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Comparison of Functional Outcomes of Comminuted and Simple Patellar Fractures Treated with Tension Band Wiring

Gergi Bandı Tekniği ile Tedavi Edilen Çok Parçalı Patella Kırıklarının Fonksiyonel Sonuçlarının, Basit İki Parçalı Kırıklarla Karşılaştırılması

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ABSTRACT

Aim: This study aimed to compare the functional outcomes of comminuted (AO/OTA C3) patellar fractures treated with tension band wiring technique to those of simple two-part fractures (AO/OTA C1) treated with the same method.
Methods: Patients who underwent surgery for patellar fractures between 2017 and 2023 were retrospectively analyzed. A total of 83 patients met the inclusion criteria (C1: n=45; C3: n=38). All patients underwent open reduction and internal fixation with the tension band wiring technique. Functional outcomes were evaluated using the Böstman score. Statistical analysis was performed with SPSS 20.0 software.
Results: There was no statistically significant difference between the groups in terms of age, sex, side, follow-up duration, or implant removal rates (p>0.05). The mean Böstman score was significantly higher in the C1 group (23.33±5.07) compared to the C3 group (19.58±6.48; p=0.005), indicating better functional outcomes in the simpler fracture type.
Conclusion: The tension band wiring technique yields satisfactory results in simple two-part patellar fractures. However, it may be insufficient for comminuted fractures, suggesting a need for evaluating alternative surgical fixation techniques for such cases.

Key Words: Patellar fractures, AO/OTA classification, Tension band wiring, Böstman score, Functional outcome

ÖZ

Amaç: Bu çalışmanın amacı, gergi bandı tekniği kullanılarak tedavi edilen çok parçalı (AO/OTA C3) patella kırıklarının fonksiyonel sonuçlarını, aynı teknikle tedavi edilmiş basit iki parçalı (AO/OTA C1) patella kırıkları ile karşılaştırmaktır.
Yöntem: 2017–2023 yılları arasında patella kırığı nedeniyle opere edilen hastalar retrospektif olarak incelendi. Dahil edilme ve dışlanma kriterlerine göre 83 hasta çalışmaya alındı (C1: n=45; C3: n=38). Tüm hastalara gergi bandı tekniği ile açık redüksiyon ve iç fiksasyon uygulandı. Fonksiyonel değerlendirme Böstman skoru ile yapıldı. Verilerin analizinde SPSS 20.0 yazılımı kullanıldı.
Bulgular: İki grup arasında yaş, cinsiyet, taraf, takip süresi ve implant çıkarılma oranları açısından istatistiksel fark saptanmadı (p>0.05). C1 grubunun ortalama Böstman skoru 23.33±5.07, C3 grubunun ise 19.58±6.48 olarak bulundu (p=0.005). C1 grubunun fonksiyonel sonuçları anlamlı düzeyde daha iyi saptandı.
Sonuç: Gergi bandı tekniği, basit iki parçalı patella kırıklarında fonksiyonel açıdan tatmin edici sonuçlar vermektedir. Ancak çok parçalı kırıklarda bu yöntemin yetersiz kalabileceği ve alternatif cerrahi tekniklerin değerlendirilmesi gerektiği düşünülmektedir.

Anahtar Sözcükler: Patella kırıkları, AO/OTA sınıflaması, Gergi bandı tekniği, Böstman skoru, Fonksiyonel sonuç

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Introduction

Patellar fractures are uncommon but clinically notable, accounting for approximately 1% of all skeletal fractures and compromising the knee extensor mechanism. They typically result from direct trauma or sudden eccentric contraction of the quadriceps, which may cause avulsion-type fractures [1]. These injuries can lead to weakness in knee extension, patellofemoral arthritis, and restricted range of motion, making their management particularly important for orthopedic surgeons [2].

Among the available classification systems, the AO/OTA classification is the most widely used. AO-/OTA-type C3 fractures are the most common, followed by type C1 [3]. Surgical intervention is indicated for cases with intra-articular step-off >2 mm, fracture displacement >3 mm, open fractures, or disruption of the extensor mechanism [4]. Various surgical techniques have been described, but for transverse two-part fractures, open reduction and internal fixation (ORIF) using the tension band wiring (TBW) technique remains the most reliable and commonly employed method [5]. The success of TBW is attributed to its biomechanical principle of converting tensile forces into compressive forces at the fracture site, which promotes healing [6].

Despite favorable outcomes, postoperative complications such as wire breakage or migration, skin irritation, infection, pain, and loss of reduction are frequently reported [7,8]. While TBW is widely accepted for simple fractures, its role in the management of comminuted fractures remains controversial. Several studies have questioned its effectiveness in AO-/OTA-type C3 fractures, citing difficulties in achieving stable fixation and maintaining articular congruity [9].

Recent evidence further suggests that in highly comminuted (AO/OTA C3) fractures, conventional methods such as TBW alone may not provide sufficient stability. For example, one series reported high failure rates in C3 fractures treated solely with locking plates, whereas augmentation with soft-tissue repair or independent fragment fixation remarkably reduced fixation loss. These findings emphasize the limitations of TBW in complex comminuted fractures and underscore the need for comparative studies on functional outcomes across fracture types [10].

Building on this evidence, the present study aimed to evaluate the functional outcomes of comminuted patellar fractures (AO/OTA type C3) treated with TBW and compare them with outcomes in simple two-part fractures (AO/OTA type C1) managed using the same technique.

Methods

Study Design and Patient Selection

This retrospective study included patients who underwent surgical treatment for patellar fractures between 2017 and 2023 at a tertiary care trauma center. The study was approved by the local ethics committee (Approval No. KAEK/2025.02.34) and conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion criteria were patients aged 20–50 yr with closed AO/OTA type C1 or C3 fractures treated with ORIF using the TBW technique, a minimum follow-up of 12 months, and adherence to scheduled clinical visits.

Exclusion criteria were open fractures, severe concomitant injuries in the same extremity (neurovascular, ligamentous, or bony), systemic conditions negatively affecting healing (e.g., metabolic bone disease, chronic renal failure, and peripheral vascular disease), use of multiple Kirschner wires or cerclage wiring, use of alternative implants, prior surgery on the same knee, pathological fractures, irregular follow-up, or incomplete documentation.

After applying these criteria, 83 patients were included. Radiological and clinical follow-up data were retrieved from the hospital database. All patients were contacted and invited for final evaluation, during which Böstman scores were recorded.

Surgical Technique and Postoperative Protocol

All operations were performed within 5 days of injury by experienced orthopedic surgeons using the standard TBW technique. Patients were positioned supine on a radiolucent table and were given regional or general anesthesia,

and a pneumatic tourniquet was applied to the proximal thigh. A longitudinal anterior incision was made over the patella, and anatomical reduction was achieved using reduction clamps under fluoroscopic guidance.

Fixation of the main fragments was performed with two parallel Kirschner wires. Once satisfactory alignment and stability were confirmed, fixation was completed with a stainless steel cerclage wire following the tension band principle [11] [Figures 1 and 2]. The K-wire ends were bent, trimmed, and buried, and the wound was closed in layers.

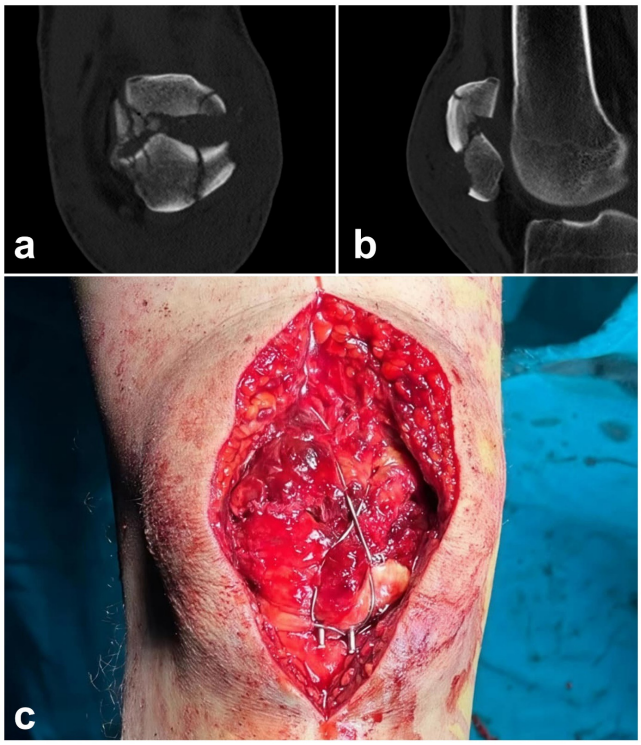

Figure 1: Preoperative computed tomography images of a patient with an AO/OTA type C3 patellar fracture in the coronal (a) and sagittal (b) planes. Intraoperative image (c) demonstrates the fixation of comminuted patellar fragments using the tension band wiring technique with Kirschner and cerclage wires, while preserving soft tissue integrity.

Figure 2: Preoperative and postoperative anteroposterior (AP) and lateral radiographs of patients with patellar fractures treated using the tension band wiring technique. AP and lateral views of a patient with an AO/OTA type C1 fracture (a). AP and lateral views of a patient with an AO/OTA type C3 fracture (b).

Postoperatively, immediate full weight-bearing was permitted. Progressive knee flexion was initiated in 30° increments every 2 weeks (30°/60°/90°). Physical therapy was prescribed when indicated. Serial radiographs were obtained during follow-up, and bone union was defined as callus formation between fracture fragments [12]. Complications such as delayed union, implant failure, infection, skin irritation, and implant removal were recorded.

Functional Evaluation

At follow-up, functional outcomes were assessed using the Böstman scoring system, a validated method for evaluating clinical results after patellar fracture treatment [13,14]. The system consists of eight parameters: range of motion (6 points), pain (6 points), work ability (4 points), quadriceps atrophy (4 points), use of walking aids (4 points), effusion (2 points), instability (2 points), and stair-climbing ability (2 points), with a maximum score of 30 [Table 1]. Scores were classified as excellent (28–30), good (20–27), or unsatisfactory (<20) [15].

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, New York). The Shapiro–Wilk test was used to assess the normality of numerical variables, and Levene's test was applied to evaluate the homogeneity of variances. Independent samples t tests were used for parametric comparisons, whereas the Mann–Whitney U test was applied when assumptions were not met. Chi-square or Fisher's exact tests were used for categorical variables. Numerical data are presented as mean ± standard deviation or median (min–max) and categorical data as frequency (n) and percentage (%). A p value <0.05 was considered statistically significant.

A post hoc power analysis was performed for variables showing significant between-group differences. Based on an effect size of 0.652 and sample sizes (C1: n = 45, C3: n = 38), the statistical power of the study was calculated as 83.3% using G*Power version 3.1.

Table 1: Böstman Scoring System

Variable	Points
Range of motion	
Full extension and range >120° or within 10° of normal side	6
Full extension, motion 90°–120°	3
Pain	
None or minimal on exertion	6
Moderate on exertion	3
In daily activities	0
Work	
Original job	4
Different job	2
Cannot work	0
Atrophy (thigh circumference difference)	
<12 mm	4
12–25 mm	2
>25 mm	0
Ambulation assistance	
None	4
Walking stick part time	2
Walking stick all time	0
Effusion	
None	2
Reported to be present	1
Present	0
Giving way	
No	2
Sometimes	1
In daily life	0
Stair climbing	
Normal	2
Disturbing	1
Disabling	0

Results

A total of 83 patients met the inclusion criteria. According to the AO classification, patients were categorized into type C1 (n = 45) and type C3 (n = 38). The mean follow-up duration was 28.33 ± 11.33 months in the C1 group and 27.97 ± 12.08 months in the C3 group. The mean patient age was 42.56 ± 10.44 yr in the C1 group and 42.08 ± 10.15 yr in the C3 group. No statistically significant differences were observed between groups with respect to age, sex distribution, fracture side, or follow-up duration ($p > 0.05$ for all comparisons).

The mean time to implant removal due to irritation was 10.91 ± 1.90 months in the C1 group and 11.43 ± 2.04 months in the C3 group. Implant removal was required in 22 patients (48.9%) in the C1 group and 22 patients (57.9%) in the C3 group, with no statistically significant difference ($p = 0.392$). No additional complications were reported in either group.

Functional evaluation with the Böstman scoring system showed a mean score of 23.33 ± 5.07 in the C1 group and 19.58 ± 6.48 in the C3 group. The difference was statistically significant ($p = 0.005$), indicating superior functional outcomes in patients with C1 fractures. A boxplot illustrating the distribution of Böstman scores between the two groups is presented in Figure 3.

A detailed summary of demographic characteristics, surgical outcomes, and functional results is provided in Table 2.

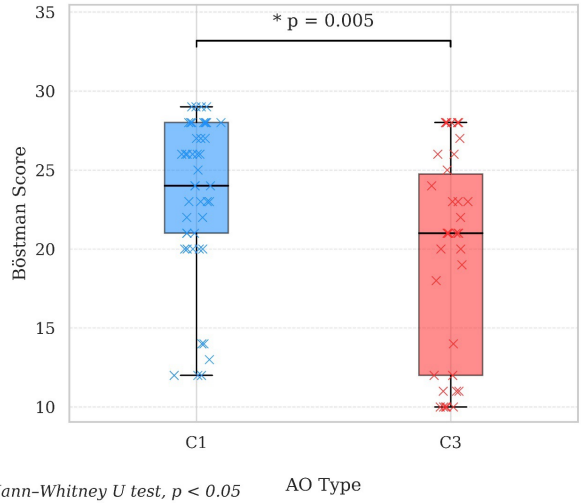

Figure 3: Dot and boxplot showing the distribution of Böstman scores in AO/OTA type C1 and C3 fracture groups. A statistically significant difference was found between the groups (p = 0.005).

Table 2: Demographic, Surgical, and Functional Data with Statistical Comparison Between C1 and C3 Groups.

Parameter	Group C1 (n = 45)	Group C3 (n = 38)	p-value
Age (years)	42.56 ± 10.44	42.08 ± 10.15	0.834
Gender (Male/Female)	32 (71.1%) / 13 (28.9%)	32 (84.2%) / 6 (15.8%)	0.249
Side (Right/Left)	21 (46.7%) / 24 (53.3%)	24 (63.2%) / 14 (36.8%)	0.200
Follow-up Duration (months)	28.33 ± 11.33	27.97 ± 12.08	0.889
Implant Removed, n (%)	22 (48.9%)	22 (57.9%)	0.550
Time to Implant Removal (months)	10.91 ± 1.90	11.43 ± 2.04	0.392
Böstman Score	23.33 ± 5.07	19.58 ± 6.48	0.005**

Values are expressed as mean ± SD for continuous variables and n (%) for categorical variables. ** $p<0.05$ was considered statistically significant (Mann–Whitney U test)

Discussion

This study compared the functional outcomes of AO/OTA type C1 and C3 patellar fractures managed with the TBW technique. The results demonstrated that patients with C1 fractures achieved remarkably higher Böstman scores than those with C3 fractures, indicating superior functional outcomes. These findings highlight the importance of fracture morphology in influencing postoperative recovery and long-term prognosis.

AO/OTA type C1 fractures are generally simple, transverse two-part fractures that allow easier anatomical reduction and more stable fixation using the tension band principle [16]. Such biomechanical suitability contributes to reliable fixation, early mobilization, and effective rehabilitation, leading to favorable outcomes. In contrast, C3 fractures represent complex comminuted patterns that present substantial challenges in achieving anatomical reduction and stable fixation, often compromising joint congruity and resulting in less optimal outcomes [17].

Consistent with our findings, Hoskins et al. [18] reported that revision surgeries following failed patellar fixation were more frequently required in patients with C3 fractures, reflecting the inherent instability and treatment challenges associated with these patterns. Although implant removal rates and timing were comparable between groups in our study, the lower Böstman scores observed in the C3 group likely reflect the mechanical limitations of TBW and the difficulties in restoring articular congruity in complex fractures.

Intra-articular fractures, such as patellar fractures, carry the long-term risk of developing osteoarthritis. Several studies have highlighted patellofemoral osteoarthritis as a complication after patellar fracture [2,19]. However, our study did not evaluate this outcome due to the relatively short follow-up period. By including only patients aged 20–50 yr, we aimed to create a standardized population with reduced baseline risk for osteoarthritis.

The TBW technique remains a widely accepted and reliable option for managing simple patellar fractures. Nonetheless, implant-related irritation and limited stability in comminuted fractures have prompted several modifications [20]. Recent reports have raised concerns regarding the adequacy of TBW for highly comminuted fractures, particularly AO/OTA type C3, because of its inability to effectively stabilize multiple small fragments [10,21,22]. Zhan et al. [23], using three-dimensional fracture mapping, demonstrated the complexity of C3 fractures and highlighted the shortcomings of traditional fixation methods in restoring stable biomechanics.

Alternative fixation strategies, such as locking plates or multiplanar constructs, have been proposed for managing comminuted patellar fractures [24,25]. Although not investigated in this study, these techniques may provide greater stability and warrant further clinical evaluation. For example, Hoskins et al. [10] reported high failure rates even with advanced patella-specific locking plates when used alone in C3 fractures. Such evidence suggests that traditional TBW and isolated plating may be inadequate in highly comminuted patterns and that combined or augmented fixation strategies should be considered in these cases. Comparative studies, such as ours, therefore play an important role in guiding treatment decisions.

Future research should incorporate a broader range of clinician- and patient-reported outcome measures to provide a more comprehensive assessment of functional recovery following patellar fracture surgery.

Limitations

This study has several limitations. First, its retrospective and single-center design may introduce selection bias and limit the generalizability of the findings. Second, only patients treated with the TBW technique were included; thus, the comparative effectiveness of alternative surgical methods was not assessed. Third, functional outcomes were evaluated exclusively with the Böstman scoring system, without incorporating additional tools such as quality-of-life assessments or patient satisfaction indices. Furthermore, functional scoring was performed retrospectively by a single evaluator, raising the possibility of

observer bias. Interobserver and intraobserver reliability were not evaluated.

Conclusion

This study demonstrated that AO/OTA type C1 patellar fractures treated with the TBW technique achieved more favorable functional outcomes than type C3 fractures. These results may be explained by the simpler anatomy and more favorable biomechanics of C1 fractures, which allow for stable fixation and effective rehabilitation. In contrast, the complexity of C3 comminuted fractures poses remarkable challenges to achieving and maintaining anatomical reduction with TBW, thereby limiting its effectiveness.

These findings suggest that the efficacy of traditional fixation methods may be restricted in complex fracture patterns such as C3. Future prospective, randomized studies comparing alternative fixation strategies are warranted to determine the optimal approach for managing comminuted patellar fractures.

Although TBW remains a widely used and effective method for simple patellar fractures, this study highlights the importance of considering patient-specific factors and fracture complexity when selecting surgical techniques.

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Ethics Committee Approval: The study was approved by Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee (Approval No: KAEK/2025.02.34) and conducted under the principles of the Declaration of Helsinki.

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