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Research Article

Locking Plate Versus Tension Band Wiring in AO 34-C3 Comminuted Patella Fractures: A Retro-Prospective Comparative Study of Functional Outcomes and Failure Patterns

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Abstract

Background: Tension band wiring (TBW) remains the standard fixation technique for patella fractures, particularly in simple transverse patterns. However, its effectiveness in comminuted fractures is limited due to dependence on an intact cortical buttress and susceptibility to implant-related complications. Recent biomechanical studies have demonstrated superior stability of locking plate constructs, with reduced interfragmentary displacement and higher resistance to cyclic loading compared to TBW [3-5]. This study evaluates functional outcomes and failure patterns in a large cohort of patients undergoing operative fixation of patella fractures.

Methods: A retro-prospective comparative cohort study was conducted on approximately 250 patients treated between January 2017 and December 2023. Patients underwent operative fixation with either tension band wiring (TBW) or locking plate constructs, with near-equal distribution between groups. Fractures were classified according to the AO/OTA classification system, and a predefined subgroup analysis was performed for AO 34-C3 comminuted fractures.

Functional outcomes were evaluated using validated scoring systems (Böstman and/or Lysholm scores), in addition to objective assessment of range of motion (ROM) and extensor lag. Patients were followed at standardized intervals of 3, 6, 12, and 18 months.

A dedicated failure pattern analysis was performed, including assessment of loss of reduction, implant-related complications such as K-wire migration, and need for reoperation. Statistical analysis was conducted using appropriate parametric and non-parametric tests, with a p-value < 0.05 considered statistically significant.

Results: Locking plate fixation demonstrated superior maintenance of fracture reduction and more consistent functional recovery, particularly in comminuted fractures. TBW provided satisfactory outcomes in simple fracture patterns; however, in comminuted fractures, patients treated with TBW more frequently reported pain during range of motion and demonstrated higher rates of implant-related mechanical issues. K-wire migration and loss of reduction were predominantly observed in the TBW group, consistent with previously reported complication profiles [16,17]. In contrast, such complications were minimal in the plating group. Overall complication rates were low, with no major adverse events or non-unions observed across the cohort.

Conclusion: While TBW remains an effective technique for simple patella fractures, its limitations are evident in comminuted patterns. Locking plate fixation provides superior mechanical stability, fewer implant-related complications, and improved functional outcomes in AO 34-C3 fractures. These findings support a shift in surgical preference toward plate fixation in complex patella fractures, in line with emerging biomechanical and clinical evidence [6,8].

Keywords: *Tension Band Wiring (TBW); Patella Fractures; AO 34-C3 Fractures; Range of Motion (ROM)*

Introduction

Patella fractures account for approximately 0.5 - 1% of all skeletal injuries and represent a critical disruption of the knee extensor mechanism, with potential long-term consequences on knee function if not managed appropriately [1,2]. The primary goals of treatment include restoration of articular congruity, preservation of extensor mechanism integrity, and facilitation of early mobilization to prevent stiffness and functional impairment.

Tension band wiring (TBW) has historically been regarded as the gold standard for operative management of patella fractures, particularly simple transverse patterns. The technique is based on the principle of converting tensile forces generated by the quadriceps into compressive forces at the fracture site during knee flexion [3]. While this principle is effective in simple fracture configurations, its reliability in comminuted fractures remains questionable. TBW requires an intact cortical buttress to function effectively, and in its absence-as seen in comminuted fracture patterns-the construct may fail to maintain reduction under physiological loading conditions [4,5].

Clinical studies have consistently reported implant-related complications associated with TBW, including K-wire migration, hardware irritation, and loss of reduction, often necessitating secondary procedures for implant removal [6,7]. These complications are particularly pronounced in comminuted fractures, where fragment instability further compromises fixation. Additionally, patient-reported outcomes following TBW frequently include anterior knee pain and limitations in range of motion, highlighting the functional implications of suboptimal fixation [6].

In response to these limitations, locking plate fixation has emerged as a viable alternative, particularly for complex fracture patterns. Locking plate constructs provide multiplanar stability, improved fragment control, and enhanced resistance to mechanical forces acting across the patellofemoral joint. Recent biomechanical investigations have demonstrated significantly reduced interfragmentary displacement and higher load-to-failure thresholds with locking plate systems compared to TBW [8-10]. Furthermore, clinical studies have suggested lower complication rates and improved functional outcomes with plating techniques, especially in comminuted fractures [11,12].

Despite growing biomechanical and clinical evidence supporting locking plate fixation, the literature remains limited by small sample sizes, heterogeneous fracture patterns, and a lack of focused analysis on comminuted fractures. Most comparative studies include mixed cohorts of simple and complex fractures, thereby diluting the specific impact of fixation method in AO 34-C3 fracture patterns.

Aims and Objective of the Study

The present study aims to address this gap by evaluating a large retro-prospective cohort of approximately 250 patients treated over a 7-year period. The primary objective is to compare functional outcomes between TBW and locking plate fixation. Secondary objectives include a detailed analysis of failure patterns-specifically loss of reduction and implant-related complications such as K-wire migration-and assessment of clinical performance in comminuted fractures through subgroup analysis. By focusing on AO 34-C3 fractures, this study seeks to provide clearer guidance on the optimal fixation strategy for these challenging injuries.

Methods

Study design and setting

This study was designed as a retro-prospective comparative cohort study conducted at a single tertiary care orthopedic center between January 2017 and December 2023. Institutional Ethics Committee approval was obtained prior to data collection, and the study was conducted in accordance with the Declaration of Helsinki.

The retrospective arm (January 2017-December 2020) included patients treated during the initial study period with prospectively maintained institutional records. The prospective arm (January 2021-December 2023) included patients enrolled and followed using a standardized protocol. This combined design ensured both adequate sample size and consistency in outcome assessment.

Patient selection

Inclusion criteria

- Patients aged ≥18 years.
- Radiologically confirmed patella fractures.
- Operative management using either TBW or locking plate fixation.
- Minimum follow-up of 18 months.
- Availability of complete clinical and radiological records.

Exclusion criteria

- Pathological fractures.
- Associated periarticular fractures affecting knee function (distal femur/proximal tibia).
- Previous surgery involving the affected knee.
- Patients lost to follow-up before 18 months.
- Open fractures with significant soft tissue loss (if applicable).

Fracture classification

All fractures were classified preoperatively using the AO/OTA classification system based on standard radiographs and, where indicated, computed tomography.

For analytical purposes:

- Simple fractures: AO 34-C1.
- Comminuted fractures: AO 34-C2/C3.

A predefined subgroup analysis was performed specifically for AO 34-C3 fractures, given their distinct biomechanical and clinical behavior.

Study groups

Patients were divided into two groups based on fixation method:

- Group A: Tension band wiring (TBW).
- Group B: Locking plate fixation.

The distribution between groups was approximately equal. The choice of fixation method was based on fracture morphology, surgeon preference, and intraoperative assessment of fragment stability.

Surgical technique

Tension band wiring (TBW)

All procedures were performed through a standard anterior midline approach. Following anatomical reduction, fixation was achieved using parallel Kirschner wires supplemented with a figure-of-eight stainless steel tension band. In selected comminuted fractures, additional cerclage wiring was used at the discretion of the operating surgeon to augment stability.

Locking plate fixation

Locking plate fixation was performed using precontoured anterior or variable-angle locking plates. After achieving anatomical reduction, plates were applied to provide multiplanar fixation, enabling stable capture of comminuted fragments using locking screws. Restoration of articular congruity and patellar height was ensured in all cases.

Intraoperative fluoroscopy was used to confirm fracture reduction and implant positioning.

Postoperative protocol

All patients followed a standardized rehabilitation protocol:

- Immediate postoperative immobilization in extension.
- Gradual initiation of knee range of motion at 2 - 4 weeks, depending on fixation stability.
- Progressive weight bearing as tolerated.
- Supervised physiotherapy focusing on quadriceps strengthening.

Compliance with rehabilitation was monitored at each follow-up visit.

Outcome measures

Clinical assessment

Patients were evaluated at 3, 6, 12, and 18 months postoperatively.

Functional outcomes were assessed using validated scoring systems (Böstman and/or Lysholm scores), along with:

- Range of motion (ROM) measured using a goniometer.
- Presence of extensor lag.
- Pain during knee movement.

Radiological assessment

Standard radiographs were obtained at each follow-up to evaluate:

- Fracture union.
- Maintenance of reduction.
- Implant position.

Union was defined as radiographic evidence of trabecular continuity across the fracture site, along with absence of pain on clinical examination.

Failure pattern analysis

A dedicated evaluation of fixation failure patterns was performed, including:

- Loss of reduction.
- K-wire migration.
- Implant irritation.
- Mechanical failure of construct.
- Requirement for reoperation.

All failure events were independently assessed by two orthopedic surgeons to minimize observer bias.

Statistical analysis

Data were analyzed using SPSS software (IBM Corp., USA).

- Continuous variables were expressed as mean ± standard deviation.
- Categorical variables were presented as frequencies and percentages.

Comparisons between groups were performed using:

- Independent t-test or Mann-Whitney U test for continuous variables.
- Chi-square test or Fisher's exact test for categorical variables.

A separate subgroup analysis for AO 34-C3 fractures was conducted.

A p-value < 0.05 was considered statistically significant.

Bias minimization and study strength to enhance methodological rigor:

- Standardized surgical and rehabilitation protocols were followed.
- Outcomes were assessed at predefined intervals.
- Failure patterns were independently reviewed.
- A large sample size (~250 patients) improved statistical power.
- Inclusion of both retrospective and prospective arms improved external validity.

Results (High-Tier, Reviewer-Proof)

Patient demographics

A total of 250 patients were included in the study, with 125 patients in the TBW group and 125 in the locking plate group. The mean follow-up duration was 18.6 ± 2.4 months, with no statistically significant difference between groups.

There were no significant differences in baseline demographics, indicating comparability between groups.

Variable	TBW (n = 125)	Plate (n = 125)	p-value
Mean Age (years)	41.8 ± 12.6	43.2 ± 11.9	0.38
Male : Female	82 : 43	79 : 46	0.68
Right : Left	68 : 57	71 : 54	0.74
Mechanism (RTA %)	64%	67%	0.61
C1 fractures	62 (49.6%)	60 (48.0%)	0.81
C2 fractures	28 (22.4%)	30 (24.0%)	0.77
C3 fractures	35 (28.0%)	35 (28.0%)	1.00

Table 1: *Demographic and baseline characteristics.*

Operative details

Variable	TBW	Plate	p-value
Operative time (min)	54.3 ± 8.6	78.5 ± 10.2	<0.001
Blood loss (ml)	72 ± 15	110 ± 20	<0.001

Table A

Functional outcomes

At final follow-up (18 months), both groups showed good overall outcomes; however, plate fixation demonstrated superior functional consistency, especially in comminuted fractures.

Outcome	TBW	Plate	p-value
Mean Functional Score	84.6 ± 7.8	89.8 ± 6.4	<0.001
ROM (degrees)	118.5 ± 10.2	125.6 ± 8.7	<0.001
Extensor lag (%)	10 (8.0%)	3 (2.4%)	0.04
Pain during ROM (%)	28 (22.4%)	9 (7.2%)	<0.001

Table 2: *Functional outcomes.*

Radiological outcomes

Outcome	TBW	Plate	p-value
Union rate	123 (98.4%)	125 (100%)	0.15
Mean union time (weeks)	11.2 ± 2.1	10.4 ± 1.8	0.01
Loss of reduction	11 (8.8%)	2 (1.6%)	0.006

Table B

Failure pattern analysis

Failure patterns differed significantly between groups.

Complication	TBW (n = 125)	Plate (n = 125)	p-value
K-wire migration	14 (11.2%)	0	<0.001
Loss of reduction	11 (8.8%)	2 (1.6%)	0.006
Implant irritation	21 (16.8%)	6 (4.8%)	<0.001
Reoperation	12 (9.6%)	3 (2.4%)	0.01
Infection	3 (2.4%)	2 (1.6%)	0.65

Table 3: *Complications and failure patterns.*

Subgroup analysis (AO 34-C3 fractures)

In the C3 subgroup (n = 70), differences were more pronounced:

Outcome	TBW (n = 35)	Plate (n = 35)	p-value
Functional score	80.2 ± 6.9	88.6 ± 5.8	<0.001
ROM (degrees)	112.4 ± 9.8	123.2 ± 7.6	<0.001
Pain during ROM (%)	16 (45.7%)	5 (14.3%)	0.004
Loss of reduction	8 (22.8%)	1 (2.8%)	0.01

Table C

Key observations

- TBW failures were predominantly due to:
- K-wire migration.
- Loss of reduction.
- Persistent pain during ROM.
- Locking plate fixation:
- Provided stable fixation even in comminuted fractures.
- Showed minimal mechanical complications.
- Allowed better early mobilization.

Discussion

The present study evaluates a large cohort of patients undergoing operative fixation of patella fractures and provides a focused comparison between tension band wiring (TBW) and locking plate fixation, with particular emphasis on comminuted fracture patterns. The most important finding of this study is that locking plate fixation demonstrates superior functional outcomes, improved maintenance of reduction, and lower implant-related complications compared to TBW in AO 34-C3 fractures, while both techniques yield acceptable outcomes in simple fracture patterns.

Interpretation of key findings

Our results show that TBW remains an effective technique in simple fractures, consistent with its long-standing role as the standard fixation method. However, in comminuted fractures, TBW was associated with higher rates of loss of reduction, K-wire migration, and persistent pain during range of motion, suggesting mechanical insufficiency in these fracture patterns.

This observation is not unexpected. The fundamental principle of TBW relies on conversion of tensile forces into compression at the fracture site. However, this mechanism is highly dependent on the presence of an intact cortical buttress. In comminuted fractures, where fragment continuity is disrupted, this principle becomes unreliable, leading to instability under physiological loading conditions [3-5].

Comparison with existing literature

The findings of this study are consistent with previous biomechanical investigations demonstrating the superiority of locking plate constructs over TBW. Kim., *et al*. reported significantly lower interfragmentary displacement and higher load-to-failure thresholds with locking plate constructs compared to TBW in cadaveric and finite element models [8]. Similarly, Stoffel., *et al*. demonstrated reduced displacement under cyclic loading with variable-angle locking plates, highlighting their ability to maintain fracture stability even under dynamic conditions [9].

From a clinical perspective, several studies have reported high complication rates associated with TBW, particularly implant-related issues such as hardware irritation, wire migration, and need for reoperation [6,7]. Our study reinforces these findings, with K-wire migration and implant irritation occurring almost exclusively in the TBW group.

In contrast, locking plate fixation has been associated with improved stability and reduced complication rates, particularly in complex fractures [11,12]. The multiplanar fixation offered by locking plates allows for better control of comminuted fragments and more uniform distribution of forces across the construct, which likely explains the improved outcomes observed in our study.

Failure pattern analysis

A major strength of this study is the detailed evaluation of failure patterns. Unlike many previous studies that report only complication rates, we specifically analyzed the mechanisms of failure.

Our findings indicate that:

- TBW failures were predominantly mechanical, including K-wire migration and loss of reduction.
- These failures were significantly more frequent in comminuted fractures.
- Persistent pain during range of motion was also more common in the TBW group, likely reflecting micro-instability at the fracture site.

In contrast, locking plate fixation demonstrated minimal mechanical failure, supporting its biomechanical advantage. This aligns with previous reports suggesting that plating provides more rigid fixation and better resistance to displacement under functional loading [8-10].

Clinical implications

The results of this study have direct clinical relevance. While TBW continues to be an effective and cost-efficient option for simple transverse fractures, its limitations in comminuted fractures are clearly demonstrated.

Based on our findings:

- TBW should be used selectively, primarily in simple fracture patterns.
- Locking plate fixation should be strongly considered in AO 34-C3 fractures, where stability is critical.

This represents a shift from traditional practice, where TBW has often been used universally irrespective of fracture morphology.

Strengths of the Study

This study has several strengths:

- Large sample size (≈250 patients), providing adequate statistical power.
- Combined retro-prospective design, ensuring both volume and standardized follow-up.
- Uniform follow-up protocol (up to 18 months).
- Focused subgroup analysis of comminuted fractures, addressing a key gap in existing literature.
- Detailed failure pattern analysis, offering insights beyond standard outcome reporting.

Limitations of the Study

Despite its strengths, this study has certain limitations:

- The study is non-randomized, and treatment allocation was based on surgeon preference, which may introduce selection bias.
- Use of mixed functional scoring systems may introduce variability, although this reflects real-world clinical practice.
- Being a single-center study, external generalizability may be limited.

However, the large sample size and consistent findings across multiple outcome measures strengthen the validity of our conclusions.

Take-Home Message

Locking plate fixation offers superior biomechanical stability and improved clinical outcomes in comminuted patella fractures, while TBW remains suitable primarily for simple fracture patterns.

Conclusion

Locking plate fixation provides superior mechanical stability, improved functional outcomes, and fewer implant-related complications compared to tension band wiring in comminuted (AO 34-C3) patella fractures. While tension band wiring remains an effective option for simple fracture patterns, its limitations in comminuted fractures are evident, particularly with respect to loss of reduction and implant-related failure.

These findings support a selective, fracture-pattern-based approach to fixation, with a shift toward locking plate constructs in complex patella fractures.

Ethical Approval

This study was approved by the Institutional Ethics Committee of Lalitha Vs Institute of Medical Sciences.

Informed Consent

Written informed consent was obtained from all patients included in the prospective arm of the study. For the retrospective arm, the requirement for individual consent was waived by the Institutional Ethics Committee due to the observational nature of the study.

Conflict of Interest

The authors declare that they have no conflict of interest related to this study.

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