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# Management of Post-Traumatic Elbow Stiffness: A Systematic Review of Randomized Controlled Trials with Meta-Analysis

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**SUMMARY**

**Introduction.** This systematic review (SR) and meta-analysis aimed to assess the effectiveness of surgical and conservative treatments for post-traumatic elbow stiffness in improving pain, functionality, and quality of life.
**Methods.** A comprehensive search of PubMed, Scopus, Web of Science, and Cochrane Library databases was conducted for English-language studies up to April 2024. Randomized clinical trials (RCTs) focusing on surgical or conservative interventions for post-traumatic elbow stiffness were included. Primary outcomes were pain, functionality, and quality of life. Study quality and risk of bias were assessed using the Cochrane Risk of Bias 2 tool, while evidence certainty was evaluated with GRADE methodology.
**Results.** Twelve RCTs met the inclusion criteria. Surgical interventions, particularly open arthrolysis combined with early structured rehabilitation and intraoperative pain modulation, significantly improved long-term range of motion (ROM) compared to standard postoperative care, though evidence quality was low due to methodological limitations. Conservative treatments, such as muscle energy techniques (MET), provided short-term improvements in pain and functionality but lacked consistent long-term data.
**Conclusions.** Conservative treatments like MET are recommended for mild to moderate post-traumatic elbow stiffness. Severe cases or those unresponsive to conservative care benefit more from open arthrolysis followed by early rehabilitation and adjunct therapies. Further high-quality RCTs are needed to confirm these findings and refine treatment protocols.

**KEY WORDS**
*Elbow; stiffness; surgery; rehabilitation; physiotherapy.*

## INTRODUCTION

The elbow plays a fundamental role in the upper limb's mobility, as it, along with the shoulder, ensures the correct positioning of the hand in space (1). Most activities of daily living (ADL) are performed within a functional ROM of 100°, ranging from 30° of extension to 130° of flexion, as well as 100° of rotation, including 50° for pronation and 50° for supination (2). Reduced elbow mobility can lead to difficulties in performing ADL to varying degrees and may restrict participation in work and social activities (3). After a traumatic event, there are multiple factors that can contribute to a reduction in the physiological ROM of the elbow (4). The complex anatomy and biomechanics make the elbow joint particularly prone to post-traumatic stiffness (5). Elbow stiffness is defined when the range of motion is 30°-120° in flexion-extension or less (6), or when pronation-supination is less than 50° (7). The incidence of post-traumatic stiffness is not well-defined in the literature, with Sojbjerg's 1996 study suggesting at least 5% (6), while a study by Zheng's group in 2018 found that more severe stiffness is associated with high-energy traumas (8).

Tissue changes that occur after a traumatic event can lead to the development of capsular fibrosis or heterotopic ossification processes (9). Post-traumatic capsular thickening leading to joint stiffness appears to be associated with a high presence of myofibroblasts, cytokine alterations, and disorganized collagen fiber production (10).

Among the classifications of post-traumatic elbow stiffness commonly used in the literature, there is Morrey's classification (11), which distinguishes types based on anatomical location: intrinsic, extrinsic, and combined. Intrinsic types involve the joint surface, such as misalignments or joint adhesions and loss of cartilaginous components. Extrinsic types include everything outside the joint, such as capsular contractures, ligament issues, heterotopic ossification, extra-articular misalignments, or fibrotic phenomena in soft tissues following burns. The most frequent category includes both intra and extra-articular elements and falls under combined types.

The multifactorial nature of stiffness necessitates a thorough clinical evaluation for proper assessment. It should encompass a comprehensive patient history with post-traumatic stiffness, seeking to identify the initial trauma and how it was managed up to the evaluation (12). Associated conditions such as neurological disorders, infections, or other traumas need to be considered for a correct diagnostic framework. Equally important are factors such as the timing of clinical manifestation, the characteristics and progression of symptoms, and the pre-morbid functional level, which influence the decision-making process. For example, stiffness detected in the mid-range of motion might indicate joint incongruity or an arthritic condition, while "end-range" stiffness could be attributed to an olecranon-humerus conflict (13). In the evaluation it is also important to consider psychosocial factors: patients with post-traumatic elbow stiffness may experience depression and anxiety (14), due to the impact that the pathology has on daily activities, therefore a transition from a purely biomedical framework to a bio-psycho-social one as already demonstrated for lateral elbow pain (15).

Treatment options for post-traumatic elbow stiffness can be surgical or conservative. The heterogeneity of clinical presentations has not yet provided a clear picture of which approach is more appropriate. In the absence of mechanical conflict causing stiffness due to poor healing, dislocations, or heterotopic ossification, conservative treatment is recommended (5). If signs and symptoms persist for at least 6-12 months, conservative treatment may not be recommended (9). Conservative treatment mainly consists of physiotherapy interventions, including manual therapy techniques, therapeutic exercise, and educational aspects. In the initial phases, treatments with static and dynamic braces have shown their effectiveness in both post-traumatic and post-operative stiffness (16, 17). The use of continuous passive motion (CPM) is highly controversial, despite its clinical use; Carpenter *et al.* have reported potential risks related to bleeding, edema, and possible ulnar nerve issues (18).

Surgical approaches have shown satisfactory outcomes after contracture release techniques (5). There are various described techniques that involve more or less extensive release, both open and arthroscopic, with or without the use of external fixators (19). The classification and decision-making algorithm proposed by Pederzini *et al.* published in 2024 (20) provide an updated framework for surgical planning in elbow stiffness, helping to distinguish between extrinsic and intrinsic forms and guide appropriate intervention strategies. Wang *et al.* (21) focused specifically on post-traumatic elbow stiffness associated with heterotopic ossification, supporting the efficacy of surgical excision combined with structured postoperative rehabilitation and prophylactic measures to prevent recurrence. Tedesco *et al.* (22) described a surgical technique for lateral ulnar collateral ligament (LUCL) repair in terrible triad injuries, a condition often resulting in significant post-traumatic elbow stiffness. Their method using a suture button contributes to restoring stability and facilitating early mobilization post-surgery. In the context of elbow release procedures, Xu *et al.* (23) explored the role of anterior ulnar nerve transposition in patients with post-traumatic elbow stiffness, concluding that this approach improves outcomes in symptomatic cases, while in situ release may be sufficient in the absence of neurological symptoms. Oliva *et al.* (24) systematically reviewed the surgical management of chronic distal triceps tendon rupture, an often-underdiagnosed condition that may coexist with or contribute to post-traumatic elbow stiffness. Recognizing and addressing these injuries is essential for optimizing functional recovery.

Currently, there are no secondary studies that have investigated through a SR whether there is a better approach, be it conservative or surgical, in terms of improving pain, function and quality of life for post-traumatic elbow stiffness. Therefore, the aim of this SR is to investigate potential differences in terms of improvement in pain, function and quality of life between different approaches in the treatment of post-traumatic elbow stiffness.

## MATERIALS AND METHODS

This SR was conducted following the methodological guidelines outlined in the PRISMA 2020 checklist (25). The review protocol has been registered in the PROSPERO system (CRD42023426417).

### Eligibility criteria

The study question was framed using the Population, Intervention, Comparison, and Outcome (PICO) model (26). The PICO question was composed by P: Adults with post-traumatic elbow stiffness; I: Conservative treatments; C: Surgical treatments; O: Pain, function, quality of life.

Articles that met the following inclusion criteria were included in this SR: 1. English written; 2. RCTs; 3. Adult population (age ≥ 18 years); 4. Patients with post-traumatic elbow stiffness; 5. Patients undergoing surgical treatment or conservative treatment; 6. Studies that measured outcomes in the domains of pain, function (*i.e.*, ROM variations, muscle strength, PROMs, *etc.*) and quality of life.

All types of post-traumatic elbow stiffness were included, whether treated conservatively or surgically. We therefore included RCTs that evaluated the effects of different conservative approaches on each other, the effects of different surgical approaches on each other, and studies that analyzed conservative *versus* surgical interventions. For conservative treatment is intended all physiotherapy approaches typically used for post-traumatic elbow stiffness such as manual therapy (*i.e.*, muscle energy techniques, mobilization with movement, passive mobilizations, manipulations, *etc.*) therapeutic exercise (active mobilizations, resistance training, aerobic training, *etc.*), splinting (static or dynamic) and CPM. We considered as surgical treatments: open release, arthroscopic release and open arthrolysis combined with or without external fixation, with or without concomitant distraction.

### Search strategy

A bibliographic search was conducted on April 2024, in the following databases: US National Library of Medicine (PubMed/MEDLINE), SCOPUS, Web of Science (WOS), and the Cochrane Database of Systematic Reviews. No time limits were applied for article inclusion.

MeSH terms and keywords specific to each database consulted were used for the search string. Additionally, manual searches were performed. The search strings are available in **supplementary materials**. To improve the research itself, the reference lists of the included studies and the relevant reviews in the literature on the topic were also consulted.

### Selection process and data extraction

Duplicates were primarily detected and excluded through the Rayyan web app for systematic reviews (27). Two reviewers (FS, LDF) independently assessed the titles and abstracts for eligibility. The reviewers who selected the trials (FS and LDF) remained independent throughout the selection process. At the conclusion of this phase, the two reviewers (FS, LDF), independently assessed the full text of the articles to confirm they met the eligibility criteria. Once the studies for inclusion were selected, the data were extracted from the two reviewers (FS, LDF) independently. Any discrepancies or disagreements between the two reviewers identified were discussed and resolved with the assistance of a third reviewer (FM, EM, ML). For studies with incomplete data or data that were not directly accessible, an initial effort was made to reach out to the corresponding author for clarification. If there was no response or if additional data could not be provided, the articles were excluded from the study.

### Study risk of bias assessment

The methodological quality of the included studies was assessed by two independent reviewers (FS, LDF) and a third reviewer (FM, EM, ML) was consulted in case of disagreements to find a resolution. The Cochrane risk of bias tool (RoB2) (28) for randomized trials was used to assess the methodological quality of the included studies. The GRADE approach was used to rate the quality and strength of evidence as high, moderate, low, and very low regarding the main outcome (pain, function, and quality of life). Results summary tables were generated using GRADE pro Software.

### Statistical analysis

Effect estimates from continuous data were calculated as mean difference (MD) or standardized mean difference (SMD) depending on the measurement scales used in the studies. MD was used when the studies included reported the outcome using the same units (*e.g.*, ROM, VAS), while SMD was chosen for continuous outcomes with different measurement units, according to section 10.5.1 of the Cochrane Handbook for systematic reviews (29). We used the ProMeta3 computer program to perform statistical analyses. We pooled data using random-effect models when large heterogeneity was assessed through I2 statistics (value greater than 50% was considered indicative of large heterogeneity) (30, 31).

## RESULTS

### Study selection

Through the systematic search of online databases, 6,198 articles were included. The analysis of duplicates using the Rayyan software led to the exclusion of 1,678 articles considered duplicates. The first screening phase through the analysis of title, abstract and keywords led to the exclusion of 4,050 articles as they did not meet the inclusion criteria. 1,632 articles were excluded because the background of the article did not meet the inclusion criteria, 1,678 articles were eliminated due to the study design, 320 studies were excluded due to the type of publication, 420 for including a population different from the one investigated (adults with post-traumatic elbow stiffness). 200 remaining articles were then analyzed in detail to assess their eligibility. 115 articles were excluded because they did not meet the inclusion criteria regarding the study design, another 29 were excluded because they were written in a foreign language (not in English), 34 were excluded because the type of publication was not deemed appropriate (study protocols), 8 articles were excluded because they included a pediatric population (under 18 years of age) and 2 studies were excluded because the outcomes did not meet the PICO question and the inclusion criteria. Finally, 12 articles were included, all RCTs. The search process is summarized in **figure 1**.

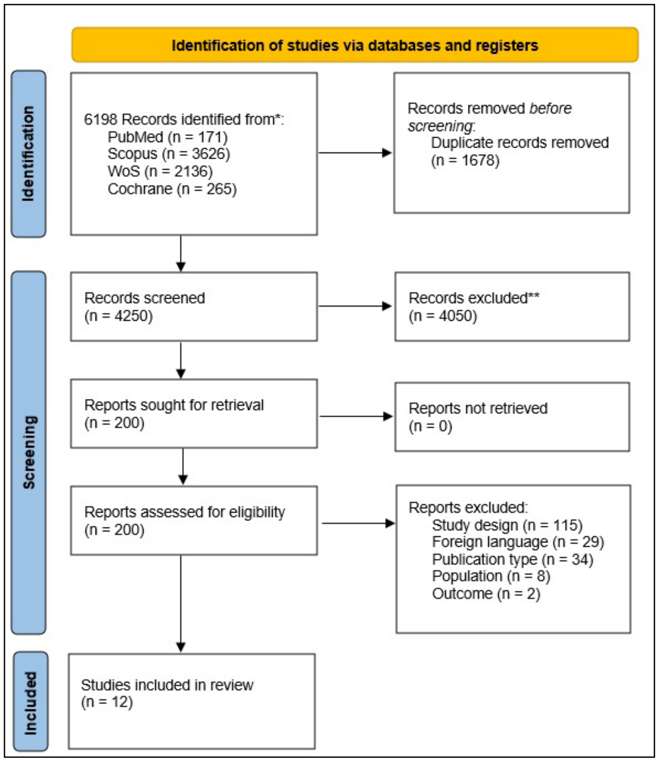


**Figure 1.** PRISMA flowchart.

### Study characteristics

A total of 12 RCTs published from 2008 to 2022 were included. The main characteristics were summarized in **table I**: author and year of publication, study design and purpose, participants, interventions, outcomes, and follow-up with the related results. The studies were conducted in different countries around the world: China (5), USA (1), India (1), Turkey (2), Brazil (1), Australia (1) and Hong Kong (1). The total sample of all participants included in the studies is 593 subjects who were enrolled in experimental or control groups. Each of them reported a diagnosis of post-traumatic elbow stiffness with limitation of ROM in flexion-extension. Only one study (32) compared the effects of conservative *versus* surgical treatment. The effects of conservative treatments were compared in six studies (33-38) while the remaining five RCTs (39-43) compared the effects of surgical treatments. **Table II** summarizes the interventions in the included RCTs. Regarding the methods of pain detection, one study (33) used the Numeric Pain Rating Scale (NPRS) at rest and in movement. The Visual Analogue Scale (VAS) at rest and in movement was used in nine studies (32, 34-36, 38, 40-43). With respect to the function domains, the ROM was detected in all studies using a goniometer, one study (35) used a digital goniometer and a dynamometer for muscles strength, while the others used a universal goniometer. The most used Patient-reported outcome measures (PROMs) were the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire (32-37) and the Mayo Elbow Performance Score (MEPS) (32, 39-41, 43).

### Risk of bias in studies

The methodological quality of the included RCTs was assessed using the Cochrane Risk of Bias tool Rob2 (28) (Review Manager RevMan) [Computer program] Version. In **figure 2** the items were summarized: randomization process, deviations from the intended interventions, miss-

**Table I.** RCTS synthesis: author and year, design and scope, participants, intervention, outcome and follow-up, results.

| Author (year) | Design and scope | Participants | Intervention | Outcome and Follow-up | Results |
|---|---|---|---|---|---|
| Bhosale (2022) | RCT, single-blind, Two-group. Effects of IASTM vs MET in patients with postoperative stiffness after elbow fracture. | Adults (>18) with post-operative elbow stiffness with loss of extension of ≥30°and/or flexion ≤120° at least 6-week post-surgery. | **Group A (13): IASTM and conventional treatment**<br>Group B (13): MET and conventional treatment.<br>Both groups received 3 weeks of supervised intervention, (twice a week), for a total of 6 sessions. | NPRS (at rest, at activity), ROM (universal goniometer), DASH, PFSF.<br>Baseline e post-treatment. | Significant improvement (p<0.05) in both groups on all outcomes. Significant difference (p<0.05) in favor of IASTM in NPRS and PFSF. |
| Birinci (2019) | RCT, single-blind, two-group. Effects of PNF vs Static Stretching in patients with post-traumatic elbow stiffness. | Adults (18-55) who had sustained<br>an elbow fracture and were treated at least 6 weeks either conservatively<br>or surgically, with an elbow limitation in extension of flexion. | **PNF group (20): PNF and conventional treatment.**<br>Static stretching group (20): passive stretching and conventional treatment.<br>Twice a week for 6 weeks, for a total of 12 sessions. | DASH, AROM (universal goniometer), VAS (rest and activity), TSK, Short Form-12, GRCs.<br>Baseline, post-treatment, 1 month follow-up. | Significant improvements in both groups. Higher PNF in DASH (p<0.03), VAS rest (p<0.03), VAS activity (p<0.01), AROM flex (p<0.04) |
| Birinci (2022) | RCT, single-blind, two group. GMI vs SE in patients with post-traumatic elbow stiffness following elbow fracture surgery. | Adults (20-55) at 4-8 weeks post-surgery with post-traumatic elbow stiffness (flex/ext joint deficit) | **GMI group (25): graded motor imagery and rehabilitation protocol. Home exercise in the follow-up period.**<br>SE group (25): structured rehabilitation protocol. Home exercise in the follow-up period.<br>Twice a week for 6 weeks, for a total of 12 sessions. | DASH, AROM (digital goniometer), VAS (rest, activity, and night), TSK, muscle strength (dynamometer), GRCs.<br>Baseline, post-treatment, and 6 weeks follow-up | Improvements in both groups. |
| Cui (2019) | RCT, single-blind, two group. Effects of ERAS vs Conventional approach in patients with post-traumatic elbow stiffness candidates for open arthrolysis. | Adults (≥18 years) with post-traumatic elbow stiffness (flex<120° and ext >30°) | **ERAS group (25): arthrolysis and Enhanced recovery after surgery.**<br>Conventional Group (25): arthrolysis and mobilization encouragement. | VAS (rest and in motion), ROM, MEPS, complications.<br>Baseline, 1 e 5 days post-surgery, 6 weeks, and 6 months follow-up. | VAS at rest and in motion better in ERAS (p<0.05) at 1- and 5-days post op then similar at 6 weeks and 6 months. Better ROM in ERAS (p<0.05). MEPS and similar complications. |
| Cui (2021) | RCT, double-blind, two group. efficacy of intravenous tranexamic acid (TXA) on post-surgery drainage, calculated blood loss,<br>and early clinical outcomes in patients undergoing OEA | Adults (≥18 years) with post-traumatic elbow stiffness (ROM≤60° according to Mansat and Morrey) candidates for OEA | **TXA group (48): arthrolysis and 1gr of TXA in 100 ml of intravenous saline solution and rehabilitation.**<br>Placebo group (48): arthrolysis and 100 ml of intravenous saline solution and rehabilitation. | Post-surgery drainage, VAS (rest and in motion), blood loss, ROM, MEPS.<br>Baseline, 1, 2, 3, 4 and 5 days after surgery, 6 weeks and 6 months follow-up. | Better short-term outcomes in the TXA group for pain, blood loss and drainage volume. After 6 weeks and 6 months there was no difference between the groups. |

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| Author (year) | Design and scope | Participants | Intervention | Outcome and Follow-up | Results |
|---|---|---|---|---|---|
| Faqih (2019) | RCT, two group. Effects of METs immediately after immobilization or after one-week post-surgery for post-traumatic elbow stiffness. | Adults (18-50 years) post-surgery for post-traumatic elbow stiffness (intra- or extra-articular fractures of the elbow without ligament injuries) | **Early MET group (15): early MET and therapeutic exercise**<br>Delayed MET group (15): the same protocol of early MET but one week later (upon removal of the immobilization)<br>6 a week for 3 weeks, for a total of 18 sessions. | VAS, ROM (goniometer), DASH.<br>Baseline and post-treatment (3 weeks) | Better results in the Early MET group for pain, elbow ROM and function. |
| Guglielmetti (2020) | RCT, single blind, two group. Effects of conservative vs surgical treatment in post-traumatic elbow stiffness. | Adults (18-65 years) with trauma in the last 6 months with 4 months of conventional treatment failure (flex<100° east>30°). | **Surgical Group (15): surgical release with posterior approach and rehabilitation protocol like the conservative one.**<br>Conservative Group (15): rehabilitation protocol, occupational therapy, CPM and static night orthoses. | Primary: elbow flex-est ROM.<br>Secondary: MEPS, VAS, DASH, prone-sup elbow ROM, complications.<br>Baseline, 6 weeks, 3 months, 6 months follow-up | Surgical group: greater ROM in flexion-extension,<br>greater absolute and relative increase compared to rehabilitation alone at 6 months follow-up. The groups did not differ in<br>clinical scores and complication rates. |
| Lindenhovius (2012) | RCT, two group.<br>Effects of dynamic vs static orthoses in post-traumatic elbow stiffness. | Adults (>18 years) with post-traumatic stiffness (loss of >30° of flex-ext) without improvements in ROM in the last 4 weeks. | **Progressive static orthoses group (35): 3 times a day for 30 minutes + stretching exercises**<br>**Dynamic orthoses group (31): 6-8 hours a day + stretching exercises** | ROM and DASH.<br>Baseline, 3, 6 and 12-months follow-up. | Orthotics and exercise are effective at 6-12 months. No significant difference between the two groups. |
| Moseley (2008) | RCT single blind, two group. Differences between serial casting and positioning in elbow stiffness after brain trauma. | Adults with traumatic brain injury and post-traumatic elbow stiffness (at least 15 degrees of flexion deficit) | **Serial casting group (14): exercise protocol and 2 weeks of brace in stretching position with increase after 7 days.**<br>Positioning group (12): exercise protocol and passive stretching by the physiotherapist for 2 weeks. | ROM, spasticity, TEMPA, VAS.<br>Baseline, post-intervention (2 weeks), post-intervention + 1 day, after 4 weeks (follow-up). | In the short term, serial casting produces better effects than positioning. In follow-ups all effects are lost. |
| Sun (2021) | RCT, double-blind, two group.<br>Effects of infiltrative therapy after arthrolysis for elbow stiffness compared to arthrolysis alone. | Adults (18-65 years) with post-traumatic elbow stiffness. | **PMDI group (28): arthrolysis, PMDI infiltration and rehabilitation protocol**<br>Control group (31): arthrolysis and rehabilitation protocol | VAS (rest and in motion), ROM, blood loss, analgesic consumption.<br>Baseline, all the first 7 post-operative days, follow-up at 3 months. | Infiltration group has greater reduction in post-operative pain and lower use of analgesics. |

| Author (year) | Design and scope | Participants | Intervention | Outcome and Follow-up | Results |
|---|---|---|---|---|---|
| Yu (2015) | RCT, single blind, two group. Effects of cryotherapy after arthrolysis for post-traumatic elbow stiffness. | Adults (18-70) with post-traumatic elbow stiffness. | **Cryotherapy group (31): arthrolysis, CryoCuff and rehabilitation protocol**<br>Control group (28): arthrolysis and rehabilitation protocol | VAS, ROM, blood loss, MEPS, analgesic consumption.<br>Baseline, all the first 7 post-operative days, follow-up at 3 months. | Cryotherapy effective in reducing pain and taking analgesics. |
| Zhang (2020) | RCT, two group. Effects of tranexamic acid in open arthrolysis for post-traumatic elbow stiffness. | Adults (>18 years) with post-traumatic elbow stiffness. | **TXA group (31): open arthrolysis, TXA and rehabilitation protocol**<br>Control group (30): open arthrolysis, saline solution and rehabilitation protocol | Tourniquet time, intraoperative blood loss, postoperative drainage, ROM, MEPS<br>Baseline, 1,2,3 post-surgery days, 6 weeks and 1 year follow-up. | Better results in the TXA group for intraoperative bleeding and reduction of blood loss. |

The groups with the best results have been highlighted in bold; RCT: randomized controlled trial; IASTM: Instrument assisted soft tissue mobilization; MET: muscle energy technique; ROM: range of motion; AROM: active range of motion; NPRS: numeric pain rating scale; VAS: visual analogue scale; DASH: Disabilities of the Arm, Shoulder and Hand questionnaire; PFSF: Patient-Specific Functional Scale; PNF: proprioceptive neuromuscular facilitation; TSK: Tampa scale of kinesiophobia; GRCs: global rating of change scale; GMI: graded motor imagery; SE: structured exercise; ERAS: enhanced recovery after surgery; MEPS: mayo elbow performance scale; OEA: open elbow arthrolysis; TXA: tranexamic acid; CMP: continuous passive mobilization; PMDI: periarticular multimodal drug injection.

**Table II.** RCTS synthesis intervention

| Author (year) | Conservative *vs* surgical | Conservative *vs* conservative | Surgical *vs* surgical |
|---|---|---|---|
| Bhosale (2022) | | X | |
| Birinci (2019) | | X | |
| Birinci (2022) | | X | |
| Cui (2019) | | | X |
| Cui (2021) | | | X |
| Faqih (2019) | | X | |
| Guglielmetti (2020) | X | | |
| Lindenhovius (2012) | | X | |
| Moseley (2008) | | X | |
| Sun (2021) | | | X |
| Yu (2015) | | | X |
| Zhang (2020) | | | X |


**Figure 2.** Risk of bias results (RoB2).

ing outcome data, measurement of the outcome, selection of the reported result.

Studies were rated as having a high, low, or unclear risk of bias for each component of the tool. Finally, an overall result was assigned which resulted in a low risk of bias in seven studies (32-35,39, 41, 42), some unclear elements in three studies (37, 40, 43) and a high risk of bias in two studies (36, 38) (**figure 2**).

| | ES | 95% CI | W | V | SE | Sig. | N | N1 | N2 |
|---|---|---|---|---|---|---|---|---|---|
| Cui 2019 | 0.15 | -0.40 / 0.71 | 15.47% | 0.08 | 0.28 | 0.595 | 50 | 25 | 25 |
| Cui 2021 | 0.37 | -0.03 / 0.78 | 29.29% | 0.04 | 0.21 | 0.071 | 96 | 48 | 48 |
| Sun 2020 | 0.26 | -0.25 / 0.77 | 18.11% | 0.07 | 0.26 | 0.323 | 59 | 31 | 28 |
| Yu 2015 | 0.09 | -0.42 / 0.60 | 18.25% | 0.07 | 0.26 | 0.728 | 59 | 28 | 31 |
| Zhang 2020 | 0.14 | -0.36 / 0.64 | 18.88% | 0.07 | 0.26 | 0.586 | 61 | 30 | 31 |
| Overall (random-effects model) | 0.22 | 0.00 / 0.44 | 100.00% | 0.01 | 0.11 | 0.046 | 325 | 162 | 163 |

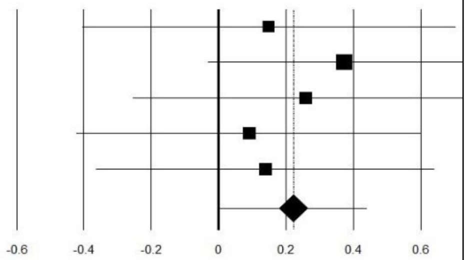


**Figure 3.** Results of meta-analysis and forest plot of ROM improvement: control group N1 (left side) *vs* experimental group N2 (right side).

## Results of synthesis

Despite the significant variability in interventions and follow-up periods, we were able to perform a meta-analysis using a random-effects model to evaluate the impact of various post-surgery treatments after open arthrolysis, compared to standard care, on the recovery of elbow joint ROM in flexion-extension for patients with post-traumatic stiffness. We included 5 RCT studies (39-43) that compared conventional surgical treatment involving open arthrolysis with enhanced surgical approaches that incorporated innovative techniques during the procedure and post-operative care. Each study was structured with two groups: a control group and an experimental group. The ROM outcomes at baseline were compared to those at long-term follow-up

**ARTHROLYSIS AND OTHER TREATMENTS COMPARED TO ARTHROLYSIS FOR IMPROVEMENT ROM IN POST-TRAUMATIC ELBOW STIFFNESS**

**Patient or population:** improvement ROM in post-traumatic elbow stiffness
**Setting:** Hospital
**Intervention:** arthrolysis and other treatments
**Comparison:** arthrolysis

| Outcomes | N° of participants (studies) Follow-up | Certainty of evidence (GRADE) (95% Cl) | Relative the effect | Anticipated absolute effects | |
|---|---|---|---|---|---|
| | | | | **Risk with arthrolysis** | **Risk difference with arthrolysis and other treatments** |
| Long-term Range of Motion (ROM) assessed with: goniometer follow-up: mean 6 months | 325 (5 RCTs) | ⊕⊕◯◯ **Low**[a,b] | – | The mean long-term Range of Motion was **0** | MD **0.22 higher** (0 to 0.44 higher) |

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI). **CI:** confidence interval; **MD:** mean difference

**GRADE Working Group grades of evidence**
**High certainty:** we are very confident that the true effect lies close to that of the estimate of the effect.
**Moderate certainty:** we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
**Low certainty:** our confidence in the effect e stimate is limited: the true effect may be substantially different from the estimate of the effect.
**Very low certainty:** we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

**Figure 4.** GRADE results: certainty of evidence for meta-analysis.

(averaging six months). All included studies used the same method for measuring ROM (universal goniometer). **Figure 3** presents the results alongside the forest plot, where the left column shows the control groups' outcomes (classical open arthrolysis, 162 patients), and the right column shows the experimental groups' outcomes (open arthrolysis with innovative elements, 163 patients). The forest plot illustrates the superior recovery of ROM in elbow flexion-extension in the experimental groups over the control groups at long-term follow-up. The overall effect size (ES) was 0.22, with a 95% confidence interval of 0.00 to 0.44, a two-tailed statistical significance (Sig.) of 0.046, a variance (V) of 0.01, and a standard error (SE) of 0.11.

### Certainty of evidence

The GRADE method applied to the 5 articles included in the meta-analysis conducted reported a low quality of evidence as two studies present some concerns in the domain of deviations from intended intervention due to the lack of blinding of the population, and the threshold value of 400 individuals analyzed between the experimental and control groups was not reached (n = 325). **Figure 4** shows the results of the GRADE method using the GRADE pro Software.

## DISCUSSION

The aim of this SR was to analyze the effectiveness of different approaches in the management of post-traumatic elbow stiffness. To this end, RCTs were analyzed that verified the effectiveness of different conservative approaches, different surgical techniques and post-surgical rehabilitation protocols and conservative treatments *versus* surgical treatments. The first fact that emerged is the high heterogeneity of the proposed treatments, especially among conservative approaches. Only one study (32) has verified the effectiveness of conservative treatment *versus* a surgical one. Despite this, when analyzing the studies that investigated the effects of surgical approaches and different post-surgical protocols, it is interesting to note that open arthrolysis is the most used technique, confirming what is already present in the literature (44). Furthermore, as regards the studies that compared different surgical techniques with post-surgical rehabilitation protocols, it was also possible to compare the results from a quantitative point of view through the meta-analysis tool.

The main finding from the meta-analysis is that the surgical approach with open arthrolysis followed by innovative elements appears to be superior to conventional open arthrolysis in the long-term recovery of elbow ROM in flexion-extension. Analyzing the studies included in the meta-analysis in detail, various innovative elements were introduced by different authors to form the experimental group:

Cui *et al.* in 2019 (40) proposed an early and structured post-operative rehabilitation protocol called "enhanced recovery after surgery" (ERAS) as an alternative to the conventional approach. The ERAS group showed, compared to conventional group, better short-term outcome in the domain of pain at rest and in motion ($p < 0.05$). Also, ROM was consistently better in the ERAS group ($p < 0.05$). In 2021, the same author (41) suggested the administration of intravenous tranexamic acid just before the surgical incision, noting clear short-term improvement in pain on movement in the experimental group. Zhang (39) conducted a study with a similar approach but proposed the dual administration of tranexamic acid directly on the surgical incision just before wound closure.

Sun and colleagues (42) in their RCT proposed intravenous treatment with different drugs than the previous studies, a multimodal administration of Ketoprofen, Ropivacaine, and Epinephrine just before wound closure, observing an improvement in pain and ROM in the short term in the experimental group, while in the long term there were no substantial differences between the groups. Lastly, Yu (43) studied the effectiveness of cryotherapy in the immediate post-operative period after open arthrolysis with a reduction, in the first 7 post-surgery days, of VAS both at rest and in motion in the cryotherapy group and also a reduction in the intake of analgesic drugs. A rehabilitation protocol is present after each surgical procedure in all these studies (39-43), both in experimental and control groups, demonstrating how rehabilitation itself is considered important and effective. A recent update by Siemensma *et al.* (2023) (45) offers a structured, stepwise approach to the management of post-traumatic elbow stiffness in both adults and pediatric populations. Their emphasis on early mobilization, brace therapy, and surgical arthrolysis where indicated aligns well with the current treatment paradigms addressed in this review.

In all the studies with surgical approaches included in the meta-analysis, the experimental group (open arthrolysis and innovative elements) showed significant improvements compared to the control group (open arthrolysis and usual care or placebo). These results seem to be in line with what was reported in the non-systematic review by Akthar in 2021 (46), which highlights the effectiveness of open arthrolysis when followed by early rehabilitation involving therapeutic exercises, CPM, and orthoses. Experimental findings from Reiter *et al.* (47) using a rat model of elbow joint contracture support the critical role of early and appropriately dosed physical therapy in preventing long-term stiffness, offering mechanistic insight into the importance of timing in rehabilitation protocols. Similar results are also confirmed by the recent overview by Siemensma (44), adding that open arthrolysis has a higher rate of complications and revisions compared to arthroscopic arthrolysis, which, on the other hand, has more limited indications. In this regard, the systematic review by Lanzerath in 2022 (48), suggests that, if indicated, arthroscopic arthrolysis should be preferred over open arthrolysis to reduce the risk of post-surgical complications. Additionally, a RCT (49), not included in this SR as it added both adult and pediatric patients, has highlighted the potential usefulness of combining continuous passive mobilizations with post-surgical rehabilitation after arthroscopic techniques.

It was not possible to conduct further meta-analyses on surgical approaches on other outcomes (pain and function) due to the heterogeneity in interventions, follow-ups and the unavailability of baseline values for pain (41). Attempts were made to contact the authors to obtain the data but without success.

RCTs that compared two different conservative treatment modalities presented heterogeneous elements that prevented a meta-analysis of the results. Nevertheless, it is possible to note that some techniques, although used with different frequencies and timing, have shown their clinical efficacy in reducing pain and improving ROM and function. An example is provided using Muscle Energy Techniques (MET) in the conservative management of post-traumatic elbow stiffness. The technique was used in two RCTs (33, 36) with different treatment frequencies: twice a week for three weeks (33), and six sessions a week for three weeks (36). Despite the high heterogeneity in treatment frequency, MET has proven to be effective in reducing short-term pain and improving ROM and function (33, 36). One study in 2018 (34) showed that stretching techniques based on the proprioceptive neuromuscular facilitation (PNF) appears superior to static stretching in improving pain, function and active ROM. It is interesting to note how there are similarities between PNF techniques and MET, despite using different frequencies and timing, they use the same principles of autogenic and reciprocal inhibition. The same author demonstrated in 2022 (35) how graded motor imagery (GMI) can have an important role among conservative treatments. Another promising conservative therapy is the one proposed by Bhosale in 2022 (33), known as instrument-assisted soft tissue mobilization (IASTM), which appears to offer similar effects to METs but with better results in reducing pain and improving patient-specific functional scores.

Two RCTs (37, 38) have shown the efficacy of using static or dynamic orthoses in the conservative treatment of post-traumatic stiffness, although they showed contrasting long-term results. In this regard, Veltman's systematic review (50) on the effectiveness of conservative treatment with orthoses emphasizes that there are no differences between static and dynamic orthoses, and their use is recommended within 12 months of the onset of stiffness or when no further increases in ROM are observed.

Only one RCT, conducted by Guglielmetti and colleagues (32), studied the effects of a conservative treatment compared to a surgical one. The study included only patients with post-traumatic elbow stiffness who did not show improvement after four months of conservative treatment. Patients were divided into two groups: a conservative group that followed a rehabilitation protocol using static and dynamic orthoses and continuous passive mobilizations, and a surgical group that underwent a posterior release procedure previously described in the literature by the same authors (51), followed by a post-surgical rehabilitation protocol like the conservative one. The surgical approach followed by the rehabilitation protocol was more effective in terms of recovering ROM in flexion-extension at the six-month follow-up and did not differ in terms of complication rates and clinical scale results. This finding is in line with what is reported in the literature (5, 44, 46), which suggests that if stiffness persists after a period of conservative treatment, surgical intervention followed by early and structured post-operative rehabilitation is recommended.

Among the main limitations of the study, it is important to highlight the high heterogeneity among the different treatment approaches for post-traumatic elbow stiffness. Despite including 12 RCTs, only one of them evaluated the effects of surgical treatment compared to conservative treatment. Among the RCTs that assessed the effects of conservative treatments, there are differences in the frequency and duration of treatments, and two (36, 38) of them have a high risk of bias. Studies that analyzed open arthrolysis with usual care compared to open arthrolysis with innovative elements consistently reported improvements in ROM and pain in the experimental groups. Although it was possible to conduct a meta-analysis of the results using the random effects model, it is still important to highlight the high level of heterogeneity present in the innovative elements across the different studies in the experimental groups: some used accelerated rehabilitation protocols, others used cryotherapy, and even among those who employed infiltrative techniques for pain modulation and postoperative bleeding, there was high heterogeneity in the choice of drug and the timing of administration.

The 12 RCTs included in this systematic review investigated various conservative and surgical approaches to post-traumatic elbow stiffness, often involving patients with heterogeneous etiologies and clinical profiles. This diversity, combined with differences in intervention protocols, treatment durations, and outcome measures, limited the possibility of conducting secondary analyses aimed at identifying the most effective treatment strategies for specific subgroups of patients.

Among these, only five studies met the criteria for inclusion in the meta-analysis. While this analysis provided valuable insights, especially regarding the potential superiority of open arthrolysis combined with innovative elements, several limitations emerged. Two of the five studies showed concerns related to deviations from intended interventions due to the lack of participant blinding. Additionally, the GRADE assessment led to a downgrading of the overall certainty of evidence to "low," not only because of the aforementioned risks of bias and the clinical heterogeneity among studies, but also due to imprecision: the total sample size of the pooled studies did not reach the optimal information size (OIS) of 400 participants, a recognized threshold for robust estimation of treatment effects in meta-analyses.

To overcome these limitations and strengthen the evidence base in this field, future research should focus on conducting adequately powered, multicenter randomized controlled trials. Standardization of intervention protocols and follow-up durations, along with the development of a core outcome set specific to post-traumatic elbow stiffness, would significantly improve comparability across studies. Moreover, stratification of patients according to key clinical characteristics, such as etiology (*e.g.*, presence of heterotopic ossification), chronicity, or prior treatment failures, could help identify the most effective treatment strategies for distinct patient populations.

## CONCLUSIONS

The treatment of post-traumatic elbow stiffness remains a significant challenge for healthcare professionals. Conservative approaches are the first treatment option in less severe cases. There are various conservative techniques available, MET seem to offer better short-term results, but further studies are needed to draw conclusions. In cases where stiffness persists or in more severe cases, surgical approaches, whether arthroscopic or open, should be considered, considering the risk of complications and the patient's characteristics. The meta-analysis suggests that open arthrolysis, when followed by innovative elements such as early rehabilitation protocols, infiltrative therapy, or cryotherapy, appears to offer better long-term recovery of the elbow flexion-extension ROM compared to open arthrolysis followed by usual care. Future high-quality methodological RCTs comparing surgical treatment to conservative treatment, considering different types of post-traumatic stiffness, are needed.

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## DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

## CONTRIBUTIONS

FS, LDF, EM, FM: conceptualization. FS, FM, LDF: methodology, investigation. FS: software. project administration. FS, FM, LR, LDF, GG, DP, AR, ML: validation. FS, FM, EM, ML, LR, AR: formal analysis. FS, FM: resources, writing – review & editing, visualization. FS, LDF: data curation. FS, FM, LR, LDF, GG, DP, AR, ML, EM: writing – original draft. FM, GG, LDF: supervision.

## CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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