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# Outcomes of Flexible Fixation Devices in Purely Ligamentous Lisfranc Injuries: A Systematic Review

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## Abstract

**Background:** Purely ligamentous Lisfranc injuries represent a challenging subset of tarsometatarsal trauma and are frequently underdiagnosed. While rigid fixation has traditionally been used, it is associated with implant-related complications and often requires secondary surgery. Flexible fixation devices have emerged as an alternative aimed at restoring stability while preserving physiological joint motion. This systematic review evaluates the outcomes of flexible fixation devices in the management of purely ligamentous Lisfranc injuries.

**Methods:** A systematic review was conducted in accordance with the PRISMA guidelines. Electronic databases including PubMed/MEDLINE, Embase, Emcare, Prospero, CINAHL, ICTRP, clinicaltrails.gov, TRIP, Base Bielefeld Academic Search Engine and the Cochrane Library were searched from inception to the October 2025. Studies reporting clinical, functional, and/or radiological outcomes following flexible fixation for purely ligamentous Lisfranc injuries were included. Data extraction and analysis were performed independently by two reviewers and when not in consensus with discussion, third independent reviewer was involved.

**Results:** Eleven studies encompassing a total of **301 patients** were included. All the studies were retrospective studies, with follow-up ranging from **12 weeks to 10 years**. Flexible fixation techniques included suture button constructs and internal brace systems, with or without adjunctive fixation. Across studies, postoperative pain improved significantly, with Visual Analogue Scale (VAS) scores decreasing from preoperative values of approximately **5.3–8.4** to **0.6–1.3**. Functional outcomes demonstrated marked improvement, measured mainly with postoperative American Orthopaedic Foot & Ankle Society midfoot scores (AOFAS) consistently ranging from **84 to 96**. Radiological outcomes showed significant improvement and maintenance of reduction in most studies. Complications were infrequent and generally minor, including transient sensory disturbances, button-site discomfort, and isolated cases of radiographic arthritis. Routine implant removal was rarely required.

**Conclusion:** Flexible fixation devices for purely ligamentous Lisfranc injuries are associated with **excellent pain relief, significant functional improvement, reliable radiological outcomes, and low complication rates**. These findings support flexible fixation as a safe and effective alternative to rigid fixation in appropriately selected patients in purely ligamentous Lisfranc injuries, although higher-quality comparative studies with long-term follow-up are needed.

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**Keywords:** Lisfranc injury; Ligamentous Lisfranc; Flexible fixation; Suture button; Internal Brace; Tarsometatarsal joint; Systematic review

**Abbreviations:** VAS: Visual Analogue Scale; AOFAS: American Orthopaedic Foot & Ankle Society; MFS: Maryland Foot Score; FAOS: Foot and Ankle Outcome Score; IM: intermetatarsal; WB: weight bearing; RTW: return to work; DPN: deep peroneal nerve; NA: not available; NR: not reported

## Introduction

Purely ligamentous Lisfranc injuries represent a challenging subset of tarsometatarsal joint trauma and are most commonly associated with low-energy mechanisms. These injuries are frequently underdiagnosed owing to subtle clinical signs and often inconspicuous radiographic findings, with conventional non–weight-bearing radiographs potentially overlooking unstable injuries. Failure to recognize and appropriately treat instability of the Lisfranc joint complex can result in midfoot collapse, chronic pain, functional limitation, and the development of post-traumatic arthritis [1,2].

Once instability is identified, operative intervention is generally recommended, with the principal goal of achieving and maintaining an anatomic reduction and restoring stability across the tarsometatarsal articulation [3,4]. Conventional surgical management has predominantly relied on rigid fixation using transarticular screws or dorsal plates [3]. While these methods provide reliable stabilisation, they are associated with limitations including iatrogenic articular cartilage injury, restriction of physiological joint motion, and potential need for secondary procedures, including hardware removal [5,6].

In response to these concerns, flexible fixation techniques—particularly suture-button constructs and internal brace–type ligament augmentation systems—have gained increasing attention. These devices aim to more closely replicate native ligament biomechanics, preserve joint motion, and potentially facilitate earlier rehabilitation [7,8]. Despite growing clinical adoption, the existing literature evaluating flexible fixation for purely ligamentous Lisfranc injuries remains heterogeneous, with variability in study design, fixation constructs, outcome measures, and follow-up duration [7,9]. Consequently, the overall effectiveness and safety profile of these devices remains unclear.

A comprehensive synthesis of the available evidence is therefore warranted. This systematic review, conducted in accordance with PRISMA guidelines, aims to evaluate the clinical, functional, and radiological outcomes of flexible fixation devices in the management of purely ligamentous Lisfranc injuries, as well as associated complications and reoperation rates.

## Methods

### Protocol and Registration

This systematic review was conducted in accordance with the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)** guidelines.

### Eligibility Criteria

Studies were selected based on predefined eligibility criteria using the PICO framework.

- **Population:** Adult patients with **purely ligamentous Lisfranc injuries**, confirmed clinically and/or radiologically, without associated fractures.
- **Intervention:** Surgical treatment using **flexible fixation devices**, including suture button constructs and internal brace systems.
- **Comparison:** no comparison groups were included in the current study due to limited available research with comparison groups in purely ligamentous Lisfranc injury.
- **Outcomes:** Clinical and functional outcomes (AOFAS, VAS), radiological outcomes (maintenance of reduction, diastasis, intermetatarsal distance, step off), complication rates, and reoperation or hardware removal.
- **Study design:** Retrospective studies with a minimum follow-up of 3 months.
- **Exclusion criteria:** Cadaveric or biomechanical studies, isolated fracture-dislocation patterns, case reports, review articles, conference abstracts, and non-English language studies.

### Information Sources

A comprehensive literature search was performed across the following electronic databases: PubMed/MEDLINE, Embase, Emcare, Prospero, CINAHL, ICTRP, clinicaltrails.gov, TRIP, Base Bielefeld Academic Search Engine and the Cochrane Library were searched from inception to the October 2025. Reference lists of included studies were manually screened to identify additional relevant articles.

### Search Strategy

The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to Lisfranc injuries and flexible fixation. Key terms included: *"Lisfranc injury," "Lisfranc ligament," "tarsometatarsal joint," "suture button," "TightRope," "InternalBrace," "flexible fixation,"* and *"ligamentous."* Boolean operators (AND/OR) were used to refine the search.

### Study Selection

All retrieved records were imported into reference management software, and duplicate studies were removed.

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Two independent reviewers screened titles and abstracts for eligibility. Full-text articles of potentially relevant studies were then reviewed independently by both reviewers. Any discrepancies were resolved through discussion, and a third reviewer was consulted if consensus could not be reached. Studies employing suture button or suspensory device constructs, with or without adjunctive fixation, were included provided outcomes for ligamentous Lisfranc injuries could be clearly identified.

## Data Extraction

Data extraction was performed independently by two reviewers using a standardized data collection form. Extracted data included study characteristics (author, year, study design), patient demographics, injury characteristics, fixation technique, follow-up duration, clinical and functional outcome measures, radiological outcomes, complications, and rates of reoperation or implant removal. Disagreements were resolved by consensus.

## Data Synthesis

Due to heterogeneity in study design, outcome measures, and follow-up duration, a **qualitative narrative synthesis** was performed. Where appropriate and sufficient homogeneous data were available, outcomes were summarized descriptively. A quantitative meta-analysis was not performed due to methodological variability across studies (Figure 1).

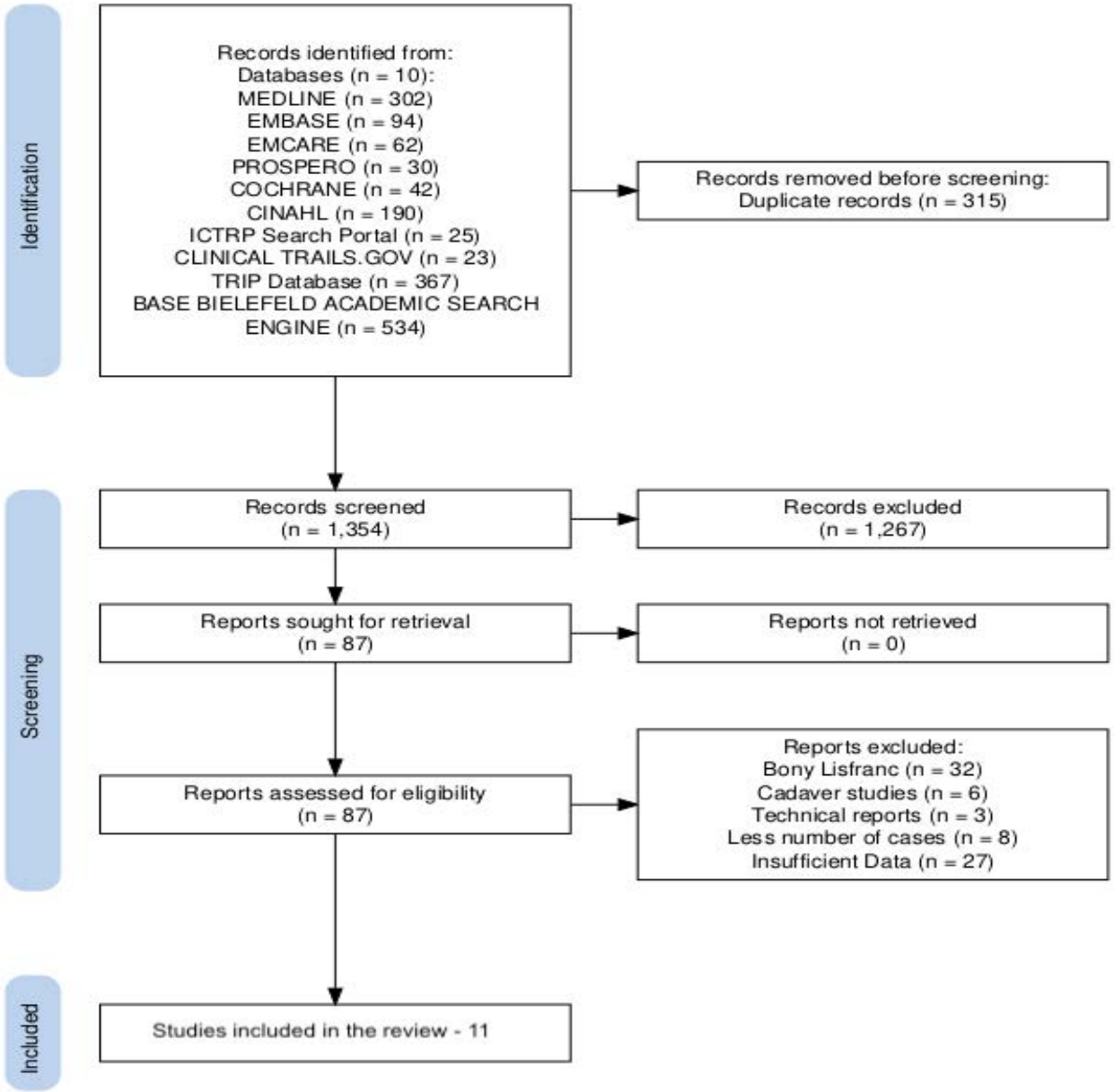


**Figure 1:** PRISMA flowchart showing the search results

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## Results

### Study Selection

A total of **11 studies** evaluating flexible fixation techniques for purely ligamentous Lisfranc injuries were included in this systematic review. These comprised **of retrospective studies**. No randomized controlled trials or prospective studies were identified.

### Study Characteristics

The included studies encompassed a total of **301 patients**, with individual study sample sizes ranging from **4 to 84 patients**. The mean age across studies ranged from approximately **22 to 41 years**, with a predominance of male patients in most cohorts. Follow-up duration varied from **12 weeks to 10 years**, with the majority of studies reporting **short- to mid-term follow-up (6–36 months)**.

Flexible fixation techniques included **suture button constructs (TightRope™)**, **interosseous suture button systems**, and **internal brace fixation**, with some studies employing **adjunctive intercuneiform screws or plates** when additional instability was present.

### Clinical Outcomes (Pain)

Pain outcomes were most commonly assessed using the **Visual Analogue Scale (VAS)**. [10-15] Across studies reporting VAS scores, there was a **significant reduction in postoperative pain** compared with preoperative values.

Preoperative VAS scores ranged from approximately **5.3 to 8.4**, while postoperative scores consistently improved to values between **0.6 and 1.3**, with statistically significant differences reported in multiple studies ($p < 0.05$). Studies involving athletic populations demonstrated particularly low postoperative pain scores, frequently approaching zero at final follow-up [15].

### Functional Outcomes

Functional outcomes were predominantly measured using the **American Orthopaedic Foot & Ankle Society (AOFAS) midfoot score**, [10-16] with one study additionally reporting the **Maryland Foot Score** [10].

Across all studies, **substantial improvements in functional scores** were observed following flexible fixation. Preoperative AOFAS scores ranged from approximately **28 to 46**, while postoperative scores consistently improved to between **84 and 96**, with most studies reporting statistically significant improvements ($p < 0.05$). Studies utilizing suture button fixation alone and those combining flexible fixation with supplementary hardware demonstrated similarly high functional outcomes.

### Radiological Outcomes

Radiological assessment demonstrated **significant improvement in Lisfranc joint alignment** following flexible fixation. Measurements including **intermetatarsal distance (M1–M2)** [10,17], **cuneiform–metatarsal distance (C1–M2)** [17], and **step-off measurements** [12] showed statistically significant reductions compared with preoperative values in studies reporting radiographic outcomes (Table 1).

### Complications

Overall, the **complication rate was low** across the included studies [10-16,18-20]. Reported complications included:

**Table 1:** Outcomes of flexible fixation devices in purely ligamentous Lisfranc injuries.

| Study | Study design | No. of patients | Mean age (years) | M/F | Fixation technique | Follow-up | Radiological outcome | Pain outcome (VAS) | Functional outcome | Complications |
|---|---|---|---|---|---|---|---|---|---|---|
| Fan Yongfei et al. [10] | Retrospective case series | 11 | 35.5 | 08-Mar | TightRope™ system | 20.5 months | IM distance significantly improved (p<0.05) | Significant reduction (p<0.05) | AOFAS 92.4 ± 4.3; MFS 94.1 ± 3.5 | None |
| Guanglong et al. [11] | Retrospective observational | 58 | 34.6 ± 9.4 | 39/19 | InternalBrace ± plate/screws | 12–24 months | Maintained reduction | 5.33 → 1.24 (p<0.01) | AOFAS 28.0 → 91.6 (p<0.01) | Arthritis (1), Infection (1), Numbness (1) |
| Cottom et al. [12] | Retrospective cohort | 84 | 37–40 | 50/34 | Interosseous suture button ± screw | 3 years | Step-off 3.15 → 0.43 mm (p<0.05) | 8.41 → 1.30 (p<0.05) | AOFAS 31 → 90 (p<0.05) | Screw removal (1) |
| Zwipp et al. [20] | Case series | 4 | 28.6 | 03-Jan | Ligament reconstruction + temporary screws | 10 years | Maintained alignment | NR | Good clinical outcome | None |
| Cho et al. [13] | Retrospective case-control | 31 | 40.9 | 18/13 | Suture button (TightRope™) | 1 year | Diastasis 7.9 → 2.3 mm (p<0.001) | NR | AOFAS 45.1 → 84.3 (p<0.001) | Recurrent diastasis (2) |

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|---|---|---|---|---|---|---|---|---|---|---|
| Saito et al. [14] | Retrospective case series | 16 | NA | NA | Interosseous suture button | 32 months | Maintained reduction | Mean 0.6 | Mean AOFAS 95.8 | Button discomfort (4), arthritis (3), loss of reduction (1) |
| Delman et al. [17] | Retrospective radiographic | 43 | NA | NA | Suture button (TightRope™) | 12 weeks | Improved M1–M2 and C1–M2 | NR | NR | NR |
| Brin et al. [16] | Case series | 5 | NA | 03-Feb | TightRope™ device | 1 year | Maintained reduction | NR | High AOFAS reported | None |
| Hoskins et al. [18] | Retrospective case series | 15 | 35.2 | 08-Jul | InternalBrace™ system | 7 months | Stable WB radiographs | NR | WB 6.6 wks; RTW 14.1 wks | Medial bursitis (1), hypersensitivity (1) |
| Tan et al. [19] | Retrospective cohort | 29 | 29 | 19-Oct | Suture button ± screw/plate | 1 year | Maintained reduction | NR | FAOS 92.9–100 | Numbness (4) |
| Jain et al. [15] | Retrospective case series | 5 | 22.1 | 5/0 | Suture button (TightRope™) | 24 months | Reduction maintained | Mean 0.6 | Mean AOFAS 94 | Transient DPN symptoms (1) |

Maintenance of reduction was generally preserved at final follow-up [13,15,18]. Although isolated cases of recurrent diastasis or loss of reduction were reported, these were infrequent and did not routinely require revision surgery.

- Transient sensory disturbances or numbness – 7 cases [11,15,18,19]
- Button-site discomfort – 4 cases [14]
- Superficial infection – 1 case [11]
- Medial bursitis – 1 [18]
- Rare cases of radiographic arthritis – 4 cases [11,14]
- Loss of reduction – 3 [13,14]
- Extensor hallucis longus tendinopathy – 1 [14]

Importantly, **routine implant removal was rarely required only when it was combined with additional screw** [12], representing a notable advantage of flexible fixation techniques compared with traditional rigid fixation. No study reported high rates of implant failure necessitating revision surgery.

## Discussion

This systematic review evaluated the clinical, functional, and radiological outcomes of **flexible fixation devices** in the management of **purely ligamentous Lisfranc injuries**. The principal finding of this review is that flexible fixation techniques—most commonly suture button constructs and internal brace systems—consistently demonstrated **significant improvements in pain, functional scores, and maintenance of reduction**, with **low complication and reoperation rates** across a heterogeneous body of predominantly observational studies. Overall, the available evidence suggests that flexible fixation provides reliable short- to mid-term outcomes while preserving midfoot biomechanics.

### Clinical and Functional Outcomes

Across the included studies, patients treated with flexible fixation for purely ligamentous Lisfranc injuries demonstrated substantial improvements in pain and functional outcomes. The available evidence reports marked improvements in validated outcome scores such as postoperative AOFAS and VAS, with many studies demonstrating excellent functional recovery and return to activity following flexible fixation **[9,21].**

A recent systematic review of suture button fixation showed a significant improvement in AOFAS scores from a weighted mean of approximately 39 preoperatively to 82.8 postoperatively at a mean follow-up of around 27 months. Patients experienced a marked reduction in pain and a 100% return to sport at a mean of 16.8 weeks, with an overall complication rate of approximately 5% and no secondary surgical procedures reported **[21].** Similarly, another systematic analysis found that suture button fixation yielded high levels of patient-reported outcomes, with postoperative AOFAS scores frequently ranging from the low 80s to high 90s and return to sport/activity reported between approximately 10.8 and 25.9 weeks. Complication rates in this series were relatively low (<8%) and hardware irritation or diastasis were uncommon **[9].**

In addition to suture buttons, flexible fixation with internal brace constructs has been reported to restore midfoot stability and function while allowing earlier return to activity. A retrospective case series using an Internal Brace reported an average time to unrestricted weight bearing of about 6.8 weeks and return to work or sport around 14.3 weeks, with minimal early complications [8]. These findings support the concept that flexible constructs may facilitate controlled physiological joint motion and potentially shorten rehabilitation timelines compared with rigid fixation protocols.

A broader review comparing flexible fixation to traditional techniques also noted comparable or superior functional scores and activity return rates, with flexible fixation showing high postoperative AOFAS and VAS scores, high return to

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activity, and relatively low complication rates [22]. Although long-term comparative data are limited, these early outcomes suggest that flexible fixation techniques—especially suture button and internal brace constructs—provide reliable short- to mid-term clinical and functional benefits in the management of ligamentous Lisfranc injuries.

### Radiological Outcomes and Maintenance of Reduction

Radiological assessment across studies demonstrated **significant improvement in intermetatarsal and intercuneiform alignment** following flexible fixation, with most studies reporting maintenance of reduction at final follow-up [10,17]. Improvements in diastasis on weight-bearing radiographs or computed tomography were consistently statistically significant when compared with preoperative measurements. Although isolated cases of recurrent diastasis were reported, loss of reduction was uncommon and rarely required revision surgery. These findings indicate that flexible fixation can achieve and maintain anatomical reduction in purely ligamentous Lisfranc injuries when appropriate patient selection and surgical technique are employed.

### Complications and Reoperations

The overall complication rate associated with flexible fixation devices was low. Reported complications were generally minor and included transient sensory disturbances, button-site discomfort, superficial infection, and occasional hardware irritation. Importantly, **routine implant removal was not required** in most series, representing a significant advantage over traditional transarticular screw fixation [10-16,18-20]. The avoidance of a planned second procedure reduces patient morbidity, healthcare costs, and delays in rehabilitation. Post-traumatic arthritis and implant failure were infrequently reported within the available follow-up periods, although longer-term data remain limited.

Several clinical studies and systematic reviews evaluating rigid fixation have reported variable functional outcomes and relatively high rates of secondary procedures, particularly elective implant removal, which may contribute to patient morbidity and prolonged recovery [24,25]. Although bridge plating and joint-preserving techniques aim to mitigate some of these concerns, they still rely on rigid constructs and may not fully accommodate the native biomechanics of the Lisfranc ligament complex [25].

In contrast, flexible fixation techniques—most commonly suture button constructs and internal brace systems—are designed to more closely replicate the biomechanical behaviour of the native Lisfranc ligament, allowing controlled physiological motion while maintaining joint stability. Cadaveric biomechanical studies have demonstrated that suture button constructs restore near-anatomic stability while avoiding transarticular cartilage violation associated with screw fixation [26,27].

Clinical outcome studies have further supported these biomechanical findings, reporting high functional scores, early return to activity, and lower rates of implant-related complications with flexible fixation compared to rigid constructs [28]. A recent comparative review noted that flexible fixation demonstrated similar or improved functional outcomes and return-to-activity rates, with fewer implant-related reoperations, when compared with traditional screw fixation [29].

While long-term randomized comparative data remain scarce, the available biomechanical and clinical evidence suggests that flexible fixation represents a promising alternative to rigid fixation, particularly in young and active patients where preservation of joint motion and avoidance of secondary surgery are important considerations.

## Limitations

Several limitations must be acknowledged. The majority of included studies were retrospective studies, with inherent risks of selection bias and heterogeneity in surgical technique, outcome measures, and follow-up duration. Sample sizes were generally small, and high-level comparative studies were scarce. Additionally, the definition of "purely ligamentous" injury varied between studies, and some included adjunctive fixation when additional instability was present. Long-term outcomes beyond five years remain underreported, limiting conclusions regarding the durability of flexible fixation and the development of late post-traumatic arthritis.

Future research should focus on **prospective comparative studies** and randomized controlled trials comparing flexible fixation with rigid fixation and primary arthrodesis in clearly defined ligamentous Lisfranc injuries. Standardization of outcome measures, longer follow-up, and cost-effectiveness analyses would further clarify the role of flexible fixation in contemporary treatment algorithms.

## Summary

In summary, this systematic review demonstrates that flexible fixation devices provide **excellent clinical, functional, and radiological outcomes** in the treatment of purely ligamentous Lisfranc injuries, with **low complication rates** and **minimal need for secondary surgery**. These findings support the growing role of flexible fixation as a viable and biomechanically favourable alternative to traditional rigid fixation in appropriately selected patients.

## Included Papers:

1. Fan Y, Liu C, Xu W, et al. Clinical outcomes of Tightrope system in the treatment of purely ligamentous Lisfranc injuries. BMC Surg 21 (2021): 395-395.
2. Zeng G, Xie Q, Huang H, et al. Internal brace fixation technique for Lisfranc injury: a retrospective study. Med Sci Monit 30 (2024): e943537-e943537.

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