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Original Research Article

A Comparative Study of Conventional versus Variable Angle Locking Compression Plates in Managing Complex Proximal Tibia Fractures

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Abstract

Background: Complex proximal tibia fractures present significant treatment challenges due to their articular involvement, comminution, and soft tissue compromise. Locking compression plates (LCPs) have improved fracture fixation, but limitations in screw trajectory with conventional LCPs have led to the development of variable angle LCPs (VA-LCPs), offering more flexible fixation options.

Aim: To compare clinical and radiological outcomes between conventional LCPs and variable angle LCPs in the management of complex proximal tibia fractures.

Materials & Methods: This prospective comparative study was conducted at a tertiary care hospital with 72 patients who sustained Schatzker type V or VI proximal tibia fractures. Patients were divided into two equal groups: Group A (n = 36) treated with conventional LCPs and Group B (n = 36) treated with VA-LCPs. Parameters such as time to union, fracture alignment, implant-related complications, Rasmussen functional score, and knee range of motion (ROM) were recorded. Data were analyzed using SPSS version 26.0, with $p < 0.05$ considered statistically significant.

Results: Both groups were comparable in demographic characteristics. Group B showed significantly faster union time (15.36 ± 2.52 weeks vs. 17.14 ± 2.86 weeks; p = 0.008), improved Rasmussen scores (27.08 ± 2.41 vs. 25.17 ± 2.89; p = 0.001), and better knee ROM (121.39 ± 9.84° vs. 114.72 ± 10.63°; p = 0.006). Implant failure was observed only in Group A (8.33%), while no failures occurred in Group B. Early full weight bearing and return to daily activities were also significantly earlier in Group B (p = 0.002 and p = 0.012, respectively).

Conclusion: Variable angle LCPs demonstrated superior clinical and radiological outcomes in the treatment of complex proximal tibia fractures. They provided more stable fixation, fewer complications, and facilitated earlier rehabilitation compared to conventional LCPs, making them a preferred option in managing these challenging injuries.

Keywords: Proximal tibia fracture, variable angle LCP, conventional LCP, Rasmussen score, knee ROM.

Introduction

Proximal tibial fractures represent a challenging group of periarticular injuries that account for approximately 1% of all fractures and nearly 8% of fractures in the elderly population. These fractures frequently result from high-energy trauma in younger individuals and low-energy osteoporotic injuries in older patients. Complex proximal tibial fractures, particularly Schatzker type V and VI fractures, are often associated with severe metaphyseal comminution, articular depression, soft-tissue compromise, and ligamentous injuries, making their management demanding for orthopedic surgeons (Elsoe et al., 2015) [1].

The primary goals of treatment of proximal tibial fractures include restoration of the articular surface, maintenance of limb alignment, preservation of soft tissues, achievement of stable fixation, and early mobilization of the knee joint. Failure to achieve these objectives may result in post-traumatic osteoarthritis, malunion, knee stiffness, chronic pain, and functional disability (Prat-Fabregat and Camacho-Carrasco, 2016) [2]. Therefore, operative fixation has become the preferred treatment modality for displaced and unstable proximal tibial fractures.

Advances in implant technology have significantly improved the surgical management of these fractures. Locking compression plates (LCPs) provide angular stability and function as internal fixators, reducing disruption of periosteal blood supply and improving fixation in osteoporotic and comminuted bone (Egol et al., 2014) [3]. Conventional locking compression plates have demonstrated satisfactory outcomes in proximal tibial fractures; however, difficulties may arise when screw trajectories are limited by fracture configuration or when additional fixation of small periarticular fragments is required.

To overcome these limitations, variable angle locking compression plates (VA-LCPs) were introduced. Unlike conventional locking plates, VA-LCP systems allow screw insertion within a defined angular range while maintaining locking capability. This feature enables surgeons to direct screws toward specific fracture fragments, avoid joint penetration, improve fixation in complex fracture patterns, and accommodate individual anatomical variations (Fensky et al., 2018) [4].

Several biomechanical studies have demonstrated that variable angle locking technology provides construct stability comparable to conventional fixed-angle locking systems while offering greater flexibility in screw placement. Fensky et al. (2018) reported that variable angle locking constructs exhibited sufficient biomechanical stability for periarticular fractures and facilitated optimal screw positioning in challenging fracture configurations [4]. Similarly, Wang et al. (2019) observed that variable angle locking plates allowed improved fragment capture and fixation in complex proximal tibial fractures without compromising mechanical strength [5].

Clinical investigations have also reported encouraging outcomes with variable angle locking systems. Biggi et al. (2019) found that locking plate fixation of bicondylar tibial plateau fractures achieved satisfactory union rates and functional recovery while minimizing secondary loss of reduction [6]. Furthermore, Gosling et al. (2020) emphasized that modern periarticular locking implants improve fixation stability and facilitate early rehabilitation in complex tibial plateau fractures [7].

Aim & Objectives

Aim: To compare the clinical, radiological, and functional outcomes of Conventional Locking Compression Plates

(CLCPs) and Variable Angle Locking Compression Plates (VALCPs) in the management of complex proximal tibial fractures (Schatzker Type V and VI).

Objectives

- To compare demographic and fracture characteristics between the two groups.
- To evaluate surgical outcomes, including operative time and bone graft requirement.
- To compare radiological outcomes such as fracture union time and malalignment.
- To assess implant-related complications.
- To evaluate functional outcomes using Rasmussen Functional Score and knee range of motion.
- To compare functional outcome categories (excellent, good, fair, and poor).
- To assess rehabilitation outcomes, including time to full weight-bearing, return to daily activities, and return to work.

Materials & Methods

Study Design: This prospective, comparative interventional study was conducted to evaluate and compare the clinical, functional, and radiological outcomes of Conventional Locking Compression Plates (CLCPs) and Variable Angle Locking Compression Plates (VALCPs) in the management of complex proximal tibial fractures. Eligible patients were randomly allocated into two equal groups using a computer-generated randomization method:

- Group A (n=36): Treated with Conventional Locking Compression Plates (CLCPs)
- Group B (n=36): Treated with Variable Angle Locking Compression Plates (VALCPs)

Study Place: The study was conducted in the Department of Orthopaedics at National Institute of Medical Sciences & Research, Jaipur, NIMS University Rajasthan, Jaipur, India.

Study Period: The study was carried out over a period of 15 months, from January 2022 to March 2023.

Study Population: A total of 80 consecutive patients presenting with complex proximal tibial fractures were initially assessed for eligibility. After applying the inclusion and exclusion criteria and accounting for patients lost to follow-up, 72 patients were included in the final analysis. The patients were equally distributed into two study groups, with 36 patients in each group.

Ethical Considerations: Prior to commencement of the study, approval was obtained from the Institutional Ethics Committee of AIIMS Patna. Written informed consent was obtained from all participants before enrollment.

Patients were informed regarding the study objectives, treatment procedures, possible benefits, and potential risks. Confidentiality of patient information was maintained throughout the study. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Inclusion Criteria

Patients fulfilling the following criteria were included in the study:

- Age between 18 and 70 years.
- Closed fractures or Gustilo-Anderson Type I open fractures.
- Schatzker Type V and Type VI proximal tibial fractures confirmed radiographically.
- Fractures managed surgically within two weeks of injury.
- Patients willing to participate and provide written informed consent.

Exclusion Criteria

Patients meeting any of the following criteria were excluded:

- Pathological fractures.
- Gustilo-Anderson Type II or Type III open fractures.
- Polytrauma patients with life-threatening injuries.
- Pre-existing knee joint disorders such as osteoarthritis or inflammatory arthritis.
- Fractures older than three weeks at presentation.
- Severe systemic illnesses precluding surgery.
- Schatzker Type IV fractures involving isolated medial condylar injury.
- Associated fractures in the ipsilateral lower limb.
- Patients unwilling to participate or lost to follow-up.

Methodology

Upon admission, a detailed history was obtained, including patient demographics, mechanism of injury, and associated medical conditions. Clinical examination was performed to assess fracture characteristics, neurovascular status, and soft tissue condition.

Initial stabilization was achieved using an above-knee posterior splint. Standard anteroposterior and lateral radiographs of the knee were obtained in all patients. Computed tomography (CT) with three-dimensional reconstruction was performed whenever necessary for detailed assessment of fracture morphology and surgical planning.

In patients with significant soft tissue swelling, calcaneal pin traction and a Böhler-Braun splint were applied until definitive fixation could be performed safely. Following enrollment, patients were randomized into either the CLCP group (Group A) or the VALCP group (Group B) using computer-generated random allocation.

Surgical Procedure: All surgical procedures were performed by the same senior orthopedic surgeon under strict aseptic precautions. Regional or general anesthesia was administered according to anesthetic assessment and patient suitability.

Patients were positioned supine on a radiolucent operating table. Depending on fracture configuration, either a minimally invasive plate osteosynthesis (MIPO) lateral approach or an anterolateral open approach was utilized.

Fracture reduction was achieved under fluoroscopic guidance. Depressed articular fragments were elevated and supported using autologous bone graft or bone substitute whenever required.

In Group A, fixation was performed using Conventional Locking Compression Plates with a combination of cortical, cancellous, and locking screws. In Group B, Variable Angle Locking Compression Plates were used, allowing screw insertion within a ±15° angulation range around the locking axis to optimize fixation of fracture fragments.

Following fixation, wound closure was performed in layers and a suction drain was placed when necessary. The drain was removed on the third postoperative day, and sutures were removed on the twelfth postoperative day.

Postoperative Management and Follow-up: Intravenous antibiotics were administered for 48 hours following surgery. Analgesics and supportive medications were provided as required. Passive and active knee range-of-motion exercises were initiated early in the postoperative period under supervision.

Patients were maintained on non-weight-bearing mobilization for approximately 10 weeks. Partial weight-bearing was gradually initiated between 10 and 14 weeks depending on radiological progress. Full weight-bearing was permitted only after evidence of fracture union on radiographs. Patients were followed up at regular intervals consisting of weekly visits during the first postoperative month, followed by assessments every three months thereafter. Final evaluation was performed at six months and subsequent visits as clinically indicated.

Investigations

Radiological Investigations

- Plain radiographs of the knee (anteroposterior and lateral views).
- Computed tomography (CT) scan with three-dimensional reconstruction for fracture mapping and preoperative planning.

Laboratory Investigations: All patients underwent routine preoperative investigations, including complete blood count, blood grouping and Rh typing, random blood sugar estimation, renal and liver function tests, serum electrolyte assessment, coagulation profile, viral marker screening (HBsAg, HCV, and HIV), urine routine examination, and a comprehensive pre-anesthetic evaluation to assess fitness for surgery and identify any underlying medical conditions that could influence perioperative management.

Outcome Measures

Functional Outcomes

Rasmussen Functional Grading System: Functional outcome was assessed using the Rasmussen Functional Score, which evaluates pain, walking capacity, knee range of motion, and stability. The maximum obtainable score is 30.

Outcome categories were defined as:

- Excellent: 27–30 points.
- Good: 20–26 points.
- Fair: 10–19 points.
- Poor: 0–9 points.

Oxford Knee Score (OKS): The Oxford Knee Score was also used to assess patient-reported knee function. The questionnaire consists of 12 items, each scored from 0 to 4, with a maximum score of 48.

Outcome categories were defined as:

- Excellent: 40–48 points.
- Good: 30–39 points.
- Fair: 20–29 points.
- Poor: 0–19 points.

Radiological Outcomes: Radiological assessment was performed using the Rasmussen Radiological Grading System, which evaluates:

- Articular depression.
- Condylar widening.
- Varus/valgus angulation.

The maximum radiological score is 18.

Radiological outcomes were classified as:

- Excellent: 18 points.
- Good: 12–17 points.
- Fair: 6–11 points.
- Poor: 0–5 points.

Additional radiological parameters evaluated included fracture union, time to union, maintenance of alignment, and implant-related complications.

Statistical Analysis: Data were entered into Microsoft Excel spreadsheets and subsequently analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages.

The normality of continuous data was assessed using the Shapiro-Wilk test. For normally distributed variables, comparisons between the two groups were performed using the independent samples Student's t-test. Non-normally distributed continuous variables were analyzed using the Mann-Whitney U test.

Categorical variables were compared using the Chi-square test or Fisher's exact test whenever appropriate. Results were reported with corresponding p-values and 95% confidence intervals wherever applicable. A two-tailed p-value of less than 0.05 was considered statistically significant.

Results

Table 1: Comparison of Demographic and Fracture Characteristics Between the Study Groups (n = 72)

Characteristics	Variable	Group A (n = 36)	Group B (n = 36)	p-value
Mean Age (years)	–	44.56 ± 10.34	45.83 ± 9.98	0.571
Gender, n (%)	Male	22 (61.11)	24 (66.67)	0.629
	Female	14 (38.89)	12 (33.33)	
Schatzker Classification, n (%)	Type V	20 (55.56)	18 (50.00)	0.637
	Type VI	16 (44.44)	18 (50.00)	
Fracture Type, n (%)	Closed Fracture	30 (83.33)	29 (80.56)	0.739
	Open Type I Fracture	6 (16.67)	7 (19.44)	

Table 1 presents the mean age of patients in Group A was 44.56 ± 10.34 years, while that of Group B was 45.83 ± 9.98 years. The difference was not statistically significant (p = 0.571), indicating comparable age distribution between the groups. Male patients predominated in both groups, accounting for 61.11% (n = 22) in Group A and 66.67% (n = 24) in Group B, whereas females comprised 38.89% (n = 14) and 33.33% (n = 12), respectively. The gender distribution was comparable between the groups (p = 0.629). According to the Schatzker classification, Type V fractures were observed in 55.56% (n = 20) of patients in Group A and 50.00% (n = 18) in Group B, while Type VI fractures accounted for 44.44% (n = 16) and 50.00% (n = 18), respectively. No significant difference was found in fracture classification between the groups (p = 0.637). Similarly, the majority of fractures were closed injuries, comprising 83.33% (n = 30) in Group A and 80.56% (n = 29) in Group B, whereas open Type I fractures accounted for 16.67% (n = 6) and 19.44% (n = 7), respectively. The difference was not statistically significant (p = 0.739). These findings indicate that both groups were well matched with respect to baseline demographic and fracture characteristics.

Table 2: Comparison of Surgical and Radiological Outcomes Between the Study Groups (n = 72)

Outcome Parameter	Group A (n = 36) Mean ± SD / n (%)	Group B (n = 36) Mean ± SD / n (%)	p-value
Time to Union (weeks)	17.14 ± 2.86	15.36 ± 2.52	0.008*
Malalignment (>5°), n (%)	5 (13.89)	1 (2.78)	0.089
Use of Bone Graft/Substitute, n (%)	9 (25.00)	7 (19.44)	0.564
Operative Time (minutes)	96.28 ± 14.71	99.17 ± 13.85	0.338

*Statistically significant (p < 0.05)

Table 2 show that the mean time to fracture union was significantly shorter in Group B (15.36 ± 2.52 weeks) compared with Group A (17.14 ± 2.86 weeks), and this difference was statistically significant (p = 0.008).

Malalignment greater than 5° was observed in 13.89% (n = 5) of patients in Group A and 2.78% (n = 1) in Group B; however, the difference did not reach statistical significance (p = 0.089). Bone graft or bone substitute was required in 25.00% (n = 9) of patients in Group A and

19.44% (n = 7) in Group B, with no significant difference between the groups (p = 0.564).

The mean operative time was 96.28 ± 14.71 minutes in Group A and 99.17 ± 13.85 minutes in Group B, showing no statistically significant difference (p = 0.338). These findings suggest that variable-angle locking compression plates were associated with faster fracture healing while maintaining comparable operative characteristics.

Table 3: Comparison of Implant-Related Complications Between the Study Groups (n = 72)

Complication	Group A (n = 36), n (%)	Group B (n = 36), n (%)	p-value
Superficial Infection	3 (8.33)	2 (5.56)	0.640
Deep Infection	2 (5.56)	1 (2.78)	0.554
Implant Failure	3 (8.33)	0 (0.00)	0.077
Total Complications	8 (22.22)	3 (8.33)	0.094

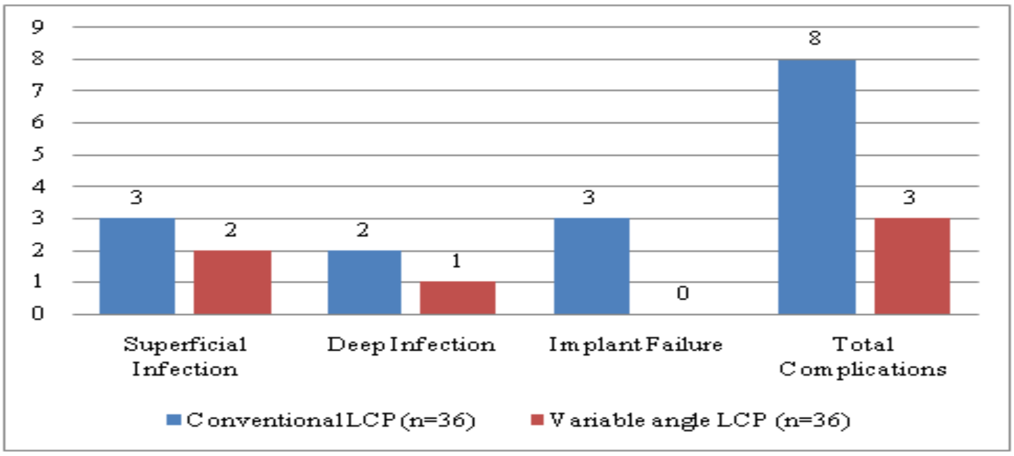

Figure 1: Implant-Related Complications

Table 3 and figure I, demonstrates the superficial infection occurred in 8.33% (n = 3) of patients in Group A and 5.56% (n = 2) in Group B, with no statistically significant difference (p = 0.640). Deep infection was observed in 5.56% (n = 2) of patients in Group A and 2.78% (n = 1) in Group B (p = 0.554). Implant failure was reported in 8.33% (n = 3) of patients treated with conventional locking plates, whereas no implant failure occurred in Group B; however, the difference was not statistically significant (p = 0.077). The overall complication rate was higher in Group A (22.22%, n = 8) compared with Group B (8.33%, n = 3), although statistical significance was not achieved (p = 0.094). These findings indicate a trend toward fewer implant-related complications in the variable-angle locking plate group.

Table 4: Comparison of Functional Outcomes at Final Follow-up Between the Study Groups (n = 72)

Outcome Parameter	Group A (n = 36)	Group B (n = 36)	p-value
Rasmussen Functional Score (Mean ± SD)	25.17 ± 2.89	27.08 ± 2.41	0.001*
Knee Range of Motion [ROM] (°), Mean ± SD	114.72 ± 10.63	121.39 ± 9.84	0.006*

*Statistically significant (p < 0.05)

Table 4 presents the mean Rasmussen functional score was significantly higher in Group B (27.08 ± 2.41) compared with Group A (25.17 ± 2.89), demonstrating superior functional recovery among patients treated with variable-angle locking compression plates (p = 0.001). Similarly, the mean knee range of motion was significantly greater in Group B (121.39 ± 9.84°) than in Group A (114.72 ± 10.63°), with the difference reaching statistical significance (p = 0.006). These results indicate that patients treated with variable-angle locking compression plates achieved better functional outcomes and greater knee mobility at final follow-up.

Table 5: Distribution of Functional Outcome Categories According to Rasmussen Functional Score

Functional Outcome Category	Group A (n = 36), n (%)	Group B (n = 36), n (%)	p-value
Excellent (27–30)	11 (30.56)	19 (52.78)	0.045*
Good (20–26)	20 (55.56)	15 (41.67)	
Fair/Poor (<20)	5 (13.89)	2 (5.56)	

*Statistically significant (p < 0.05)

Table 5 illustrates that excellent outcomes were achieved in 52.78% (n = 19) of patients in Group B compared with 30.56% (n = 11) in Group A. Good outcomes were observed in 55.56% (n = 20) of patients in Group A and 41.67% (n = 15) in Group B. Fair or poor outcomes occurred in 13.89% (n = 5) of patients in Group A and only 5.56% (n = 2) in Group B. The overall distribution of functional outcomes differed significantly between the groups (p = 0.045), demonstrating a higher proportion of excellent outcomes and a lower proportion of fair-to-poor outcomes in patients treated with variable-angle locking compression plates.

Table 6: Comparison of Follow-up and Return-to-Activity Outcomes Between the Study Groups (n = 72)

Parameter	Group A (n = 36)	Group B (n = 36)	p-value
Follow-up Duration (months), Mean ± SD	12.94 ± 1.82	13.08 ± 1.67	0.689
Time to Full Weight Bearing (weeks), Mean ± SD	13.89 ± 2.17	12.25 ± 1.94	0.002*
Return to Daily Activities (weeks), Mean ± SD	16.36 ± 3.45	14.33 ± 2.91	0.012*
Return to Work, n (%)	22 (61.11)	27 (75.00)	0.202

*Statistically significant (p < 0.05)

Table 6 presents the mean duration of follow-up was comparable between Group A (12.94 ± 1.82 months) and Group B (13.08 ± 1.67 months), with no statistically significant difference (p = 0.689). Patients in Group B achieved full weight-bearing significantly earlier (12.25 ± 1.94 weeks) than those in Group A (13.89 ± 2.17 weeks), and the difference was statistically significant (p = 0.002).

Similarly, the mean time required to return to daily activities was significantly shorter in Group B (14.33 ± 2.91 weeks) compared with Group A (16.36 ± 3.45 weeks) (p = 0.012). Return to work was achieved by 75.00% (n = 27) of patients in Group B and 61.11% (n = 22) in Group A; however, the difference was not statistically significant (p = 0.202). These findings suggest that variable-angle locking compression plates facilitated earlier rehabilitation and functional recovery, allowing patients to resume normal activities sooner than those treated with conventional locking compression plates.

Discussion

The current study included 72 patients with complex proximal tibial fractures, evenly divided into two groups: Group A (conventional LCP) and Group B (variable angle LCP). The mean age in conventional LCP was 44.56 ± 10.34 years, and in variable angle LCP was 45.83 ± 9.98 years, which aligns with the age range seen in similar studies.

For instance, Singh and Chandranna (2020) reported a mean age of 43.9 years in patients treated with locking compression plates [8]. Additionally, the fracture types (Schatzker V and VI) and the gender distribution in our study are similar to those observed by Rademakers et al. (2007), who emphasized the importance of these high-energy injuries primarily affecting middle-aged, active individuals [9].

In our study, Group B (VA-LCP) demonstrated a significantly shorter mean time to radiological union (15.36 ± 2.52 weeks) compared to Group A (CLCP) (17.14 ± 2.86 weeks; p = 0.008), indicating enhanced healing efficiency. This aligns with the findings of Aseri et al. (2018), who reported a mean union time of around 21 weeks using locking compression plates in proximal tibial fractures, underscoring the potential for even faster union with variable-angle constructs [10]. Völk et al. (2021) reported a mean union time of 15.9 weeks using polyaxial locking plates, which closely mirrors our findings in variable angle LCP. This supports the theory that variable angle systems allow more optimized screw trajectories, improving mechanical stability and promoting early callus formation [11]. In contrast, Khatri et al. (2016) reported an average union time of 18.6 weeks using conventional locking systems in similar fracture types, which is slightly higher and consistent with our conventional LCP results [12].

The operative time between the groups was comparable (96.3 ± 14.7 vs. 99.2 ± 13.9 minutes; p = 0.338), suggesting that using VA-LCPs does not add significant procedural complexity. This corresponds with Voelk et al. (2021), who observed no significant differences in surgical duration between polyaxial VA-LCP and other locking systems, while maintaining similar clinical and radiological outcomes [11].

Although the malalignment (>5°) was lower in Group B (variable angle LCP) (2.78% vs. 13.89%), the difference did not reach statistical significance (p = 0.089), suggesting a favorable but inconclusive trend. Citak et al. (2019) comparing unilateral versus dual locking plate fixation for bicondylar tibial plateau fractures found no significant difference in postoperative malalignment across groups, emphasizing that plate configuration and surgical technique equally contribute to alignment outcomes [13].Yoo et al. (2010) demonstrated that the use of dual or variable locking plates reduced malalignment in posteromedial fracture patterns compared to fixed-angle systems, which tend to have limited adaptability in multi-fragmented articular fractures. Our findings reinforce that variable angle systems may offer better control in maintaining reduction, particularly in complex configurations [14]. In present study show the lower complication rate in Group B (VA-LCP) compared to Group A (CLCP): total complications were 8.33% versus 22.22%, respectively (p = 0.094), suggesting a favorable trend for variable-angle locking constructs. Though differences weren't statistically significant, the absence of implant failure in Group B stands out (0% vs. 8.33% in Group A, p = 0.077), highlighting the potential mechanical advantage of VA-LCPs in complex proximal tibia fractures.

The rates of superficial infection (8.33% vs. 5.56%) and deep infection (5.56% vs. 2.78%) in our CLCP and VA-LCP groups fall within ranges documented in previous studies by Helfet DL et al., observed that complex proximal tibia fractures treated with locking plates reported deep infection in 22% of cases, along with superficial wound complications and hardware irritation [15].

In another prospective series, superficial infection occurred in ~8% of patients treated with locking compression plates, alongside knee stiffness as the most common complication, aligning closely with our findings [16].

While our CLCP group exhibited implant failures (8.33%) and VA-LCP had none, earlier literature describing locking plate systems such as LISS similarly reported hardware-related complications, including malalignment and implant prominence, but implant failure rates per se were not always segregated [16]. The lack of failure in VA-LCP suggests its enhanced biomechanical stability in challenging fracture patterns. Phillips et al. (2021) found that newer-generation VA-LCPs improved screw placement in posterior fragments, reducing the risk of mechanical failure [17].

In our study, deep infection rates were 5.56% in conventional LCP and 2.78% in variable angle LCP, consistent with the infection rates of 3–6% reported by Khatri et al. (2016) in closed, high-energy proximal tibia fractures [12]. Similarly, Sangwan et al. (2002) emphasized that minimally invasive techniques, which are more compatible with VA-LCPs, help preserve soft tissue and reduce infection risks [18].

Our results showed superior functional outcomes in the VA-LCP group, with a higher mean Rasmussen functional score (27.08 ± 2.41) compared to the conventional group (25.17 ± 2.89; p = 0.001). Additionally, 52.78% of patients in variable angle LCP achieved “Excellent” outcomes versus 30.56% in conventional LCP (p = 0.045). The mean knee ROM was significantly higher in variable angle LCP (121.39 ± 9.84°) than in conventional LCP (114.72 ± 10.63°; p = 0.006). These findings are consistent with Lin et al. (2018) demonstrated that stable fixation allowing early mobilization was associated with improved postoperative knee motion and reduced stiffness in patients with tibial plateau fractures [19]. Likewise, Feng et al. (2020) observed that patients treated with modern locking plate systems achieved mean knee flexion exceeding 120°, which was associated with favorable functional outcomes and patient satisfaction [20]. Zhang et al. (2021), who reported that advanced locking plate technologies resulted in improved functional scores and enhanced knee mobility in complex proximal tibial fractures [21].

Singh and Chandranna (2020) also documented improved functional outcomes using locking plates, with mean Rasmussen scores ranging between 24.7 and 27.1, aligning closely with our findings in both groups [8]. Importantly, the superior range of motion in Group B reflects the stability offered by the variable angle system, which allows for earlier, safe mobilization without compromising fracture fixation. Kumar et al. (2019) reported excellent or good functional outcomes in over 90% of patients managed with contemporary locking plate constructs, attributing these results to improved fracture stability and early rehabilitation protocols [22]. Patients in variable angle LCP achieved full weight bearing earlier (12.25 ± 1.94 weeks) compared to conventional LCP (13.89 ± 2.17 weeks; p = 0.002), and returned to daily activities significantly sooner (14.33 ± 2.91 weeks vs. 16.36 ± 3.45 weeks; p = 0.012). These findings are in agreement with Völk et al. (2021), who emphasized the role of early mobilization in enhancing long-term function and minimizing complications such as joint stiffness and muscle atrophy [11]. Although the return to work was higher in variable angle LCP (75.00%) compared to conventional LCP (61.11%), this difference was not statistically significant (p = 0.202). Rademakers et al. (2007) also noted that early functional rehabilitation is a key determinant of return to work, particularly in younger, working-age populations [9].

Limitations of the study

- Single-centre design may limit the generalizability of the findings to other healthcare settings.
- Moderate sample size may reduce statistical power, particularly for detecting differences in less frequent complications.
- Short-term follow-up (mean ~13 months) may not capture late complications such as post-traumatic osteoarthritis or implant fatigue failure.
- The surgeries were performed by a single senior surgeon, which standardizes technique but may not reflect outcomes across different skill levels.
- The study did not include a cost-effectiveness analysis, which could be relevant in resource-limited settings.

Conclusion

The present study demonstrates that Variable Angle Locking Compression Plates (VA-LCP) offer significant advantages over Conventional Locking Compression Plates (CLCP) in managing complex proximal tibia fractures. Patients treated with VA-LCP achieved faster radiological union, earlier full weight-bearing, better knee range of motion, and higher functional scores at final follow-up. Although differences in complication rates and implant failures did not reach statistical significance, the trend favored VA-LCP, suggesting improved biomechanical stability in complex fracture configurations. Given these findings, VA-LCP may be considered the preferred fixation method for complex proximal tibia fractures, especially where early rehabilitation and optimal joint function are priorities. However, larger multi-centre trials with longer follow-up are recommended to confirm these results and assess long-term outcomes.

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