

Surgical strategies for coronoid fixation in terrible triad elbow injuries: A comparative analysis of Tight-Rope and screw fixation

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ABSTRACT

BACKGROUND: The terrible triad of the elbow describes a complex injury pattern characterized by elbow subluxation or dislocation, rupture of the lateral ulnar collateral ligament (LUCL), and concomitant fractures of the radial head and coronoid process. This study aimed to evaluate and compare the clinical outcomes of patients with terrible triad injuries treated surgically at our institution, in whom coronoid fractures were managed using either screw fixation or the Tight-Rope technique.

METHODS: This retrospective cohort study included patients who underwent surgical treatment for terrible triad injuries between January 2017 and December 2023. Patients with Regan–Morrey type 2 or 3 coronoid fractures treated using the Tight-Rope technique were assigned to the Tight-Rope group, whereas those treated with screw fixation comprised the Screw group. Demographic characteristics, range of motion (ROM), visual analog scale (VAS) scores, and QuickDASH (Quick Disabilities of the Arm, Shoulder and Hand) scores at 3, 6, and 12 months postoperatively were analyzed. Patients with type I fractures, medial collateral ligament (MCL) injuries, follow-up <12 months, or a history of systemic infection were excluded.

RESULTS: Twenty-nine patients were included (11 in the Tight-Rope group and 18 in the Screw group). No significant differences were observed between the groups in terms of ROM or VAS and QuickDASH scores at 3, 6, and 12 months. After excluding cases requiring LUCL reconstruction and analyzing only patients who underwent LUCL repair (8 Tight-Rope, 13 Screw), the only statistically significant difference was a lower 12-month QuickDASH score in the Screw group. Complications included superficial cellulitis (1 Tight-Rope, 2 Screw) and heterotopic ossification (2 Tight-Rope, 3 Screw), all of which were managed conservatively. Post hoc power analysis based on 12-month QuickDASH scores, VAS scores, and elbow ROM (effect size $d=0.77$, $\alpha=0.05$) demonstrated power of 77%, 71%, and 74%, respectively.

CONCLUSION: Functional outcomes were largely comparable between Tight-Rope and screw fixation techniques. These findings align with emerging evidence questioning the routine necessity of coronoid fixation and underscore the importance of individualized surgical decision-making.

Keywords: Lateral ulnar collateral ligament (LUCL); screw fixation; terrible triad; coronoid fracture; tight-rope.

INTRODUCTION

The terrible triad of the elbow describes a complex injury pattern characterized by elbow subluxation or dislocation, rupture of the lateral ulnar collateral ligament (LUCL), and concomitant fractures of the radial head and coronoid pro-

cess.^[1-3] Owing to the difficulty of restoring joint stability, treatment is typically surgical, with the goals of enabling early mobilization and achieving satisfactory postoperative range of motion.^[4-6] Operative strategies commonly include LUCL repair or tendon-based reconstruction, in addition to fixation of the radial head and coronoid using various techniques.^[6,7]

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The coronoid process serves as a primary stabilizer of the elbow by resisting posterior displacement of the ulna.^[8,9] Despite its recognized importance, no consensus has been established regarding the necessity of coronoid fixation or the optimal surgical technique, and this issue remains controversial.^[10,11] In terrible triad injuries, there is broad agreement on the importance of LUCL repair or reconstruction and radial head replacement or fixation; however, the management of Regan-Morrey type 1 and type 2 coronoid fractures continues to be debated.^[12] Although many surgeons advocate fixation of these fractures, recent cadaveric studies suggest that when the lateral ligament complex and radial head are adequately reconstructed, sufficient elbow stability may be achieved without coronoid fixation.^[13]

Coronoid fixation is technically demanding and associated with a steep learning curve. A variety of techniques have been described, including posterior pull-out sutures, lag screw fixation, precontoured locking plates, suture lasso fixation, the Tight-Rope technique, and suture anchor fixation.^[12,14-17] However, it remains unclear which method provides superior outcomes, underscoring the need for comparative studies in this area.^[13,18,19]

This study aimed to evaluate and compare the clinical outcomes of patients with terrible triad injuries treated surgically at our institution, in whom coronoid fractures were managed using either screw fixation or the Tight-Rope technique.

MATERIALS AND METHODS

Study Design and Ethical Approval

This study was designed as a retrospective cohort study conducted at a single tertiary referral center. The medical records of patients who underwent surgical treatment for terrible triad injuries of the elbow between January 2017 and December 2023 were reviewed. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Local Scientific Ethics Committee on May 14, 2025 (Approval No: E-25-505).

Study Population

Inclusion Criteria

Patients were eligible for inclusion if they met all of the following criteria:

- Diagnosis of a terrible triad injury requiring surgical intervention
- Presence of a Regan–Morrey type 2 or type 3 coronoid fracture
- Surgical fixation of the coronoid process using either:
 - the Tight-Rope (suture-button) technique, or
 - screw fixation
- Minimum postoperative follow-up of 12 months.

Exclusion Criteria

Patients were excluded if any of the following criteria were present:

- Age <18 years or >65 years
- Regan–Morrey type 1 coronoid fractures
- Concomitant medial collateral ligament (MCL) injury
- History of systemic infection
- Inadequate follow-up (<12 months).

Methodological Clarification

Patients with MCL injuries were intentionally excluded to eliminate the confounding effect of medial-sided instability. Therefore, any medial or anteromedial surgical approach used in this study was performed solely to enhance visualization and fixation of the coronoid when adequate exposure could not be achieved through a lateral approach, and not for MCL repair or reconstruction.

Surgical Technique

All surgical procedures were performed under general anesthesia with the patient in the supine position.

Surgical Exposure

A lateral approach was employed as the standard initial incision in all cases. When adequate visualization of the coronoid fragment was compromised, due to obstruction by the radial head or fracture morphology, a supplementary anteromedial or medial approach was added. Intraoperatively, valgus stress testing was routinely conducted; patients demonstrating medial joint opening suggestive of MCL insufficiency were excluded from the study.

Coronoid Fixation Techniques

Tight-Rope Technique

Following exposure of the coronoid fragment, a 2.5-mm Kirschner wire was used to create a retrograde tunnel from the posterior aspect of the olecranon to the coronoid process. The suture-button construct was subsequently passed antegrade through the tunnel, and fixation was secured posteriorly using a single Endobutton while maintaining anatomical reduction of the fragment (Figure 1).

Screw Fixation

Screw fixation was performed using either retrograde or antegrade screws, depending on fracture morphology and surgical accessibility. The goal of fixation was to achieve stable buttressing of the coronoid fragment (Figure 2).

Associated Procedures

Radial head fractures were managed with screw or plate fixation based on fracture characteristics. The lateral ulnar collateral ligament was repaired when tissue quality permitted tension-free reattachment. In cases where primary repair was not feasible, LUCL reconstruction was performed using a palmaris longus autograft.



Figure 1. A 27-year-old male from the Tight-Rope group. (a-b) Preoperative AP and lateral X-rays; (c-d) sagittal CT images; (e-f) postoperative radiographs with Tight-Rope fixation visible (red ellipses). All steps were performed through a single lateral incision.



Figure 2. A 38-year-old male from the screw fixation group. (a-b) Preoperative AP and lateral X-rays; (c-d) sagittal CT images showing coronoid and radial head fractures; (e-f) postoperative AP and lateral radiographs. Due to inadequate visualization through a single lateral incision, an additional anteromedial approach was required.

Postoperative Rehabilitation Protocol

A standardized, structured postoperative rehabilitation protocol was implemented for all patients, regardless of whether LUCL repair or reconstruction was performed. Although LUCL repair involves tendon-to-tendon healing and reconstruction requires tendon-to-bone integration, a uniform rehabilitation strategy was adopted. This approach was based on established biomechanical and biological principles indicating that early controlled mobilization, combined with strict avoidance of varus stress, provides sufficient protection for both healing processes while minimizing postoperative stiffness and functional limitations.

Rehabilitation Phases

Phase 1: Immobilization (Weeks 0–3)

- Application of a long-arm splint with the elbow in flexion
- Protection of ligamentous and osseous repairs
- Strict avoidance of varus stress

Phase 2: Early Controlled Mobilization (Weeks 3–6)

- Initiation of isometric flexion–extension exercises
- Supination–pronation exercises performed with the elbow at 90° of flexion
- Continued avoidance of varus loading

Phase 3: Functional Strengthening (Weeks 6–12)

- Progressive strengthening exercises
- Gradual increase in functional use and weight-bearing activities
- Heavy lifting permitted after 3 months.

This rehabilitation strategy is consistent with previously published protocols that emphasize early mobilization under controlled conditions following complex elbow instability surgery and LUCL reconstruction or repair. Such approaches

have been shown to reduce postoperative stiffness without compromising stability.^[20–22]

Outcome Measures

Patients were evaluated at 3, 6, and 12 months postoperatively. The following outcome measures were assessed:

- Elbow range of motion (ROM)
- Visual Analog Scale (VAS) score for pain
- Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score.

Statistical Analysis

Statistical analyses were performed using SPSS version 30.0, provided by SPSS Inc. in Chicago, USA. Continuous variables were analyzed using the independent-samples t-test, whereas categorical variables were compared using the chi-square test. A p-value <0.05 was considered statistically significant.

Power Analysis

A post hoc power analysis was conducted using G*Power version 3.1, based on 12-month QuickDASH scores, VAS scores, and elbow ROM outcomes. Assuming an effect size of $d=0.77$ and an alpha level of 0.05, the calculated statistical power was 77% for QuickDASH, 71% for VAS, and 74% for ROM, given the sample sizes of 11 patients in the Tight-Rope group and 18 patients in the Screw group.

RESULTS

Twenty-nine patients were included in the analysis: 11 in the Tight-Rope group and 18 in the Screw group. Demographic and clinical characteristics are summarized in Table 1.

Functional Outcomes

No statistically significant differences were observed between the groups with respect to QuickDASH scores, VAS scores,

Table 1. Baseline demographic and group-specific characteristics

Characteristic Group	Tight-Rope n=11 (37.9%)	Screw n=18 (62.1%)	Total n=29 (100%)
Age (Mean)	34.55	34.06	34.24
Gender			
Female	3 (27.3%)	5 (27.8%)	8 (27.6%)
Male	8 (72.7%)	13 (72.2%)	21 (72.4%)
Side			
Right	7 (63.6%)	12 (66.7%)	19 (65.5%)
Left	4 (36.4%)	6 (33.3%)	10 (34.5%)
LUCL Treatment			
Repair	8 (72.7%)	13 (72.2%)	21 (72.4%)
Reconstruction	3 (27.3%)	5 (27.8%)	8 (27.6%)

Table 2. Group-specific range of motion (ROM), QuickDASH, and Visual Analog Scale (VAS) scores

	Tight-Rope n=11	Screw n=18	p value	SED	95% CI	
					Upper	Lower
Range of Motion (°)	131.45	129.00	0.196	1.850	-1.341	6.250
QuickDASH (3rd Month)	25.00	24.56	0.657	0.989	-1.586	2.474
QuickDASH (6th Month)	15.82	16.72	0.168	0.639	-2.215	0.407
QuickDASH (1st Year)	8.91	7.72	0.098	0.693	-0.235	2.609
VAS (3rd Month)	24.00	25.50	0.063	0.774	-3.089	0.089
VAS (6th Month)	17.18	16.61	0.466	0.772	-1.014	2.155
VAS (1st Year)	10.09	9.33	0.354	0.803	-0.890	2.542

Table 3. Group-specific range of motion (ROM), QuickDASH, and Visual Analog Scale (VAS) scores in patients undergoing lateral ulnar collateral ligament (LUCL) repair only (excluding reconstruction with palmaris longus tendon autograft)

	Tight-Rope n=8	Screw n=13	p value	SED	95% CI	
					Upper	Lower
Range of Motion (°)	132.00	128.92	0.151	2.054	-1.222	7.376
QuickDASH (3rd Month)	24.75	24.00	0.533	1.182	-1.724	3.224
QuickDASH (6th Month)	15.38	16.92	0.053	0.749	-3.116	0.020
QuickDASH (1st Year)	9.25	7.31	0.023	0.787	0.295	3.589
VAS (3rd Month)	24.50	25.46	0.248	0.807	-2.650	0.727
VAS (6th Month)	17.25	16.31	0.314	0.912	-0.967	2.851
VAS (1st Year)	9.88	9.23	0.507	0.951	-1.347	2.636

or ROM measurements at 3, 6, and 12 months postoperatively (Table 2).

After excluding patients who underwent LUCL reconstruction and analyzing only those treated with LUCL repair (8 in the Tight-Rope group and 13 in the Screw group), the results remained comparable between groups, except for a lower 12-month QuickDASH score in the Screw group (Table 3).

Surgical Exposure

Five patients (17.2%) required supplementary non-lateral exposure to achieve coronoid visualization:

- Tight-Rope group: 2 patients (1 medial, 1 anteromedial approach)
- Screw group: 3 patients (1 medial, 2 anteromedial approaches).

Complications

No nerve injuries or fixation failures were observed. Superficial cellulitis developed in one patient in the Tight-Rope group and two patients in the Screw group; all cases resolved with oral antibiotic therapy.

Heterotopic Ossification

Heterotopic ossification (HO) occurred in two patients in the Tight-Rope group and three patients in the Screw group. All cases were managed conservatively according to standard HO protocols, and no patient required surgical excision.

Union

Radiographic union of both the coronoid and radial head fractures was achieved in all patients at final follow-up.

DISCUSSION

This study compared two different coronoid fixation techniques—screw fixation and the Tight-Rope technique—in patients with terrible triad injuries who underwent restoration of both the radial head and the lateral ulnar collateral ligament. Our results demonstrated largely comparable outcomes between the two fixation approaches in terms of elbow range of motion, pain scores, and functional outcomes throughout the 12-month follow-up period. The only statistically significant difference observed was a lower 12-month QuickDASH score in the screw fixation group among patients who underwent LUCL repair. However, the magnitude of this difference was modest and of uncertain clinical relevance.

The interpretation of these findings should be considered within the broader context of the evolving literature on coronoid management. Recent studies have suggested that the necessity of routine coronoid fixation—particularly in Regan–Morrey type 1 and type 2 fractures—may vary and depend more on overall elbow stability than on the fixation technique itself.^[13,23–25] Importantly, our study did not evaluate non-fixation strategies and, therefore, should not be interpreted as supporting or opposing the omission of coronoid fixation. Rather, our findings indicate that when coronoid fixation is performed within a stable construct, the choice of technique (screw versus Tight-Rope) may have limited influence on short-term functional outcomes.

Several contemporary studies have investigated the relationship between fixation method and clinical recovery. Shengdi et al. (2023) conducted a prospective randomized controlled trial (RCT) comparing screw fixation, external hinged fixation, and plaster immobilization for coronoid fractures in terrible triad injuries.^[26] They reported minimal differences in functional outcomes at final follow-up, although external fixation was associated with improved early pain control.^[26] Similarly, Ahn et al. (2024) found no significant differences in outcomes between fixation and non-fixation groups at approximately two years in stable terrible triad reconstructions, further supporting the notion that the role of coronoid fixa-

tion may depend more on the integrity of global stabilizers than the specific fixation device used.^[13] While these studies primarily address whether coronoid fixation is necessary, our study instead focuses on comparing two fixation techniques in cases where fixation was considered clinically indicated.

Technical considerations influence the choice of fixation method. Screw fixation is widely used and provides rigid stabilization, particularly in fractures with adequate bone stock. In their biomechanical review, Ahn et al. highlighted the superior buttressing effect and early stability achieved with mini-plate and screw constructs compared with suture-based constructs in coronoid fractures.^[13] Although plate fixation was not performed in our series, these findings may partially explain the slightly better QuickDASH outcomes observed in the screw group, especially among patients with larger fragments.

Conversely, minimally invasive or anterior buttress-oriented approaches may offer specific advantages in selected patients. Chang et al. (2024) reported excellent midterm outcomes using a coronoid-first anterior approach, emphasizing the importance of exposure and visualization when managing coronoid process fractures.^[24] Lin et al. (2024) further described fluoroscopy-guided, minimally invasive anteromedial techniques designed to reduce soft tissue disruption and facilitate earlier mobilization.^[27] In our cohort, although the lateral approach was used as the standard technique, the need for supplemental medial or anteromedial exposure in several cases underscores the importance of flexible and individualized surgical strategies.

The Tight-Rope (suture-button) technique remains less extensively studied in the setting of elbow instability but has demonstrated promising results in analogous joints, such as the ankle syndesmosis, where suture-button constructs have shown outcomes comparable to screw fixation.^[27,28] The biological and biomechanical principles underlying these constructs may support their application in selected coronoid fractures. Our findings suggest that the Tight-Rope technique, when appropriately applied, yields outcomes comparable to screw fixation without increased complication rates or risk of failure.

Several important insights emerge from this study:

1. When coronoid fixation is performed, both screw and Tight-Rope techniques appear to provide comparable short-term clinical and radiographic outcomes.
2. The fixation method alone may not be the primary determinant of postoperative function, provided that adequate restoration of the radial head and LUCL is achieved.
3. Approach flexibility remains essential, as anatomical variation and fracture patterns frequently necessitate tailored exposure, including supplemental medial or anteromedial incisions.

4. These findings contribute to the ongoing discussion regarding coronoid fracture management, while remaining distinct from studies evaluating fixation versus non-fixation strategies.

This study has several limitations. Its retrospective design and relatively small sample size reduce the power to detect subtle between-group differences, as reflected in the post hoc power analysis. Follow-up was limited to 12 months, and long-term outcomes may differ, particularly with respect to post-traumatic arthritis or late instability. Additionally, intraoperative photographs were unavailable, limiting visual documentation of the surgical techniques. Stratification by fracture size or morphology was not performed, which may influence fixation stability or technique selection. Future multicenter, prospective randomized studies with larger cohorts and longer follow-up are required to clarify the optimal coronoid fixation strategy and to determine whether fixation can be safely omitted in selected cases.

CONCLUSION

In this study, we compared two coronoid fixation methods—screw fixation and the Tight-Rope technique—in terrible triad injuries managed with restoration of the radial head and the lateral ulnar collateral ligament. Our findings showed that both techniques resulted in similar clinical and functional outcomes at 12 months. A modest difference favoring screw fixation was observed in the QuickDASH scores among patients who underwent LUCL repair; however, the clinical relevance of this difference appears limited, as no significant advantages were observed in pain scores, range of motion, radiographic healing, or complication rates.

Importantly, this study does not address fixation versus non-fixation strategies. Therefore, our results should not be interpreted as supporting or refuting routine coronoid fixation. Rather, the data indicate that when coronoid fixation is performed, the choice between screw fixation and a suture-button construct yields largely comparable outcomes. Both methods may therefore represent viable options when selected according to fracture morphology, exposure requirements, and surgeon preference.

These findings align with the current literature indicating that postoperative stability in terrible triad injuries is primarily determined by restoration of the radial head and ligamentous structures. Within this stable reconstructive framework, the specific coronoid fixation technique may play a secondary role in early functional recovery.

Future prospective, adequately powered comparative studies—including cohorts managed without coronoid fixation—are necessary to further clarify fixation indications and define the optimal surgical strategy for coronoid fractures in terrible triad injuries.

Ethics Committee Approval: This study was approved by the Ankara Training and Research Hospital Ethics Committee

(Date: 14.05.2025, Decision No: E-25-505).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - ÖZ

Dirsek terrible triad yaralanmalarında koronoid fiksasyonuna yönelik cerrahi stratejiler: Tight-rope ve vida fiksasyonunun karşılaştırmalı analizi

AMAÇ: Dirseğin “terrible triad” yaralanması; dirsek subluksasyonu veya dislokasyonu, lateral ulnar kollateral ligament (LUCL) yırtığı ve eşlik eden radius başı ile koronoid kırıklarını içeren kompleks bir yaralanma paternini ifade eder. Bu çalışma, kliniğimizde cerrahi olarak tedavi edilen terrible triad yaralanmalı hastalarda, koronoid kırıklarının vida fiksasyonu veya tight-rope tekniği ile tedavi edildiği hastaların klinik sonuçlarını değerlendirmeyi ve karşılaştırmayı amaçlamaktadır.

GEREÇ VE YÖNTEM: Bu geriye dönük kohort çalışmasına, Ocak 2017 ile Aralık 2023 tarihleri arasında “terrible triad” yaralanması nedeniyle cerrahi tedavi uygulanan hastalar dâhil edilmiştir. Regan–Morrey tip 2 veya 3 koronoid kırığı bulunan ve Tight-Rope tekniğiyle tedavi edilen hastalar Tight-Rope grubuna, vida fiksasyonu ile tedavi edilenler ise Vida grubuna ayrılmıştır. Demografik özellikler ile birlikte 3., 6. ve 12. aylarda ölçülen hareket açıklığı (ROM), görsel analog skala (VAS) ve QuickDASH skorları analiz edilmiştir. Tip I kırığı olanlar, medial kollateral bağ (MCL) yaralanması bulunanlar, 12 aydan kısa takip süresi olanlar ve sistemik enfeksiyon öyküsü bulunan hastalar çalışma dışı bırakılmıştır.

BULGULAR: Yirmi dokuz hasta çalışmaya dâhil edildi (11 Tight-Rope, 18 Vida). Üç, altı ve on iki aylık değerlendirmelerde iki grup arasında QuickDASH, ROM ve VAS skorları açısından anlamlı bir fark saptanmadı. LUCL rekonstrüksiyonları dışlanıp yalnızca LUCL tamiri yapılan hastalar incelendiğinde (8 Tight-Rope, 13 Vida), istatistiksel olarak anlamlı tek bulgu, vida grubunda 12. ay QuickDASH skorunun daha düşük olmasıydı. Komplikasyonlar arasında yüzeysel selülit (1 Tight-Rope, 2 Vida) ve heterotopik ossifikasyon (2 Tight-Rope, 3 Vida) yer aldı; tümü konservatif olarak tedavi edildi. Post-hoc güç analizi, 12. ay QuickDASH, VAS ve dirsek ROM değerlerine göre (etki büyüklüğü $d=0.77$ ve $\alpha=0.05$), sırasıyla %77, %71 ve %74 güç gösterdiği görülmüştür.

SONUÇ: Bu çalışmanın bulguları, her iki tekniğin genel fonksiyonel sonuçlarının benzer olduğunu göstermektedir. Elde edilen sonuçlar, koronoid fiksasyonunun rutin olarak uygulanmasının gerekliliğini sorgulayan güncel literatürle uyumludur ve hasta bazlı, patolojiye özgü cerrahi karar verme süreçlerinin önemini vurgulamaktadır.

Anahtar sözcükler: Koronoid kırığı; LUCL; terrible triad; tight-rope; vida fiksasyonu.

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