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Original Research Article

Radiological Assessment of Restoration of Articular Alignment and Its Correlation with Functional Outcome After Internal Fixation of Intra-Articular Proximal Tibial Fractures

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Conflict of interest: Nil

Abstract:

Background: Intra-articular proximal tibial fractures are challenging injuries that affect knee function and stability.

Aim: To assess radiological restoration of articular alignment and its correlation with functional outcome after open reduction and internal fixation (ORIF) of intra-articular proximal tibial fractures.

Materials and Methods: This prospective observational study included 36 patients with intra-articular proximal tibial fractures treated with ORIF with plating at Government R.D.B.P Jaipuria Hospital, RUHS College of Medical Sciences, Jaipur, from May 2018 to May 2019, with minimum 6-month follow-up. Fractures were classified using Schatzker's classification. Functional outcomes were assessed using Modified Rasmussen Criteria for Clinical Assessment (MRCA) and radiological outcomes using Modified Rasmussen Criteria for Radiological Assessment (MRRA).

Results: The mean age was 40.02 ± 13.58 years with male predominance (88.88%). Road traffic accidents were the most common mechanism (86.11%). Schatzker Type II and V were most frequent (27.77% each). The mean ROM was 122.36° ± 9.14 and mean fracture union time was 13.86 ± 1.82 weeks. On MRCA, 33.33% had excellent and 36.11% had good outcomes. On MRRA, 36.11% had excellent and 50% had good outcomes. Articular depression showed significant positive correlation with MRCA (R=0.501, p=0.00185). Tibial angulation (R=0.371, p=0.026) and osteoarthrosis (R=0.321, p=0.046) also showed significant correlations. MRRA and MRCA showed significant positive correlation (R=0.480, p=0.003). Complications occurred in 30.55%.

Conclusion: ORIF is a rational treatment option for proximal tibial fractures. Anatomical articular reduction and restoration of tibial alignment are significant predictors of better functional outcomes. Radiological parameters significantly correlate with clinical outcomes.

Keywords: Proximal tibial fracture; Tibial plateau; ORIF; Modified Rasmussen criteria; Articular depression; Condylar widening; Schatzker classification; Functional outcome.

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Introduction

Proximal tibial fractures account for approximately 1% of all fractures in adults and represent a significant clinical challenge due to their intra-articular nature, associated soft tissue injury, and potential for long-term functional impairment. [1–3] These fractures commonly result from high-energy injuries such as road traffic accidents and falls, with associated complications including vessel injuries, compartment syndrome, cartilage destruction, and open fractures. [4,5]

Proper management is crucial as these fractures directly affect knee function and stability. [6] The goals of surgical treatment include anatomical reduction of the articular surface, restoration of the limb mechanical axis, stable internal fixation, and early mobilisation.[7] Open reduction and internal fixation with modern locking plate systems has

become the mainstay of treatment, providing stable fixation that allows early range of motion exercises. [2,8,9] Lachiewicz and Funcik emphasised that anatomic reduction, stable fixation, minimal soft tissue handling, and early joint movement are prerequisites for good clinical results. [10] Tscherne and Lobenhoffer similarly highlighted the importance of achieving these goals to optimise outcomes. [11]

However, the literature remains divided regarding the relationship between postoperative radiological parameters and functional outcomes. Some studies suggest that residual articular incongruity does not compromise long-term outcomes, [12] while others have demonstrated significant correlations between anatomical reduction and functional recovery. [13,14] This study was conducted to assess the correlation between radiological restoration of articular alignment—including articular depression, condylar widening, tibial alignment, and osteoarthrosis—and functional outcomes after ORIF of intra-articular proximal tibial fractures in an Indian population where good knee range of motion is essential for daily activities such as squatting, bending, and sitting cross-legged.

Aim and Objectives

Aim: Radiological assessment of restoration of articular alignment and its correlation with functional outcome after internal fixation of intra-articular proximal tibial fractures.

Objectives:

1. To study the union time in tibial plateau fractures after internal fixation.
2. To study radiological outcomes (articular depression, condylar widening, tibial alignment, osteoarthrosis) after internal fixation.
3. To study the functional outcomes using Modified Rasmussen Clinical Assessment criteria.
4. To assess complications during management.

Materials and Methods

Study Design and Setting: This prospective observational study was conducted at the Department of Orthopedics, Government R.D.B.P Jaipuria Hospital, attached to RUHS College of Medical Sciences, Jaipur, Rajasthan, from May 2018 to May 2019. The study was conducted after obtaining necessary institutional permissions. Written informed consent was obtained from all participants prior to enrolment. All procedures performed were in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki Declaration and its later amendments.

Study Population: Thirty-six patients with intra-articular proximal tibial fractures who underwent ORIF with plating were included. The sample size was calculated based on Elabjer et al., [15] who reported excellent Rasmussen Clinical score in 82.8% of patients operated with ORIF. With a precision of 0.15 at 95% confidence level, the minimum required sample size was 24 patients.

Inclusion Criteria: Patients aged >18 years, both genders, closed fractures and Gustilo-Anderson Grade 1 open fractures.

Exclusion Criteria: Skeletally immature patients, neurovascular injuries or compartment syndrome, concomitant lower limb fractures, Grade 2/3 open fractures, bilateral proximal tibial fractures, and pathological fractures other than osteoporosis.

Surgical Technique: All patients underwent ORIF under anaesthesia using image intensifier guidance. Anterolateral approach centred over Gerdy's tubercle was used for lateral condylar fractures. Additional medial or posteromedial approach was employed for bicondylar fractures. Implants included proximal lateral tibial locking plates, T-buttress plates, and L-buttress plates. Impacted articular fragments were elevated using a bone impactor through the fracture or a cortical window, and the defect was filled with autologous cancellous bone graft from the ipsilateral iliac crest where indicated.

Postoperative Protocol: Above-knee slab for minimum 2 weeks. Static quadriceps exercises started on day 3–4. Suture and slab removal at 2 weeks. Passive and active ROM exercises initiated at 2 weeks under physiotherapist guidance. Partial weight-bearing at 6 weeks and full weight-bearing at 12 weeks based on radiological evidence of union.

Follow-up and Outcome Assessment: Periodic radiographs (AP and lateral views) were obtained at 6, 12, 16, and 24 weeks. Functional outcomes were assessed at 6 months using Modified Rasmussen Criteria for Clinical Assessment (MRCA) evaluating pain, walking capacity, extension, ROM, and stability (scored 0–30; Excellent 28–30, Good 24–27, Fair 20–23, Poor <20). Radiological outcomes were assessed using Modified Rasmussen Criteria for Radiological Assessment (MRRA) evaluating articular depression, condylar widening, angulation, and osteoarthrosis (scored 0–10; Excellent 9–10, Good 7–8, Fair 5–6, Poor <5). Articular depression was measured on postoperative radiographs; tibial alignment was assessed using the method of Freedman and Johnson;[16] condylar widening was calculated according to Thamyongkit et al.;[17] and osteoarthrosis was graded using Resnick and Niwayama criteria.[18]

Statistical Analysis: Data were analysed using SPSS version 20.0. Continuous variables were compared using Student's unpaired t-test and categorical variables using Chi-square test.

Correlation was calculated using Spearman's Rho (R ranges from –1.0 to +1.0). A p-value ≤0.05 was considered statistically significant.

Results

A total of 36 patients were included. The demographic and clinical profile is summarised in Table 1.

Table 1: Demographic and Clinical Characteristics (n=36)

Characteristic	Number (n)	Percentage (%)
Age Group (Years)		
18–30	11	30.55
31–40	9	25.00
41–50	8	22.22
51–60	5	13.88
61–70	2	5.55
71+	1	2.77
Gender (M : F = 8:1)		
Male	32	88.88
Female	4	11.11
Side Involved		
Left	19	52.77
Right	17	47.22
Mode of Injury		
Road Traffic Accident	31	86.11
Fall on Level Surface	3	8.33
Fall from Height	2	5.55
Schatzker's Classification		
Type I	2	5.55
Type II	10	27.77
Type III	2	5.55
Type IV	9	25.00
Type V	10	27.77
Type VI	3	8.33

Mean Age: 40.02 ± 13.58 years; Range: 21–76 years; Mean Trauma-to-Surgery Time: 6.05 ± 2.22 days

The mean age was 40.02 ± 13.58 years (range 21–76), with the majority in the 18–30 years age group (30.55%). Males predominated (88.88%). Left side was more commonly involved (52.77%). Road traffic accidents were the most common mechanism (86.11%). Schatzker Type II and V were most frequent (27.77% each), followed by Type IV (25%). Mean trauma-to-surgery time was 6.05 ± 2.22 days, with maximum waiting time in Type VI fractures (10 days) due to associated swelling and blisters.

The functional and radiological outcomes are presented in Table 2.

Table 2: Functional and Radiological Outcomes (n=36)

Parameter	Value
Range of Motion	
Mean ROM (°)	122.36 ± 9.14 (Range: 100–135)
MRCA (Mean: 25.41 ± 3.27)	
Excellent (28–30)	12 (33.33%)
Good (24–27)	13 (36.11%)
Fair (20–23)	8 (22.22%)
Poor (<20)	3 (8.33%)
Fracture Union Time	
Mean (weeks)	13.86 ± 1.82 (Range: 12–18)
MRRA (Mean: 8.0 ± 1.49)	
Excellent (9–10)	13 (36.11%)
Good (7–8)	18 (50.00%)
Fair (5–6)	4 (11.11%)

Poor (<5)	1 (2.77%)
Radiological Parameters	
No Articular Depression	19 (52.77%)
<5mm Depression	17 (47.22%)
No Condylar Widening	16 (44.44%)
<5mm Widening	20 (55.55%)
No Angulation	22 (61.11%)
<10° Varus	9 (25.00%)
<10° Valgus	5 (13.88%)
No OA Progression	20 (55.55%)
OA by 1 Grade	15 (41.66%)
OA by >1 Grade	1 (2.77%)
Complications (n=11, 30.55%)	
Knee Stiffness	5 (13.88%)
Stiffness + Extension Lag	2 (5.55%)
Extension Lag	1 (2.77%)
Instability	1 (2.77%)
Infection	2 (5.55%)

The mean ROM was 122.36° ± 9.14. The mean MRCA score was 25.41 ± 3.27, with 33.33% excellent, 36.11% good, 22.22% fair, and 8.33% poor outcomes. The mean fracture union time was 13.86 ± 1.82 weeks. The mean MRRA score was 8.0 ± 1.49, with 36.11% excellent, 50% good, 11.11% fair, and 2.77% poor outcomes.

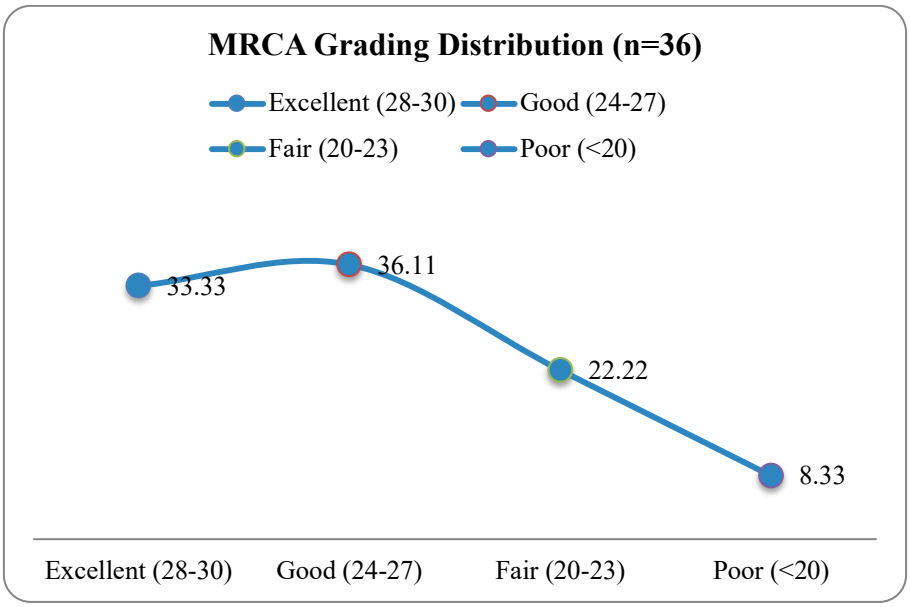

Figure 1: Modified Rasmussen Clinical Assessment (MRCA) Grading Distribution

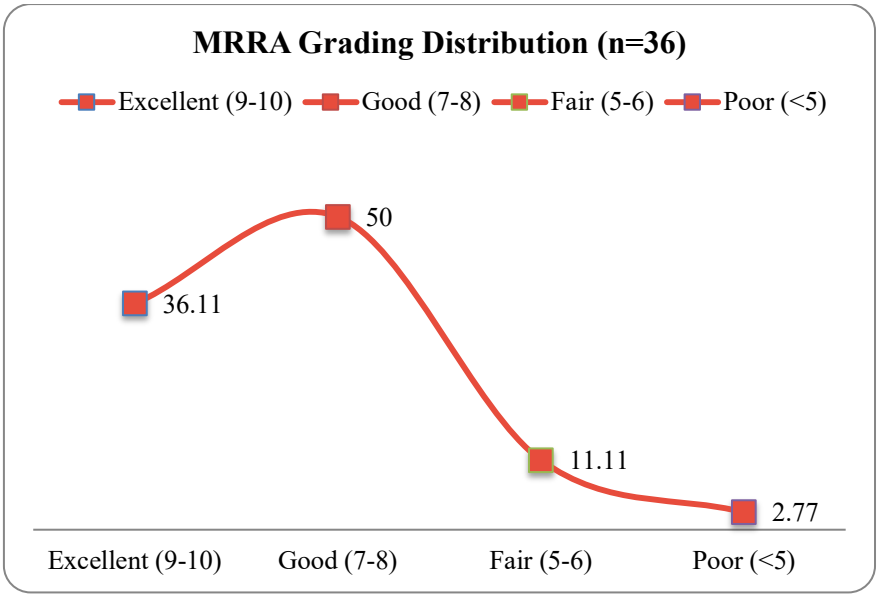

Figure 2: Modified Rasmussen Radiological Assessment (MRRA) Grading Distribution

The correlation between radiological parameters and clinical outcome is presented in Table 3.

Table 3: Correlation of Radiological Parameters with Clinical Outcome (MRCA)

Radiological Parameter	Spearman's R	p-value	Interpretation
Articular Depression vs MRCA	0.501	0.00185*	Significant positive correlation
Condylar Widening vs MRCA	0.251	0.138	Weak; not statistically significant
Tibial Angulation vs MRCA	0.371	0.026*	Significant; ↑angulation → poor MRCA
Osteoarthrosis vs MRCA	0.321	0.046*	Significant; ↑OA → poor MRCA
MRRA vs MRCA	0.480	0.003*	Significant; poor radiology → poor function

*Statistically significant ($p \leq 0.05$)

Articular depression showed significant positive correlation with MRCA (R=0.501, p=0.00185). Tibial angulation (R=0.371, p=0.026) and osteoarthrosis (R=0.321, p=0.046) also showed significant correlations. MRRA and MRCA showed significant positive correlation (R=0.480, p=0.003). Condylar widening showed weak positive correlation (R=0.251) that was not statistically significant (p=0.138). Complications occurred in 11 patients (30.55%).

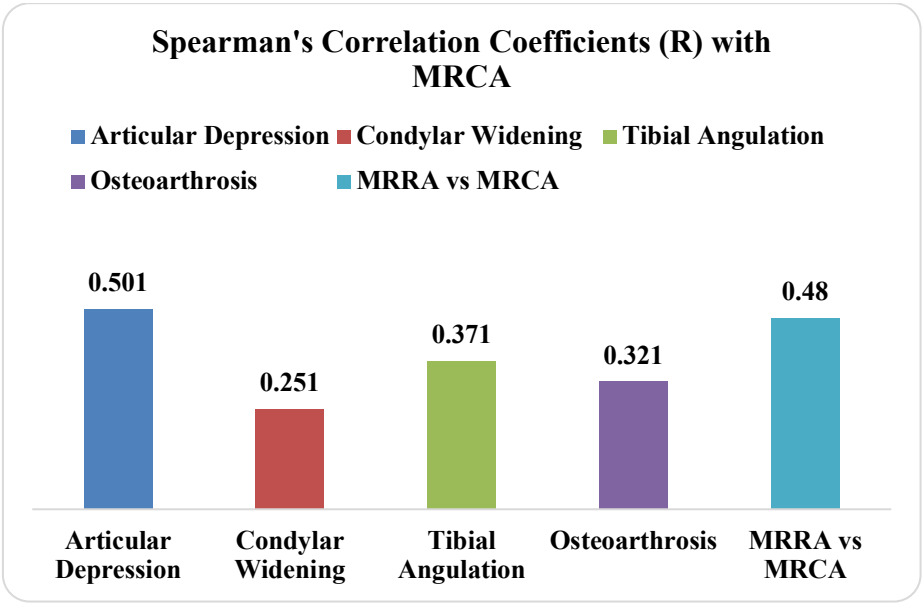

Figure 3: Correlation of Radiological Parameters with Clinical Outcome (Spearman's R Values)

The comparative analysis with published literature is presented in Table 4.

Table 4: Comparative Analysis with Published Literature

Parameter	Paleti et al. (n=40)	Prasad et al. (n=30)	Present Study (n=36)
Peak Age	3rd–4th decade	3rd–4th decade	3rd–4th decade
Male (%)	70%	66.6%	88.88%
RTA (%)	60%	56.6%	86.11%
MRCA: Excellent	47.5%	33.3%	33.33%
MRCA: Good	40%	50%	36.11%
MRCA: Fair	7.5%	10%	22.22%
MRCA: Poor	5%	6.7%	8.33%
MRRA: Excellent	12.5%	6.7%	36.11%
MRRA: Good	67.5%	73.2%	50.00%
MRRA: Fair	12.5%	13.4%	11.11%
MRRA: Poor	7.5%	6.7%	2.77%
Mean ROM (°)	–	–	122.36
Union (wks)	–	–	13.86
Knee Stiffness	12.5%	10%	13.88%

Discussion

Demographic Profile: The demographic profile in our study—mean age 40.02 years, male predominance (88.88%), left side predilection (52.77%), and RTA as the most common mechanism (86.11%)—is consistent with published literature. Paleti et al. [19] in their study of 40 patients reported maximum patients in the 3rd and 4th decades with 70% male predominance and RTA as the most common mechanism (60%). Prasad et al.[20] similarly reported 66.6% patients in the 3rd–4th decade with 66.6% male predominance, left side involvement in 63.4%, and RTA in 56.6%. The higher male predominance in our study (88.88% vs 70% and 66.6%) likely reflects the Indian demographic pattern of greater male exposure to road traffic, occupational hazards, and sports-related injuries. The predominance of young adults highlights the socioeconomic impact of these fractures as they affect the most productive age group.

Fracture Pattern and Timing of Surgery: In our study, Schatzker Type II and V each constituted 27.77% of cases, followed by Type IV at 25%. This differs from Paleti et al. [19] (Type II: 25%, Type III: 20%) and Prasad et al. [20] (Type II: 30%, Type III: 23.4%), who reported fewer bicondylar fractures. The higher proportion of Type V fractures in our cohort likely contributed to the relatively fairer and poorer MRCA outcomes, as bicondylar fractures involve greater soft tissue damage, prolonged immobilisation, and delayed rehabilitation. Jansen et al. [21] reported a mean trauma-to-surgery time of 4 days; our mean of 6.05 ± 2.22 days was slightly longer, with maximum delay (10 days) in Type VI fractures owing to significant swelling and blister formation requiring soft tissue conditioning prior to definitive fixation.

Range of Motion and Fracture Union: The mean ROM of 122.36° is comparable to Urruela et al. [22] who reported 126° in 94 patients after ORIF. The mean fracture union time of 13.86 weeks is consistent with Vasanad et al. [23] (14 weeks), though shorter than Conserva et al. [24] (17.2 weeks). The marginally shorter union time in our study may be attributed to strict adherence to postoperative protocols and early initiation of quadriceps exercises, which promote fracture healing through controlled mechanical stimulation.

Functional Outcomes (MRCA): The MRCA scores showed 33.33% excellent and 36.11% good outcomes (combined 69.44%). This is lower than Paleti et al. [19] (87.5% excellent–good) and Prasad et al. [20] (83.3% excellent–good). The higher proportion of fair and poor results (30.55%) in our study can be attributed to the greater percentage of bicondylar fractures (Schatzker Type V: 27.77%), in whom postoperative knee mobilisation was delayed due to the complex fracture pattern and associated soft tissue injury. Lachiewicz and Funcik [10] emphasised that anatomic reduction, stable fixation, and early movement are prerequisites for good outcomes, and any compromise in these elements—particularly delayed mobilisation—adversely affects functional recovery.

Radiological Outcomes (MRRA): In contrast, the MRRA scores were superior, with 36.11% excellent and 50% good outcomes (combined 86.11%). This is better than Paleti et al. [19] (80% excellent–good) and Prasad et al. [20] (79.9% excellent–good), suggesting that while anatomical reduction was well achieved in our cohort, the functional recovery was limited by other factors including fracture complexity, soft tissue damage, and patient compliance with rehabilitation.

Correlation of Articular Depression with Functional Outcome: Our finding of significant

positive correlation between articular depression and MRCA (R=0.501, p=0.00185) indicates that increasing articular depression is associated with poorer functional outcomes. This contradicts several earlier studies. Lucht and Pilgaard [25] in 1971, reviewing 109 tibial plateau fractures, found that most patients with residual depression of 3–10 mm, and even those with >10 mm depression, had acceptable functional results at 7 years. Rasmussen [26] in 1973 reported no difference in functional outcome between patients with <5 mm and >5 mm articular depression at 7.3 years follow-up, with no change even at 20-year follow-up. Similarly, Jensen et al. [27] found no clear association between articular depression and clinical outcome. However, in our study, patients with anatomical reduction (52.77%) had significantly better MRCA scores than those with <5 mm depression (47.22%), supporting the principle that restoration of articular congruity translates to better function.

Correlation of Condylar Widening with Functional Outcome: Condylar widening showed weak positive correlation with MRCA (R=0.251) that was not statistically significant (p=0.138). This is consistent with Mathur et al. [28] who reviewed 27 operated tibial plateau fractures and concluded that there is no statistical correlation between condylar widening and functional outcome. However, Piątkowski et al. [29] in their study of 13 patients concluded that condylar widening strongly correlates with clinical outcome. The discrepancy may reflect differences in sample size, fracture severity, and measurement techniques. In our study, no patient had >5 mm condylar widening, which may have limited the ability to detect a significant correlation.

Correlation of Tibial Alignment with Functional Outcome: Tibial angulation showed significant positive correlation with MRCA (R=0.371, p=0.026), indicating that greater varus/valgus malalignment is associated with poorer functional outcomes. This supports Honkonen [30] who operated 131 tibial plateau fractures and concluded that tibial malalignment >10° correlates with poor long-term functional results. Russell et al. [31] also confirmed that normal tibial alignment is a statistically significant predictor of better functional outcome. In our study, all patients with angulation had <10° deformity, yet even this degree of malalignment significantly affected clinical scores, underscoring the importance of achieving neutral alignment during surgery.

Correlation of Osteoarthrosis with Functional Outcome: Osteoarthrosis progression showed significant positive correlation with MRCA (R=0.321, p=0.046). This contradicts Van Dreumel et al.[32] who retrospectively analysed 71 patients and found no significant relationship between radiological osteoarthritis and functional outcome. The discrepancy may be partly explained by the fact that in our study, the postoperative radiograph was taken in supine position while the 6-month follow-up was taken in weight-bearing standing position, potentially exaggerating the apparent progression of joint space narrowing. Nevertheless, the significant finding highlights the importance of articular surface restoration in preventing early degenerative changes.

Correlation between Radiological and Clinical Outcomes: The significant positive correlation between MRRA and MRCA (R=0.480, p=0.003) is a key finding, indicating that poor radiological outcomes adversely affect functional outcomes. This contradicts Paleti et al. [19] who found no significant association between clinical and radiological results (p=0.176). However, our finding supports the fundamental orthopaedic principle that anatomical restoration of the articular surface and mechanical axis translates to better clinical function, particularly in an Indian population where high-demand activities such as squatting and cross-legged sitting require excellent knee ROM and stability.

Complications: Complications were observed in 11 patients (30.55%). Knee stiffness was the most common (13.88%), comparable to Paleti et al. [19] (12.5%) and Prasad et al. [20] (10%). Stiffness was predominantly seen in Type V and VI fractures where knee mobilisation was delayed. One patient (2.77%) had an associated ACL tear that was not reconstructed, resulting in anteroposterior instability and poor functional outcome. Surgical site infection occurred in 2 patients (5.55%), managed conservatively with culture-guided antibiotics. No cases of non-union, wound dehiscence, or compartment syndrome were observed.

Conclusion

ORIF with plating is a rational treatment option for intra-articular proximal tibial fractures. The surgical aim must be to achieve anatomical articular congruency by restoration of the depressed articular fragment and neutral tibial alignment, followed by rigid fixation. Articular depression (R=0.501, p=0.002), tibial angulation (R=0.371, p=0.026), and osteoarthrosis progression (R=0.321, p=0.046) all significantly correlate with poorer functional outcomes. Importantly, radiological and clinical outcomes show significant positive correlation (R=0.480, p=0.003), confirming that quality of radiological reduction directly influences functional recovery. Complications like knee stiffness and extension lag are predominantly seen in bicondylar fractures (Schatzker Type V and VI). Longer follow-up is necessary to assess the development of secondary osteoarthritis and its long-term impact on function.

Limitations

1. Relatively short follow-up period of 6 months.
2. Associated comorbidities and their effect on fracture healing were not specifically analysed.
3. Small sample size of 36 patients limits subgroup analysis.
4. Single-centre study may limit generalizability.

Declarations

Ethics Approval and Consent: The study was conducted at the Department of Orthopedics, Government R.D.B.P Jaipuria Hospital, attached to RUHS College of Medical Sciences, Jaipur, after obtaining necessary institutional permissions. Written informed consent was obtained from all participants prior to enrolment in the study. The study was conducted in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki Declaration and its later amendments. Patients were informed about the study objectives, procedures, potential risks, and their right to withdraw at any stage without consequences to their treatment.

Conflict of Interest: The authors declare no conflict of interest.

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