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RESULTS OF PROXIMAL TIBIA FRACTURE MANAGED WITH MINIMALLY INVASIVE PERCUTANEOUS PLATE OSTEOSYNTHESIS

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ABSTRACT

Background: Proximal tibial fractures are complex injuries that may involve the articular surface and surrounding soft tissues. Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) aims to provide stable fixation while minimizing soft-tissue disruption and preserving the biological environment required for fracture healing. The present study evaluated the clinical, functional, and radiological outcomes of proximal tibial fractures managed using the MIPPO technique.
Methods: This prospective study included 40 patients with proximal tibial fractures treated with MIPPO at Zydus Medical College and Hospital, Dahod, during the study period. Patients aged 20–70 years with closed proximal tibial fractures and selected Grade I open fractures were included. Patients with pathological fractures, Grade II and III open fractures, neurovascular injuries, or age outside the specified range were excluded. Preoperative evaluation included radiographs and CT scans, and fractures were classified according to the Schatzker classification. Clinical and functional outcomes, duration of hospital stay, fracture union time, knee range of motion, extension lag, and postoperative complications were assessed.
Results: The study included 27 males (67.5%) and 13 females (32.5%), with a mean age of 43.7 ± 13.2 years. Road traffic accidents were the most common mechanism of injury, accounting for 62.5% of cases. The mean hospital stay was 6.9 ± 2.7 days, with 67.5% of patients hospitalized for 6–10 days. The mean fracture union time was approximately 3.5 months, with 65% of patients achieving radiological union within 3–3.5 months. Postoperative knee range of motion ranged from 100° to 125°, with most patients achieving 105°–115°. Full knee extension without lag was achieved in 92.5% of patients. Postoperative complications were minimal, with stiffness and superficial infection reported in 10% of patients each, while 80% had no complications.
Conclusion: MIPPO provides a minimally invasive and effective approach for the management of proximal tibial fractures, offering stable fixation, satisfactory fracture healing, good knee mobility, and a low rate of postoperative complications. The findings support MIPPO as a useful technique for achieving favorable clinical and functional outcomes while minimizing soft-tissue disruption.

Keywords*: Proximal tibial fracture; Tibial plateau fracture; Minimally invasive percutaneous plate osteosynthesis; MIPPO; Knee function.*

INTRODUCTION

Fractures involving the proximal tibia represent complex injuries that often disrupt the knee's articular surface and are frequently accompanied by significant soft-tissue trauma. Such fractures is about 1–2% of all adult fractures and occur most commonly due to high-energy trauma such as road traffic accidents in young adults and low-energy falls in elderly osteoporotic patients. The proximal tibia plays a essential role in load transmission across the knee, and improper management can result in malalignment, instability, joint stiffness, and post-traumatic osteoarthritis(1).
The main objectives in managing proximal tibial fractures are anatomical reduction of the articular surface, restoration of

alignment, stable fixation, and early mobilization. Conventional open reduction and internal fixation (ORIF) using standard plates achieves rigid fixation but often at the cost of extensive soft tissue dissection and periosteal stripping, leading to infection, delayed union, or wound complications.(1,2)

Most studies report satisfactory union rates, good range of motion, and minimal complications compared with conventional plating methods..(36)

Given the increasing popularity of minimally invasive methods, there is a need to evaluate and document clinical outcomes in diverse populations. This study aims to assess the radiological and functional results of proximal tibial fractures managed with MIPPO, analyze union time,complications, and overall knee function, and compare them with results from previous studies[36].

AIMS AND OBJECTIVES

AIMS:

- To evaluate the advantage of minimally invasive percutaneous plating techniques
- To evaluate the functional and radiological, clinical outcome after minimally invasive percutaneous plate fixation

OBJECTIVES:

- To assess clinical and radiological outcome
- To assess time period for union
- To evaluate post operative complication

The Hohl and Moore classification (1970) is an early and clinically relevant system for describing tibial plateau fractures, particularly those resulting from high-energy trauma. It emphasizes the mechanism of injury, fracture pattern, and degree of displacement, while also incorporating associated soft tissue damage. This system was among the first to recognize the complexity and variability of bicondylar and metaphyseal injuries, and remains useful for understanding post-traumatic instability and treatment planning.

Unlike the simpler Schatzker classification, which primarily focuses on lateral and medial condyle involvement, the Hohl and Moore system includes patterns that involve fracture– dislocation mechanisms and posterior shear injuries. It divides tibial plateau fractures into five types, based on the direction of force, condylar involvement, and joint displacement.

Type I – Coronal Split Fracture

- It is characterized by a coronal plane fracture of one tibial condyle, usually the lateral condyle, without significant depression of the articular surface.
- The fragment is displaced posteriorly or anteromedially due to shear forces.
- The opposite condyle and metaphysis are generally intact.

Mechanism:

Shear force applied in the coronal plane, often during a rotational injury or dashboard-type trauma.

Clinical Significance:

- It represents a low-velocity shear fracture and requires anatomical reduction to restore the joint surface and posterior stability.

Type II – Entire Condyle Fracture (Condyle with Plateau)

- It involves fracture and displacement of an entire condyle, either medial or lateral, including both the articular surface and subchondral metaphyseal bone.
- The condyle remains intact as a single large fragment but is separated from the rest of the tibia.

Mechanism:

Combination of axial compression and valgus (for lateral) or varus (for medial) stress. Clinical Significance:

- It commonly associated with ligamentous disruption (especially the MCL or LCL, depending on the side) may lead to joint instability and articular incongruity if not anatomically reduced and requires open reduction and internal fixation to restore articular congruence and alignment.

Type III – Rim Avulsion Fracture (Peripheral Depression or Avulsion)

- It involves avulsion of a small rim fragment at the peripheral margin of the tibial plateau, usually at the anterior or posterior aspect.
- It may be associated with ligamentous or capsular avulsion, especially the posterolateral corner, posteromedial rim, or anterior cruciate insertion.

Mechanism:

Indirect force from rotational stress or hyperextension, leading to capsuloligamentous avulsion at the articular margin.

Clinical Significance:

- Small in size but biomechanically significant, as these fractures indicate ligamentous detachment and potential instability and often require fixation or repair of associated ligamentous structures to restore stability.

Type IV – Rim Compression (Central Depression) Fracture

- It involves impaction and central depression of the tibial plateau without major condylar split.
- The articular cartilage and subchondral bone are depressed due to axial loading, often in osteopenic bone.

Mechanism:

Axial compression along the mechanical axis of the limb — typically from a fall from height or direct blow on an extended knee.
Clinical Significance:

- Articular surface is depressed but not displaced peripherally and requires elevation of depressed fragments and bone grafting to restore joint congruity.
- It may be associated with meniscal injury due to impaction forces.

Type V – Bicondylar Fracture (Fracture–Dislocation Type)

- It represents the most severe form, involving both condyles and often displacement or subluxation of the tibial plateau relative to the femur.
- There is complete articular disruption with metaphyseal comminution.
- The diaphysis may be separated from the condylar block.

Mechanism:
High-energy axial loading, rotational, or shearing forces, often seen in motor vehicle accidents. Clinical Significance:

- It is associated with massive soft tissue injury, neurovascular compromise, and ligamentous disruption.
- High risk of compartment syndrome and post-traumatic arthritis.
- Management often requires staged surgical fixation:
- Initial external fixation for soft tissue protection, followed by
- Definitive open reduction and internal fixation (ORIF) once swelling subsides[1].

(a) Schatzker Classification
Type I – Lateral Condyle Split Fracture
A pure split fracture involving the lateral tibial condyle, resulting in a vertical fracture line extending through the articular surface into the metaphysis without depression. The medial condyle and diaphysis remain intact.
Mechanism of Injury: It caused by a low-energy valgus force directed to the lateral aspect of the knee in young patients with good bone quality. The lateral femoral condyle acts as a wedge, splitting the lateral tibial plateau.
Radiological Features:

- A linear vertical fracture line on AP view.
- No depression or comminution.

Clinical Correlation:

- Common in younger individuals (due to dense cancellous bone).
- Associated with lateral meniscal injuries.

Management:

- Non-displaced: conservative treatment with immobilization.
- Displaced: open reduction and internal fixation (ORIF) using cancellous screws or buttress plate to restore joint congruency.

Type II – Lateral Condyle Split-Depression Fracture
This type features a combination of a vertical split of the lateral condyle with articular surface depression of the fragment. Both cleavage and compression components coexist.
cMechanism of Injury: It results from a combined valgus and axial compressive force applied to the knee, more common in older patients with osteopenic bone.
Radiological Features:

- A split line with central or posterolateral depression visible on CT scan.
- Lateral condyle involvement is evident with loss of articular height.

Clinical Correlation:

- May be associated with lateral meniscus entrapment in the fracture gap.
- Ligamentous injuries are less common but should be ruled out.

Management:

- Requires elevation of depressed fragment, bone grafting, and buttress plating to maintain anatomical restoration.

Type III – Pure Lateral Condyle Depression Fracture
This is a pure depression fracture without cortical split. The articular surface of the lateral tibial plateau is impacted downward into the underlying cancellous bone.
Mechanism of Injury: It caused by axial loading of the lateral femoral condyle on the tibial plateau with the knee in slight flexion. Frequently occurs in elderly osteoporotic patients due to weak subchondral bone.
Radiological Features:

- No split or displacement of lateral cortex.
- Depression of articular surface is clearly seen on lateral and CT views.

Clinical Correlation:

- Usually a low-energy compression injury.
- Minimal risk of ligament damage but significant joint incongruity if untreated.

Management:

- Elevation of depressed fragments, bone grafting, and subchondral screw fixation are often required.

- May be treated conservatively if depression is <5 mm and alignment is preserved.

Type IV – Medial Condyle Fracture

Fracture involving the medial tibial condyle, which may be split, depressed, or both. Often associated with significant displacement and instability.

Mechanism of Injury: It results from a varus force applied to the knee.

The medial femoral condyle imparts compressive and shearing stress on the medial tibial plateau. Usually, a high-energy injury and may be accompanied by neurovascular compromise due to proximity of the popliteal structures.

Radiological Features:

- Vertical or oblique fracture line on the medial side.
- Medial condylar depression or posteromedial fragment displacement.

Clinical Correlation:

- Frequently associated with posteromedial fragment rotation, PCL injury, or popliteal vessel stretch.
- Occurs more in young adults exposed to high-velocity trauma.

Management:

- Requires ORIF via a posteromedial approach.
- Dual plating may be necessary for stability.
- Early recognition of vascular injury is critical.

Type V – Bicondylar Fracture

Involvement of both medial and lateral condyles with a vertical split through the intercondylar eminence. The articular surface remains connected to the shaft, but both condyles are fractured.

Mechanism of Injury: It is caused by axial compression with the knee in extension, driving the femoral condyles into the tibial plateau. Commonly seen in high-energy falls or road traffic accidents.

Radiological Features:

- Displacement of both condyles with widening of the tibial plateau.
- Depression often present in one or both condyles.

Clinical Correlation:

- Often accompanied by meniscal tears, cruciate ligament injury, and significant soft tissue damage.
- High risk of compartment syndrome.

Management:

- ORIF using dual plates (medial and lateral) to restore alignment.
- Bone grafting for depressed segments.
- External fixator may be used temporarily for soft tissue protection before definitive fixation.

Type VI – Bicondylar Fracture with Metaphyseal–Diaphyseal Dissociation

This is the most severe form, involving complete dissociation of the metaphysis and diaphysis. Both condyles are fractured and detached from the shaft, often with comminution and depression.

Mechanism of Injury: It results from high-energy trauma, such as motor vehicle accidents or falls from height. The axial load transmitted through the femur causes crushing and splitting of both condyles.

- Radiological Features:
  - Complete metaphyseal separation from diaphysis.
  - Articular depression and comminution frequently present.
  - Associated soft tissue injury is extensive.
- Clinical Correlation:
  - Severe soft tissue compromise, compartment syndrome, and neurovascular injury are common.
  - Associated with ligamentous avulsions and meniscal tears.
- Management:
  - Staged approach: Temporary external fixation to allow soft tissue recovery, followed by definitive internal fixation with plates and bone graft.
  - Early soft tissue evaluation and vascular assessment are mandatory[30].

Figure-10: CT scan based three column classification

The three-column classification divides fractures based on column involvement:

Type	Column Involvement	Fracture Pattern / Notes
Single- column fracture	Lateral OR Medial OR Posterior	Isolated fracture of one column; typically low- energy; may be treated with single-column fixation.
Two- column fracture	Any combination of Lateral + Medial / Lateral + Posterior /Medial + Posterior	Requires fixation of both involved columns; approach selection is critical.

Three- column fracture	Lateral + Medial + Posterior	Complex bicondylar fracture with posterior involvement; usually high-energy; staged or dual approaches may be needed.

Surgical Technique

1. Preoperative Planning

- Detailed radiographs and CT scans are essential to understand fracture morphology.
- Pre-contoured anatomical locking plates (lateral or medial) are selected based on fracture pattern.
- The patient is positioned supine on a radiolucent table with the knee flexed to relax soft tissues.

2. Reduction

- Achieved through manual traction, ligamentotaxis, or joystick technique using percutaneous Schanz pins.
- Articular surface reduction, if required, may be achieved via small limited incisions and bone elevators under fluoroscopic control.

3. Plate Insertion

- A small proximal incision is made near the joint line.
- A submuscular or subperiosteal tunnel is created using a periosteal elevator or tunneler.
- The plate is slid along the bone surface across the fracture site, ensuring minimal periosteal stripping.

4. Fixation

- Proximal fixation: Locking screws are inserted under fluoroscopy to secure the plate to the metaphysis or condyles.
- Distal fixation: Screws are placed percutaneously through small stab incisions using a drill guide.
- Fluoroscopic verification ensures proper reduction, screw length, and alignment in both planes.

5. Closure

- Incisions are closed in layers; drains are rarely needed due to minimal dissection[33-35].

MATERIALS AND METHODS

A prospective study of evaluation of results of 40 patients who sustained tibial plateau fracture and were treated by Minimally invasive percutaneous plate osteosynthesis (MIPPO) at Zydus Medical College and Hospital, Dahod during the period of October 2023 to September 2025.

METHOD OF COLLECTION OF DATA

- By interview
- By clinical examination
- By analyzing case papers

The data included patients who were willing to be a part of the study, after giving the informed and written consent, were taken into account in this study

INCLUSION CRITERIA:

- Age between 20-70 years
- Proximal tibia fractures (closed fractures)
- Gustillo-Anderson classification [Open grade I fracture]
- No medical contraindications to general anaesthesia

EXCLUSION CRITERIA:

- Age < 20 and > 70 years.
- Open grade II & III (Gustillo-Anderson classification) fractures.
- Pathological fracture
- Associated with neuro-vascular injury

PRE-OPERATIVE PREPARATION AND ASSESSMENT:

Emergency treatment:

- As per the institutional protocol all the patients were managed by the ATLS guidelines where Airway, Breathing, Circulation was secured and patients were hemodynamically stabilized. Injuries to the head, chest or abdomen were ruled out and treated accordingly.
- After stabilizing the patient, Ultrasonography (FAST) focused assessment with sonography in trauma was done in patients with high velocity trauma. Standard Antero-posterior and lateral radiograph were done. CT-Scan of the affected knee with upper end tibia was done for better understanding of the fracture pattern. Fractures were then classified as per Schatzker classification.
- Skeletal traction and/or above knee slab was applied and limb was elevated on a Bohler Braun splint.
- In patients with excessive edema of limb surgery was postponed till edema subsided. In such patients we used Steinmann pin traction or external fixator till edema subsided.
- In all the other fractures, after all routine investigation and getting anesthetic clearance, the patient was electively posted for surgery.
- Antibiotics, Analgesics were given to all patients.
- Injection tetanus was given as and when required.

DEFINITIVE MANAGEMENT AND SURGICAL TECHNIQUE:
Anesthesia: Spinal/epidural/general anesthesia was given.
IMPLANTS USED:

1. LATERAL PLATES:
   1. Periarticular Upper End Tibia Plate-Hockey plate
   2. Lateral anatomical Plates (Proximal tibia Raft locking plates)
2. MEDIAL PLATES:
   1. Medial anatomical plate
   2. L & T BUTTRESS PLATE

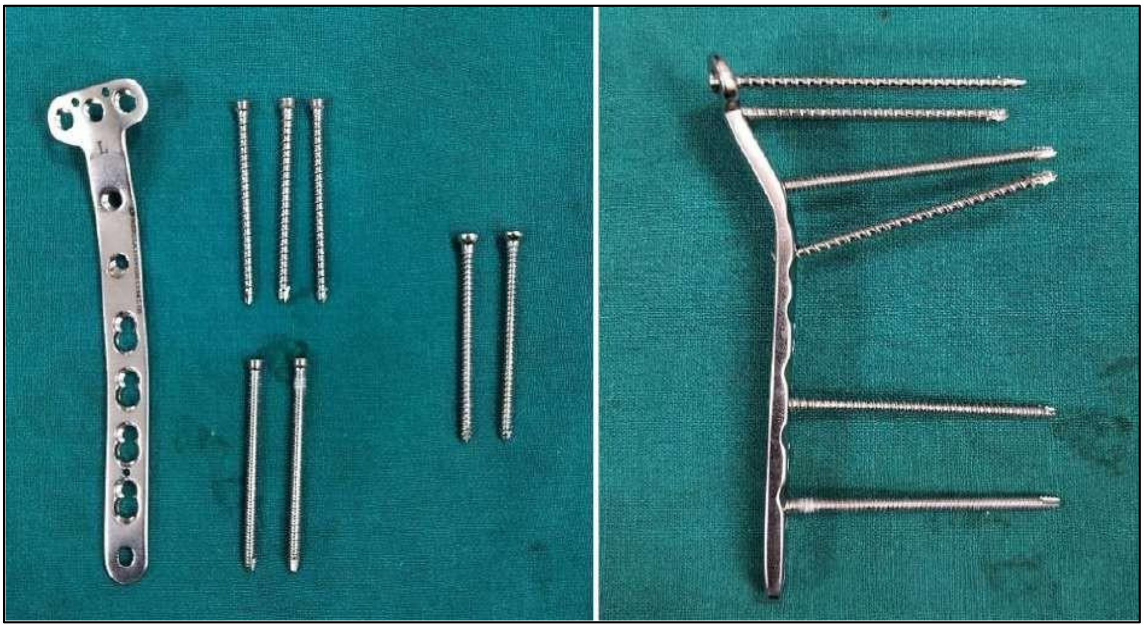

Figure-13: Medial anatomical plate with screws

3. SCREWS:
   1. Cannulated cancellous screw (4.0 mm and 6.5 mm)
   2. Locking cancellous screw
   3. Cortical screw
   4. Simple locking screw

Figure-14: 4mm and 6.5mm cannulated cancellous screws

Figure-15: Proximal tibia implant set

4. GENERAL INSTRUMENTS USED:

1. K wire
2. St pin
3. T handle
4. Plier
5. Bone punch
6. Mallet
7. Osteotome
8. Periosteal elevator
9. Lamina spreader
10. AO clamp
11. Condylar clamp
12. Cobb elevator

Position: The patient was placed supine on a radiolucent table with firm wedge beneath the knee to flex the joint or supine on fracture table as per surgeons' choice.

Approaches for proximal tibia:

Various approaches were used for the proximal dissection depending on the fracture pattern. For the periarticular region laterally a direct antero-lateral approach or sub meniscal approach was used and medially the direct medial approach used. For distal diaphysis stab incisions were used for percutaneous screw insertion under IITV guidance.

1. The anterolateral approach:

Incision: Proximally the incision was made just proximal and lateral to Gerdy's tubercle and extended distally in a curvilinear fashion for approximately 5 cm to 6 cm.

2. Medial Approach:
For additional medial plate, the medial approach was used.
Incisions: A 6-cm longitudinal incision is made overlying the proximal tibia. The exact length of the incision will depend on the the implant to be used
Internervous plane: There is no internervous plane in this approach. Subcutaneous fat and tissue cut in line with skin incision. Subcutaneous fat and tissue cut in line with skin incision. Subcutaneous tunnel was created and appropriate size plate was slide through it.
Distally the plate was fixed to the tibia shaft with screws but thorough stab incision.

3. Sub meniscal approach: This approach was used to reduce the depressed intra-articular fracture fragments and to free the entrapped meniscus between fracture fragments.
For fractures of the lateral condyle:
We use a slightly curvilinear anterolateral incision, starting 3 to 5 cm above the joint line proximally and extending distally below the inferior margin of the fracture site from just anterior to the lateral femoral epicondyle to Gerdy's tubercle.
Proximally the deep fascia was incised in the line of the skin incision. The iliotibial band was reflected from its insertion on Gerdy's tubercle both anteriorly and posteriorly. The intra- articular exposure was achieved- by incising the coronary / infra-meniscotibial ligament by sub meniscal arthrotomy and retracting the meniscus superiorly after placement of nonabsorbable meniscocapsular tagging sutures.

RESULTS

This study was conducted with enrolment of 40 patients with the aim to evaluate the advantage of minimally invasive percutaneous plating techniques in patient population. To evaluate the functional and radiological, clinical outcome after minimally invasive percutaneous plate fixation, to assess time period for union. Knee Society Score was calculated for evaluation.

1. Age-wise distribution of study population:

Table-1: Age-wise distribution (n=40).

Age (in years)	Number of patients (n=40) (%)
21-30	7 (17.5%)
31-40	11 (27.5%)
41-50	9 (22.5%)
51-60	9 (22.5%)
61-70	4 (10%)
>70	0
Mean ± SD	43.7 ± 13.2

The age of the study participants with a mean age of 43.7 ± 13.2 years. The majority of patients were between to the 31–40 years age group (27.5%), followed by 41–50 years and 51–60 years age groups (each 22.5%). A smaller number of patients were resulted in the 21–30 years age group (7 patients; 17.5%), while only 4 patients (10%) were aged between 61–70 years. Notably, no participants were above 70 years of age.

2. Gender-wise distribution of study population:

Table-2: Gender-wise distribution (n=40).

Gender	Number of patients (n=40) (%)
Male	27 (67.5%)
Female	13 (32.5%)

In the present study, out of a total of 40 patients, 27 (67.5%) were males and 13 (32.5%) were females, resulted in male-to-female ratio of approximately 2.1:1. This indicates a male predominance among the study population.

3. Mode of injury-wise distribution of study population:
Table-3: Mode of injury-wise distribution (n=40).

Mode of injury	Number of patients (n=40) (%)
Domestic fall	5 (12.5%)
Fall from height	10 (25.0%)
RTA	25 (62.5%)

In the present study of 40 patients, road traffic accidents (RTAs) were the most common mode of injury, resulted for 25 (62.5%) of the total cases. Falls from height were observed in 10 (25.0%) patients, while domestic falls contributed to 5 (12.5%) cases. This distribution concludes that high-energy trauma, particularly from RTAs, constituted the predominant mechanism of injury in the study population.

4. Hospital stay-wise distribution of study population:

Table-4: Hospital stay-wise distribution (n=40).

Hospital stays (in days)	Number of patients (n=40) (%)
1-5	11 (27.5%)
6-10	27 (67.5%)
11-15	2 (5%)
Mean ± SD	6.9 ± 2.7

The duration of hospital stays among patients ranged from 1 to 15 days, with a mean stay of 6.9 ± 2.7 days. The majority of patients (27; 67.5%) remained hospitalized for 6–10 days, while 11 (27.5%) had a shorter stay of 1–5 days. Only 2 (5%) patients required a longer hospital stay of 11–15 days. Most patients experienced a moderate duration of hospitalization, due to typical postoperative recovery period and the time required for adequate rehabilitation and wound care

DISCUSSION

The present prospective observational study was conducted at Zydus Medical Hospital, Dahod, a 1034-bedded tertiary care hospital with a high patient inflow. 40 patients with proximal tibial fractures managed using minimally invasive percutaneous plate osteosynthesis (MIPPO) were studied between October 2023 and January 2026. The study aimed to evaluate clinical and functional outcomes, fracture union rates, and complications, providing evidence for the efficacy and safety of MIPPO in achieving stable fixation with minimal soft tissue damage.

Socio-demographical characteristics

In the present study, the mean age of patients was 43.7 ± 13.2 years, comprising 27 males (67.5%) and 13 females (32.5%). These findings are comparable to those of Gajanan Chintawar et al.(36), who reported a mean age of 42.3 ± 14.3 years with 90.6% male predominance, and Kranthi Kiran et al.(37), where most cases occurred between 40–60 years of age. Similarly, Kim et al.(38) (2012) documented a mean age of 44.4 years (range 24–69 years) among 24 men and 6 women, while Sahu and Pandey(39) (2020) observed 38 patients aged 20–75 years, with the most affected group being 20–50 years. Collectively, these findings indicate that the active middle-aged population is most commonly affected, reflecting their higher exposure to road traffic accidents and occupational hazards. Thus, the demographic pattern consistently demonstrates that proximal tibial fractures predominantly occur in the productive age group, showing a uniform trend across multiple studies.

Hospital stays

In the present study, the mean hospital stay was 6.9 ± 2.7 days, with most patients (67.5%) discharged within 6–10 days, indicating early postoperative recovery and minimal complications. This finding contrasts with Ambulgekar et al.(41) (2016), who reported a mean hospital stay of 14.8 ± 2.67 days, with 68% discharged within 15 days and a longer duration in cases with associated injuries or delayed surgery. The shorter stay in the current study likely reflects improved perioperative care, minimally invasive technique efficiency, and early mobilization protocols associated with modern MIPPO fixation.

Laterality wise distribution

In the present study, injuries were slightly more common on the right side (62%) compared to the left (38%). Similar findings were observed in previous studies — Sivakumar Arumugam et al.(40) (2017) also noted a marginal right-side dominance. This consistent pattern across studies suggests that right-sided fractures are marginally more frequent, possibly due to higher prevalence of right-leg dominance during vehicular impacts.

Time between injury and definitive surgery (in days)-wise distribution

In the present study, 47.5% of patients underwent surgery within 1–3 days, and 42.5% within 4–6 days, showing prompt surgical intervention once soft tissue conditions stabilized. This finding aligns with Sivakumar Arumugam et al.(40) (2017), where 55% were operated within a week and 22% within 1–2 weeks, and with Chintawar et al.(36) (2016), who reported most cases operated between 3–7 days post-injury. Kranthi Kiran et al.(37) (2023) also performed surgery within 3–5 days in the majority. The early fixation trend across studies demonstrates the advantages of MIPPO—minimized soft tissue damage, early mobilization, and reduced infection rates.

Complication-wise distribution

In the present study, postoperative complications were minimal—stiffness in 10% and superficial infection in 10% of cases, while 80% had no complications. These results are comparable to Sivakumar Arumugam et al.(40) (2017), who reported knee stiffness in 27.7% and infection in 5.5%, and Santosh Kumar Sahu et al.[39] (2020), who observed stiffness in 2.6% and infection in 5%. Similarly, Kranthi Kiran et al.[37] (2023) noted infection in 6.6% and stiffness in 13.3%. The lower complication rate in the current study highlights the benefits of the MIPPO technique, including minimal soft-tissue disruption and early mobilization.

Implants used-wise distribution

In the present study, Hockey plates were the most frequently used implants (52.5%), followed by RAFT plates (37.5%) and locking compression plates (10%). This trend reflects a preference for stable fixation with minimal soft-tissue disturbance. Similarly, Sahu et al.[39] (2020) primarily used locking compression and buttress plates, while Kranthi Kiran et al.[37] (2023) and Sivakumar Arumugam et al.[40] (2017) reported predominant use of T- and L-buttress locking plates for both unicondylar and bicondylar fractures. These findings collectively indicate that buttress and locking constructs provide superior stability and alignment maintenance in high-energy tibial plateau fractures treated with the MIPPO technique.

Union time (in months)

In the present study, the mean union time was around 3.5 months, with most patients (65%) achieving radiological union within 3–3.5 months, reflecting efficient bone healing following the MIPPO technique. These results are comparable to Sivakumar Arumugam et al.[40] (2017), who reported an average union time of 16.7 weeks (≈4 months),.

knee range of motion (ROM)

In the present study, postoperative knee range of motion (ROM) varied from 100° to 125°, with the majority achieving 105°–115°, indicating good joint mobility and functional recovery. These findings are comparable to Sivakumar Arumugam et al.[40] (2017), who reported a mean ROM of 120°, This consistent trend across studies supports that the MIPPO technique, with early mobilization and minimal soft-tissue handling, effectively restores knee function after tibial plateau fractures.

Extension LAG (degree)

In the present study, 92.5% of patients achieved full extension (0° lag), while only 7.5% exhibited a minimal 5° extension lag, reflecting excellent postoperative knee function. These results closely align with Sivakumar Arumugam et al.[40] (2017), who reported full extension in 88.9% of cases, and Ramsagar Pandit et al.[42] (2021), where 82% regained complete extension. The near-complete restoration of extension across studies underscores the efficacy of MIPPO in preserving knee mechanics through stable fixation and early physiotherapy.

CONCLUSION

The present study highlights that Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) is a highly effective and reliable technique for the management of proximal tibial fractures. It provides stable fixation while preserving the biological environment essential for bone healing.

Most patients in this study achieved early radiological union, excellent knee mobility, and good to excellent functional outcomes according to the Knee Society Score (KSS). The incidence of complications such as infection and stiffness was minimal and manageable with conservative measures.

By minimizing soft tissue damage and promoting early mobilization, the MIPPO technique ensures faster recovery and better functional restoration compared to traditional open methods.

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