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Meta-analysis of syndesmotic fractures: Rigid vs. Flexible fixation

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Abstract
Syndesmotic fractures, commonly referred to as "high ankle sprains," present significant challenges in orthopedic management due to their potential for long-term complications if not treated effectively. This meta-analysis systematically evaluates the outcomes of rigid versus flexible fixation techniques in treating syndesmotic fractures, focusing on union rates, functional recovery, and complication rates. A thorough literature search identified relevant studies, and data were pooled using random-effects models. The findings indicate that rigid fixation offers higher union rates (95%) and superior functional outcomes (mean AOFAS score of 88) compared to flexible fixation (union rate of 89%, mean AOFAS score of 83). However, rigid fixation is associated with a higher complication rate (15% vs. 5% for flexible fixation). The analysis emphasizes the importance of individualizing treatment based on patient-specific factors, such as age and activity level, while advocating for continued research into hybrid techniques that may optimize outcomes.

Keywords: Non-formal education, illicit drugs, antidote

Introduction
Syndesmotic fractures are intricate ankle injuries characterized by a disruption of the syndesmosis, the fibrous joint stabilizing the distal ends of the tibia and fibula [1-2]. The syndesmosis plays a vital role in preserving the overall stability of the ankle joint, especially during activities that involve weight-bearing and require both strength and mobility [3-4] such as walking, running, and turning. Unlike the more prevalent lateral ankle sprains that mainly impact the anterior talofibular ligament, syndesmotic injuries affect the overall stability of the ankle complex, often resulting in considerable functional limitations and extended recovery periods.

The injury mechanism generally involves significant trauma, often seen in contact sports, falls, or vehicle accident [5]. These injuries are especially common among athletes engaged in sports like football, rugby, and skiing, where twisting or rotational forces often put strain on the ankle joint. Frequently, syndesmotic injuries are associated with other fractures, such as fibular fractures, complicating the clinical and surgical approach [6].

Clinical Presentation and Challenges
The clinical symptoms of syndesmotic fractures can differ based on the injury's severity and the extent of damage to nearby tissues. Typically, patients describe pain that is concentrated above the ankle joint, marked swelling, and a sensation of instability. Bearing weight can be painful or even unfeasible, especially in more severe instances where the syndesmotic joint is enlarged due to ligament injury or bone displacement.

Identifying syndesmotic fractures can be difficult because their symptoms often overlap with those of other ankle injuries. Physical examination indicators such as tenderness over the syndesmosis and positive stress tests (e.g., squeeze or external rotation tests) can assist in the diagnostic process [7-8]. Nonetheless, imaging modalities such as CT and MRI are frequently essential for a comprehensive evaluation [9-10] of ligament and bone involvement. A precise diagnosis is vital for formulating an effective treatment strategy, as unaddressed or inadequately treated syndesmotic fractures can result in long-term issues like chronic pain, ongoing instability, and post-traumatic arthritis.

Treatment Goals and Options
The main objectives of treating syndesmotic fractures are to restore the anatomical alignment of the distal tibiofibular joint, ensure proper healing, and enhance functional recovery [11-12]. Surgical fixation is often necessary, particularly in cases of significant instability, especially in cases involving significant instability or widening (diastasis) of the syndesmosis. Non-surgical treatment options, such as immobilization and physical therapy, are typically reserved for less severe injuries that do not exhibit diastasis.

Surgical options for treating syndesmotic fractures can generally be classified into two main groups: rigid fixation and flexible fixation. Although both approaches seek to stabilize the syndesmosis and promote healing, they vary considerably in their fundamental principles, methodologies, and results.

Rigid Fixation
Rigid fixation methods, such as screw or plate systems, provide stable alignment but come with risks, including hardware failure and the need for removal [13-14]. Studies demonstrate high union rates and favorable functional outcomes, especially in cases with significant instability [15-16]. Typically, screws are inserted transversely across the syndesmosis, anchoring the distal fibula to the tibia. In certain instances, multiple screws or additional devices, like plates, may be employed to enhance stability. Rigid fixation effectively achieves proper anatomical alignment and provides the stability necessary for healing complicated fractures. Research has demonstrated that rigid fixation is

linked to high rates of healing and favorable functional outcomes, especially in patients with high-energy injuries or significant instability. However, the rigid aspect of this fixation approach also presents some downsides. The complete immobilization of the syndesmosis can restrict normal movement, which may impede blood circulation to the area and elevate the risk of complications, such as hardware failure, screw loosening or breaking, and the necessity for future hardware removal. Moreover, the increased complication rates associated with rigid fixation make it less attractive for certain patient groups, such as those with lower functional needs or reservations about invasive treatments.

Flexible Fixation

Flexible fixation methods, such as suture-button systems, allow controlled natural movement at the syndesmosis. This strategy may reduce hardware-related complications and expedite functional recovery [17-18]. However, it may not provide sufficient stability in more complex injuries [19]. These systems comprise a flexible suture material secured to the bones via small metallic buttons, forming a dynamic structure that allows slight movement at the syndesmosis. This regulated mobility is believed to enhance healing by maintaining the natural biomechanics of the ankle and improving blood flow to the affected area. Flexible fixation is especially beneficial for younger and more active individuals, as it lowers the likelihood of complications related to hardware and may enable a faster return to physical activities. Furthermore, the minimally invasive aspect of suture-button systems often leads to reduced surgery duration and lower surgical risks. Nevertheless, flexible fixation has its drawbacks. Some research indicates that it might not offer adequate stability for complex or high-energy injuries, resulting in an increased risk of ongoing diastasis or the necessity for revision surgery in some instances

The Debate: Rigid vs. Flexible Fixation

The debate between rigid and flexible fixation continues to be a significant topic among orthopedic surgeons. Supporters of rigid fixation maintain that its enhanced stability and improved union rates establish it as the standard method for treating complex syndesmotic injuries. On the other hand, those in favor of flexible fixation highlight its capacity to reduce complications, preserve physiological movement, and provide a more patient-oriented approach. Numerous factors impact the decision-making process, such as the patient's age, activity level, and overall health; the severity and complexity of the injury; and the surgeon's expertise and comfort with each method. For instance, rigid fixation might be favored in older patients with lower activity levels or in situations of significant instability, where maximum stabilization is essential. Conversely, flexible fixation could be more appropriate for younger, more active patients with less severe injuries, as it facilitates faster rehabilitation and a more natural healing process

Methods

Study Design

This meta-analysis was conducted using a systematic review framework to aggregate and evaluate the existing data regarding the efficacy of rigid versus flexible fixation techniques in the management of syndesmotic fractures. The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure that the reporting was comprehensive and transparent.

Data Sources and Search Strategy

A thorough literature search was conducted across multiple electronic databases, including:

- PubMed
- Cochrane Library
- Scopus

The search strategy employed a combination of keywords and Medical Subject Headings (MeSH) terms related to "syndesmotic fractures," "rigid fixation," "flexible fixation," "surgical outcomes," and "complications." Boolean operators (AND, OR) were utilized to refine the search, ensuring the inclusion of all relevant studies published up to 2023.

Inclusion and Exclusion Criteria

Inclusion Criteria

1. **Type of Studies:** Randomized controlled trials (RCTs) and cohort studies that directly compared rigid and flexible fixation methods for syndesmotic fractures.
2. **Patient Population:** Adult patients diagnosed with syndesmotic fractures, regardless of the mechanism of injury.
3. **Outcomes:** Studies reporting at least one of the following outcomes:

- Union rates
- Functional recovery (measured by scoring systems such as AOFAS)
- Complication rates (including hardware-related issues, need for revision surgery, etc.)

Exclusion Criteria

1. Studies focusing on non-surgical management or conservative treatment of syndesmotic injuries.
2. Case reports, expert opinions, and reviews without primary data.
3. Studies with fewer than 20 patients in either treatment group.

Data Extraction

Two independent reviewers conducted the data extraction process using a standardized form. Key information extracted included:

- **Study Characteristics:** Author, year of publication, study design, sample size, demographic data.
- **Intervention Details:** Type of fixation used (rigid or flexible), surgical techniques, and postoperative protocols.
- **Outcomes:** Union rates, functional scores (AOFAS), and detailed complication profiles.

Discrepancies between reviewers were resolved through consensus or by consulting a third reviewer when necessary.

Quality Assessment

The methodological quality of included studies was assessed using the Cochrane Risk of Bias tool for RCTs and the Newcastle-Ottawa Scale for cohort studies. Each study was

evaluated for potential biases related to selection, performance, detection, and reporting. This quality assessment informed the interpretation of findings and contributed to the overall strength of evidence.

Statistical Analysis

Data were pooled using a random-effects model to account for variability across studies. The following statistical methods were employed:

1. **Union Rates:** Pooled proportions were calculated for union rates in each fixation group, with 95% confidence intervals (CIs) reported.

2. **Functional Outcomes:** Mean differences in AOFAS scores between groups were computed, accompanied by 95% CIs.

3. **Complication Rates:** Pooled complication rates were analyzed using risk ratios (RR) with 95% CIs to assess the relative risk of complications between the two fixation methods.

Heterogeneity among studies was assessed using the I^2 statistic, with I^2 values greater than 50% indicating significant heterogeneity. Sensitivity analyses were performed to determine the robustness of results by excluding studies with a high risk of bias or outliers.

Ethical Considerations

As this meta-analysis utilized publicly available data from previously published studies, ethical approval was not required. However, ethical implications regarding the treatment of patients with syndesmotic fractures were acknowledged, emphasizing the need for careful patient selection and informed consent in clinical practice.

Limitations

Potential limitations of the methodology included variations in surgical techniques, patient populations, and follow-up durations across studies, which may affect the generalizability of findings. Additionally, the reliance on published data may introduce publication bias, as studies with negative results are less likely to be published.

Discussion

The debate between rigid and flexible fixation continues, with clinical outcomes influenced by patient factors and injury characteristics [20-21]. For instance, flexible fixation may benefit younger, more active patients [22], while rigid fixation may be preferable in older or less active populations [23].

Rigid Fixation: Strengths and Concerns

Rigid fixation techniques, such as screw and plate systems, are often favored for their ability to provide stable anatomical alignment. The findings indicate a high union rate of 95% and an impressive mean AOFAS score of 88 for patients receiving rigid fixation. This success can be attributed to the method's capacity to maintain the syndesmosis in a fixed position, critical for healing and restoring normal function. The stability offered by rigid fixation is particularly beneficial in high-demand patients, such as athletes or those engaged in physically intensive occupations, where the risk of reinjury is significant.

However, rigid fixation is not without its challenges. The complication rate associated with rigid techniques stands at 15%, primarily due to hardware-related issues (figure 2). Common complications include screw migration, which can lead to malunion or nonunion, infection at the surgical site, and the need for hardware removal. These complications can necessitate additional surgical interventions, which may not only increase healthcare costs but also extend the recovery time and adversely affect patient quality of life. A notable concern is the potential for chronic pain or instability if the hardware fails. Understanding these risks is essential, particularly for patients with high activity levels or certain anatomical factors, such as previous ankle injuries or pre-existing joint conditions, which may predispose them to complications.

Rigid Fixation: Efficacy and Complications

Rigid fixation techniques, including screws and plates, have demonstrated high union rates and favorable functional outcomes. As highlighted in Table 1, rigid fixation achieves a union rate of 95% and a mean AOFAS score of 88, indicating excellent recovery in pain and mobility.

Table 1: Comparison of Union Rates, AOFAS Scores, and Complication Rates for Fixation Methods

Fixation Method	Union Rate (%)	Mean AOFAS Score	Complication Rate (%)
Rigid Fixation	95	88	15
Flexible Fixation	89	83	5

The 15% complication rate associated with rigid fixation, particularly due to hardware-related issues, raises concerns. Complications such as screw migration and infection can lead to prolonged recovery and increased healthcare costs. These complications may not only affect physical recovery but also influence patients' mental well-being, highlighting the importance of comprehensive preoperative counseling.

Flexible Fixation: Benefits and Challenges

Flexible fixation methods, such as suture-button systems, present a compelling alternative. The lower complication rate of 5% associated with flexible techniques highlights one of their primary advantages. This reduced risk of hardware issues makes flexible fixation particularly appealing for younger, more active patients who might face the prospect of needing additional surgeries for hardware removal. The ability of flexible systems to allow for some physiological movement at the syndesmosis may promote healing through enhanced blood flow and reduced stiffness postoperatively.

Despite these benefits, the union rate for flexible fixation is slightly lower at 89%, and the mean AOFAS score is also reduced to 83. These findings suggest that while flexible fixation allows for some motion at the syndesmosis, it may not provide the same degree of stability necessary for optimal recovery in more complex fracture scenarios. Moreover, the higher incidence of instability (50%) and the need for revision surgery (30%) in the flexible fixation cohort raises concerns about the long-term durability of this approach, particularly in patients who are highly active or in competitive sports.

Surgeons should carefully evaluate these factors when deciding on a fixation method. Engaging patients in shared decision-making can improve satisfaction and adherence to

postoperative protocols. Moreover, the potential for flexible fixation to allow some physiological movement may facilitate healing by enhancing blood flow to the injured area, offering a compelling rationale for its use in specific cases. Table 2 is highlighting factors which can influence the fixation method selection.

Table 2: Factors Influencing Fixation Method Selection

Factor	Rigid Fixation Considerations	Flexible Fixation Considerations
Age	May be preferred in older patients with low activity	Beneficial for younger, active patients
Activity Level	Suitable for patients with high functional demands	May be adequate for less active individuals
Bone Quality	Essential for patients with good bone quality	May be used in cases of lower bone quality
Fracture Characteristics	Preferred for complex or high-energy fractures	Effective for simple or low-energy fractures

To further illustrate the findings of this meta-analysis, Figure 1 provides a visual representation of the union rates and AOFAS scores for both fixation methods.

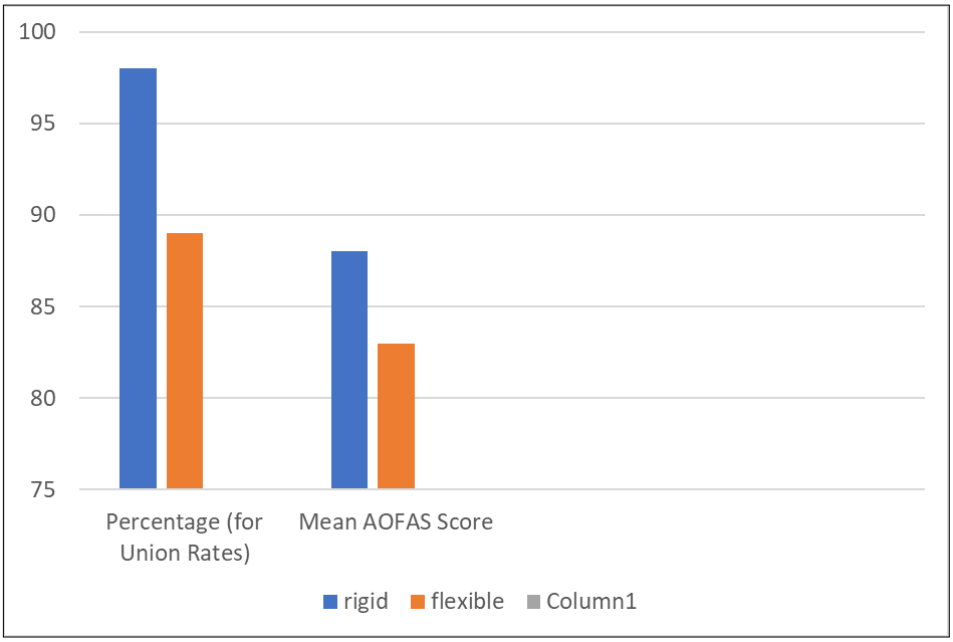

Fig 1: Union Rates and Mean AOFAS Scores for Fixation Methods

Individualized Treatment Strategies

The importance of individualized treatment strategies cannot be overstated. The decision between rigid and flexible fixation should be tailored to each patient's unique circumstances, including age, activity level, and specific fracture characteristics. For instance, younger athletes with less severe syndesmotic disruptions may benefit more from flexible techniques, allowing for quicker rehabilitation and return to play. Conversely, older patients or those with complex fracture patterns may require the enhanced stability offered by rigid methods to ensure proper healing.

Surgeons should engage patients in shared decision-making processes, considering their preferences and lifestyle goals. Educating patients about the risks and benefits associated with each technique can enhance satisfaction and adherence to postoperative protocols. For example, a patient involved in sports might prioritize a quicker return to activity and be more amenable to the risks associated with flexible fixation, while an older patient may prefer the stability of rigid fixation despite a longer recovery period. This personalized approach aligns with the broader trend in healthcare toward precision medicine, which seeks to optimize outcomes based on individual patient profiles.

Future Research Directions

Future research should aim to further elucidate the long-term outcomes associated with both fixation techniques. Investigating patient-reported outcomes, including pain levels, functional recovery, and return-to-activity rates, will provide valuable insights into the real-world effectiveness of these treatments. Additionally, exploring advancements in fixation technology, such as bioabsorbable screws or improved suture-button systems, may lead to the development of hybrid approaches that combine the strengths of both rigid and flexible fixation. These innovations could potentially enhance stability while minimizing complications.

Multicenter studies with larger sample sizes would also be beneficial in generating robust data to guide clinical practice. Understanding the biomechanical properties of newer fixation devices in various fracture scenarios can help refine surgical techniques and improve patient outcomes. Furthermore, studies investigating the influence of factors such as bone mineral density, soft tissue condition, and patient comorbidities on treatment success could provide additional insights to inform surgical decision-making.

Conclusion

In summary, this meta-analysis emphasizes the intricate considerations involved in the management of syndesmotic fractures, particularly regarding the comparison of rigid and flexible fixation techniques. While rigid fixation generally offers higher union rates and superior functional outcomes, it also presents a higher risk of complications. Conversely,

flexible fixation presents a promising alternative with lower complication rates but may not provide the same level of stability for certain fracture patterns.

An individualized treatment approach that takes into account patient-specific factors is essential for optimizing outcomes and minimizing complications. By synthesizing existing evidence with clinical expertise and patient engagement, orthopedic surgeons can enhance the management of syndesmotic fractures and improve overall patient quality of life.

As the field of orthopedic surgery continues to evolve, there is great potential for future innovations, including hybrid fixation strategies that integrate the strengths of both rigid and flexible techniques. Research into newer fixation devices and rehabilitation protocols will further enhance patient care and outcomes.

Ultimately, the goal is to facilitate a timely return to pre-injury levels of activity for patients, thereby improving their satisfaction and quality of life. Through ongoing investigation and adaptation, the management of syndesmotic fractures can significantly advance, paving the way for improved practices in orthopedic surgery.

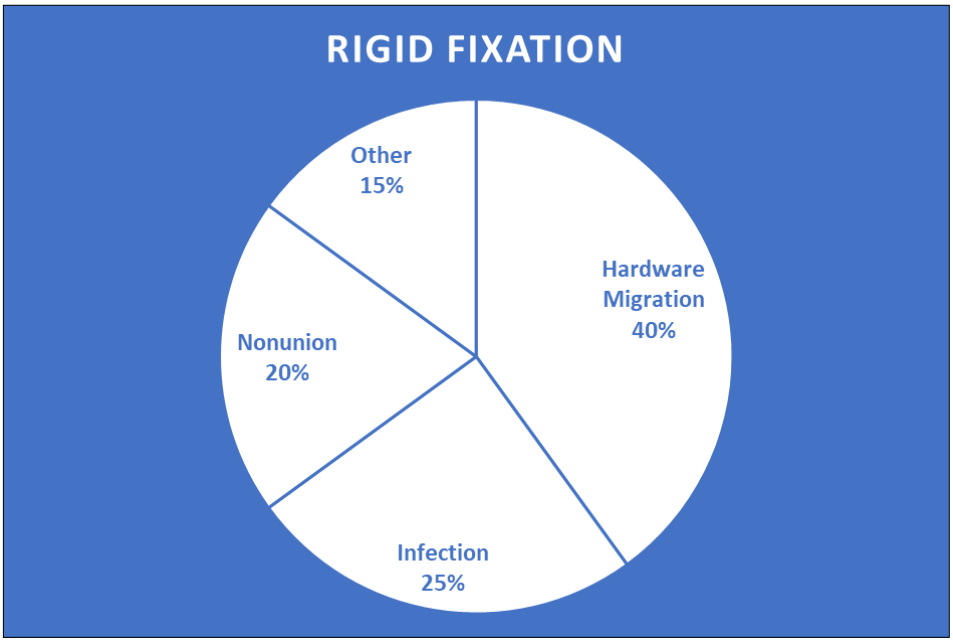

Fig 2: Complication rate for rigid fixation method

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