this study aims to compare outcomes of Intramedullary Nailing and minimally invasive plating in treating tibial shaft fractures, and also, compares outcomes and complications of both modalities.

3. METHODS

This is a single blinded retrospective cohort study in the Orthopedic department at King Abdullah University Hospital (KAUH), Irbid, Jordan. Ethical approval was obtained from institutional review board (IRB) committee at KAUH and Jordan University of Science and Technology prior to starting the study. A total of 90 patients with tibial shaft fractures who presented to the emergency department or were referred to KAUH between 2018 and 2020 were included in the study population. The inclusion criteria were: acute traumatic tibial shaft fractures (extra-articular) and no concomitant multiple fractures. Gustilo-Anderson fractures (Type IIIB, IIIC), multiple trauma patients, patients with severe cognitive impairment and severe disability were excluded from the study. For each patient, multiple parameters were recorded including patient’s age, gender, side of the fracture, fracture morphology, comorbidities, and surgery course including the amount of bleeding. The patients either underwent intramedullary nail fixation (Figure 1) or minimally invasive percutaneous plating (Figure 2) by one of the attendings at KAUH and similar surgical techniques were followed by all surgeons. All patients were followed up for a mean period of 15.3 months and

### Table 1. Demographic characteristics of the patients

|                           | Total          | Nail 59 (65.6%) | MIPPO 31 (34.4%) | P-value |
|---------------------------|----------------|-----------------|------------------|---------|
| **Age**                   |                |                 |                  |         |
| Total                     | 36.89 (9 to 79) year | 38.75           | 33.35            | .149    |
| **Gender**                |                |                 |                  |         |
| Male                      | 60 (66.7%)     | 37 (61.7%)      | 23 (38.3%)       | .349    |
| Female                    | 30 (33.3%)     | 22 (73.3%)      | 8 (26.7%)        |         |
| **Side of fracture**      |                |                 |                  |         |
| Right                     | 44 (48.9%)     | 27 (61.4%)      | 17 (38.6%)       | .507    |
| Left                      | 46 (51.1%)     | 32 (69.6%)      | 14 (30.4%)       |         |
| **Site of fracture**      |                |                 |                  |         |
| Proximal third            | 5 (5.6%)       | 3 (60.0%)       | 2 (40.0%)        |         |
| Mid shaft                 | 46 (51.1%)     | 35 (76.1%)      | 11 (23.9%)       | .096    |
| Distal third              | 39 (43.3%)     | 21 (53.8%)      | 18 (46.2%)       |         |
| **Diagnosis**             |                |                 |                  |         |
| Fibrous dysplasia         | 1 (1.1%)       | 1 (100.0%)      | 0 (0.0%)         |         |
| Comminuted closed         | 17 (18.9%)     | 7 (41.2%)       | 10 (58.8%)       |         |
| Oblique closed            | 16 (17.8%)     | 10 (62.5%)      | 6 (37.5%)        |         |
| Spiral closed             | 11 (12.2%)     | 7 (63.6%)       | 4 (36.4%)        |         |
| Transverse closed         | 17 (18.9%)     | 15 (88.2%)      | 2 (11.8%)        | .099    |
| Segmental closed          | 6 (6.7%)       | 3 (50.0%)       | 3 (50.0%)        |         |
| Open Gustilo 1            | 14 (15.6%)     | 11 (78.6%)      | 3 (21.4%)        |         |
| Open Gustilo 2            | 3 (3.3%)       | 1 (33.3%)       | 2 (66.7%)        |         |
| Open Gustilo 3a           | 1 (1.1%)       | 0 (0.0%)        | 1 (100.0%)       |         |
| Malunion                  | 1 (1.1%)       | 1 (100.0%)      | 0 (0.0%)         |         |
| Non-union                 | 3 (3.3%)       | 3 (100.0%)      | 0 (0.0%)         |         |
| **Comorbidities**         |                |                 |                  |         |
| DM                        | 16 (17.8%)     | 9 (56.3%)       | 7 (43.8%)        | .399    |
| Smoking                   | 23 (25.6%)     | 16 (69.6%)      | 7 (30.4%)        | .800    |
| HTN                       | 25 (27.8%)     | 17 (68.0%)      | 8 (32.0%)        | .810    |
| Osteoporosis              | 4 (4.4%)       | 2 (50.0%)       | 2 (50.0%)        | .606    |
in each visit the patient was screened for complications including: surgical site infection, non-union, mal-union, re-fracture and the need for reoperation due to any reason. Plain anterior posterior and lateral tibial radiographic views were obtained preoperatively, post-operatively and at approximately 6-week interval thereafter until fracture union. Malunion was defined as > 5 degree of angular deformity or shortening/translation of ≥ 5 mm. Nonunion was defined as lack of bone consolidation after 6 months. Data was entered and analyzed using IBM SPSS statistics version 23. There was no loss to follow up or missing data as we included only patients who agreed to the study and were followed up for a mean period of 15.3 months. Patients were grouped based on the type of fixation. The relation of various complications and type of fixation were assessed by Pearson chi-square test. Using T-test, we studied the difference in mean blood loss between the two groups. In addition, the odds ratio nail/plate was obtained for each complication. Results were considered significant at p<0.05.

4. RESULTS

A Total of 90 patients were involved in this study. 60 patients (66.7%) were males and 30 patients (33.3%) were females, with mean age of 36.9 years (ranging from 9 to 79 years). Patients were followed up for a mean of 15.3 months (range 11.4-37.2). The left leg was the most common fractured leg in our review in 46 patients (51.1%). Most fractures were in mid-shaft 46 (51.1%) where nails were the preferred method for fixation. 39% of fractures were in the distal third of the shaft where plating was used, almost equally as nails. Only minimally invasive percutaneous plate osteosynthesis was used. Patients’ demographic characteristic is summarized in Table 1.

Overall, nails were used in 59 cases (65.6%) and plates in 31 cases (34.4%). 9 patients (15.9%) of IMN group developed complications, while 3 patients (9.67%) of MIPPO group developed complications. The odd ratio (OR) for complication risk IMN/ minimally invasive plating was 1.576 CI (0.460 to 5.405). Of the total patient population, 7 patients (7.8%) had non-union; 6 of them were treated with IMN and only one patient with plate (p=0.415) and the OR was 3.153 with CI (0.397 to 25.030). Surgical site infection was reported in 5 patients (5.6%); 4 of them were in the IMN group and only in the MIPPO group (p=0.656) and the OR was 2.102 with CI (0.245 to 18.002). A total of 8 patients (8.9%) underwent

![Figure 1](image1.png)

**Figure 1.** a) AP and Lateral radiographs at presentation demonstrating right distal 1/3 tibia shaft oblique fracture; b) AP and Lateral radiographs immediately post-operative following MIPPO; c) AP and Lateral radiographs 9 months post-operative following MIPPO demonstrating fracture healing and alignment

![Figure 2](image2.png)

**Figure 2.** d) AP and Lateral radiographs at presentation demonstrating right tibia midshaft comminuted fracture with butterfly fragment; e) AP and Lateral radiographs immediately post-operative following IMN; f) AP and Lateral radiographs 18 months post-operative following IMN demonstrating complete fracture healing
reoperation, 7 patients were in the IMN group and only one patient in the MIPPO group; p = .255 and the OR was 3.678 with CI (0.474 to 28.561). The reoperation was to remove the device either because of infection or non-union. Perioperative blood loss average was 81.19 ml for IMN and 175 ml for MIPPO (P-value .000) as summarized in Table 2.

Of the 5 patients that suffered from surgical site infection (SSI), the first presented with tibial midshaft open fracture (Gustilo type I) underwent intramedullary nailing. He developed proximal interlocking screw site infection 2 months following the operation and underwent removal of proximal locking screw and debridement along with IV antibiotics. The second patient presented with a closed proximal 1/3 comminuted tibia shaft fracture and underwent intramedullary nailing complicated by SSI and microbiology cultures were positive for Acinetobacter baumannii and MRSA nine months postoperatively. She underwent serial debridements and developed acute lower limb ischemia after 2 months. Thereafter she underwent above knee amputation and died 1 year later from sepsis. The third patient who presented with a closed mid-shaft spiral fracture treated with intramedullary nailing developed osteomyelitis 1 year after. She underwent nail removal, external fixator application, debridement along with IV antibiotics for a period of 6 weeks and on follow-up, fracture showed complete healing 7 months later and external fixator was removed. The last patient in the IMN group presented with tibial midshaft open fracture (Gustilo type I). He developed superficial wound infection for which he was managed with IV antibiotics. Only one patient in the MIPPO group who presented with a distal 1/3 tibia shaft closed comminuted fracture suffered from surgical site infection 1.5 months following the surgery and was managed with IV antibiotics alone.

Regarding the non-union and reoperation rates, 6 patients in the IMN group underwent subsequent reoperation for non-union. First patient with non-union underwent IMN removal after 1 year and revision ORIF with compression plating which healed completely. Fracture healing was not evident in the second patient following 11 months, so she underwent exchange tibia nailing (larger diameter) and bone grafting with demineralized bone matrix (DBM) which was followed by nail dynamization 6 months after. On subsequent imaging, fracture showed complete healing 9 months following nail dynamization. Third patient developed non-union 7 months following IMN and underwent nail dynamization and complete healing was achieved on follow-up. Fourth patient developed non-union 8 months following IMN insertion. She underwent nail removal, revision ORIF with compression plating and autologous iliac crest grafting and fracture union was evident by 6 months on follow-up. The Fifth patient showed fracture healing arrest 6 months following the initial surgery, so he underwent nail dynamization and 12 months following dynamization fracture healing was evident. The last patient in the IMN group to develop non-union underwent fracture site refreshment with autologous iliac crest grafting and showed subsequent fracture healing. In the MIPPO group only one patient suffered from fracture non-union 7 months following plating. The surgeon decided to remove the metal, proceed with fracture site refreshment, compression plating and bone grafting with demineralized bone matrix (DBM).

Only one patient in the study population suffered from a refracture 8 months post intramedullary nailing of closed mid-shaft tibia fracture presented to the emergency department with leg pain and radiographs showed proximal tibia anterior cortex fracture which was managed conservatively.

5. DISCUSSION

Management of extra-articular tibial fractures is considered a dilemma for orthopedic surgeons, especially if surgical treatment is decided; as there are many accepted options for management such as external fixation, open reduction and plate, IMN and MIPPO. MIPPO and IMN are considered now the mainstay of management of tibial shaft fractures (8, 10-13, 32). This study compared the complications between these two methods in patients with extra-articular tibial fractures. In our study, although not statistically significant, MIPPO had fewer complications reported than IMN, 3 (9.67%) vs 9 (15.25%), respectively. From IMN group six patients (10.16%) developed non-union and underwent additional surgery to achieve healing and plating was used in two of them instead of IMN. On the other hand, only one patient treated with MIPPO had non-union. No patients required a second operation for mal-union, and the degree of the mal-union in our study was negligible. Literatures estimated the rates of delayed healing after plate insertion up to 20% in comparison with patients treated with IMN which estimated to occur in up to 42% of the patients. Therefore, MIPPO might be the best option to achieve healing without re-operation, but in many studies the difference was statistically insignificant, most likely due to the small sample size of each individual study (8, 10-29, 32-37). Vallier et al (8), Sug-
gested that regardless of the type of fixation, preservation of the blood supply and soft tissue surrounding the fracture by indirect reduction techniques help in fracture healing. In addition, many other factors affect fracture healing such as age, gender, comorbidities, type of fracture (5, 30, 31). Furthermore, the difference in non-union and delayed union comes from selection bias; as many surgeons prefer to use IMN in more severe cases than MIPPO. In addition, the medullary blood supply might be injured during nail insertion, resulting in delayed healing or non-union. Vallier et al. (8), reported high rates of non-union among patients with open fractures. However, in this study the rate of non-union was higher among patients with closed fracture.

In the present study, the infection rate was higher among patients treated with IMN. Most of the patients had superficial infection of the wound, and only two patients underwent device removal; one of them was treated by plating and the other was treated by nailing. None of the patients developed osteomyelitis or deep surgical complication from the infection. The finding in this study is concordant with published literatures (8, 15-20, 38, 39).

Some studies reported that fibular fractures affect healing and alignment of tibial fractures especially fractures of the distal tibia (38, 39). Two patients in our study had fibular fixation along with nail placement and developed non-union. Fibular fixation may be indicated when there is open fracture, syndesmosis injury and distal fibular fracture that compromise ankle function. Some studies reported a higher rate of non-union among patients with concurrent fibular fixation (8, 40, 41). However, in some cases, stabilization of the fibula may ease reduction and fixation of the tibia with appropriate alignment (40, 41). On other hands, some studies reported little malalignment of the tibia associated with nailing of distal tibial fractures with concurrent fibular fixation, with up to 42% of patients had additional procedures to achieve proper healing and alignment (8, 42). In our study only three patients had malalignment with less than 5 degrees, so it was clinically insignificant, while most of the published literatures reported higher malalignments when using IMN. Furthermore, pain was reported in most of patients with IMN and only in two patients with plates. One patient complained from palpable plate and screw in the medial shin, while in the literatures, more than half of patients experienced knee pain after IMN insertion (43, 44). In addition, MIPPO had a significantly higher mean of blood loss than IMN (175 ml vs. 81.19 ml) respectively. However, Wang et al (45) reported higher amount of hidden blood loss with nail than plates, and they suggested the use of plates in anemic patients or patients with multiple injuries.

Regarding the functional outcomes, Kumbaracı et al. (46) reported that MIPPO had poorer functional outcomes and more soft tissue problems, while IMN had more angular deformity and union time. However, a recent meta-analysis suggested that IMN had significantly lower risk of wound complications, but it associated with limited time for re-union. However, when they divided the patients according to the type of fractures there was no statistically significant difference between IMN and MIPPO. They suggested that IMN to be the preferred technique over MIPPO for managing distal tibial fractures (29).

The limitations of our study: Firstly, it is a retrospective observational study. In addition, a larger number of included cases are needed and lastly, similar techniques and implants had been used by different orthopaedic surgeons.

6. CONCLUSION
Both IMN and MIPPO are considered a safe option for managing extra-articular tibial injury. However, MIPPO had a less complication rate than IMN, especially in non-union rates. But, because of the small sample size we could not give a clear recommendation regarding the use of both modalities. Therefore, Randomized, prospective evaluation of distal tibia fractures with a larger sample size, may clarify the efficacy of plate versus nail treatment and optimize patient care.

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