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Review

Comparative study of different fixation methods for osteosynthesis of ankle fractures: clinical outcomes and bone consolidation rates

Marcos Aurélio Silva Oliveira[1], Hayani Yuri Ferreira Outi[2], Edvard José dos Santos Neto[1], Pedro Luiz Belei Garcia[3], Givago Lessa Batista[4], Bárbara Menns Augusto Pereira[4], Cassiano Coelho de Almeida[5], Diego Silva Bessa[5]

1. Faculdades Integradas Padrão Afya, Guanambi, BA, Brazil.
2. Centro Universitário de Adamantina, Adamantina, SP, Brazil.
3. Universidade Positivo, Curitiba, PR, Brazil.
4. Hospital do Oeste, Barreiras, BA, Brazil.
5. Hospital das Clínicas da UFG / EBSERH, Goiânia, GO, Brazil.

Abstract

Objective: To describe and analyze the evidence on the effectiveness of different fixation methods for osteosynthesis of ankle fractures, highlighting clinical outcomes and bone consolidation rates.

Methods: This study is a systematic literature review conducted to gather and evaluate the available evidence on different fixation methods for osteosynthesis of ankle fractures. The PubMed, Scopus, Web of Science, Cochrane Library, and Virtual Health Library (VHL) databases were used. We included studies published in the last 10 years, available in full text, and in English, Portuguese, or Spanish that compared fixation methods. Screening was performed by two independent reviewers in two stages (titles/abstracts and complete evaluation). A third reviewer resolved disagreements. Extracted data included population, interventions, outcomes, and conclusions.

Results: The analysis included studies published in the last 10 years, encompassing diverse populations and methodologies. The results indicate that the choice of fixation method should consider not only functional outcomes, but also fracture severity and pattern. Intramedullary fixation has shown advantages in less complex fractures and in patients at higher risk of infectious complications. Plate fixation remains the technique of choice in complex fractures, although it is associated with higher complication rates in patients with comorbidities and older patients. The use of external fixators, in turn, is indicated for extensive soft-tissue injuries or as a temporary measure before definitive surgery.

Conclusion: The choice of fixation method should be individualized, considering the severity of the fracture, the patient's clinical status, and any associated complications. Intramedullary fixation tends to be more favorable in simple cases, while plate fixation is indicated for complex fractures. External fixators remain an important option in specific situations.

Level of Evidence II; Systematic Review.

Keywords: Ankle Fractures; Fracture Fixation, Internal; Fracture Healing.

Introduction

Ankle fractures are one of the most frequent injuries in orthopedics, especially among older patients, who are more prone to falls due to bone fragility and osteoporosis. According to an epidemiological study by Woo et al.[1], the incidence of ankle fractures has increased significantly with population aging, emerging as a growing public health concern. These fractures can result in serious complications, including prolonged functional disability and the development of post-traumatic arthrosis, especially if not treated properly[2].

Study performed at the Faculdades Integradas Padrão Afya, Guanambi, BA, Brazil.

Correspondence: Marcos Aurélio Silva Oliveira. **Email:** ms.aureliofacul@gmail.com.
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The management of these fractures depends on several factors, including the type of fracture, the patient's age, comorbidities, and the condition of the soft tissues around the injury. Osteosynthesis, or surgical fixation of fractured bones, is commonly necessary to ensure joint stability and promote bone consolidation, both of which are essential for the recovery of ankle function[3].

Several surgical techniques are available, each with its specific indications, advantages, and possible complications. Internal fixation with plates and screws is the most widely used technique for complex fractures, such as bimalleolar and trimalleolar fractures. This approach allows stable, aligned fixation of the bone fragments, which is crucial for early functional recovery. A study by Alcelik et al.[4] demonstrated that internal fixation with plates and screws achieves a high bone consolidation rate and reduces the risk of postoperative misalignment, thereby contributing to better functional outcomes. However, complications can occur, including infections and fixation failures, particularly in diabetic patients or in other conditions that compromise healing[5].

In recent years, the use of intramedullary nails to fix distal tibial shaft fractures, which often accompany ankle fractures, has gained attention. This technique is less invasive, preserving soft tissues and reducing the risk of superficial infection. Peng et al.[6] conducted a retrospective review suggesting that intramedullary fixation may be a viable alternative in certain cases, offering good stability without the need for an extensive soft-tissue approach. However, this technique is not appropriate for all types of fractures, and its application remains limited to selected cases[7].

In situations where fractures are accompanied by significant soft-tissue injuries or involve open fractures, external fixators are often used as a temporary or definitive measure. According to Chen et al.[8], external fixators allow immediate stabilization of the fracture, reducing the risk of infection and allowing treatment of soft-tissue injuries before definitive surgical intervention. Despite their effectiveness, the prolonged use of external fixators is associated with significant patient discomfort and an increased risk of complications at pin insertion sites.

This study aims to conduct a comparative analysis of fixation methods used in osteosynthesis of ankle fractures, considering clinical outcomes, consolidation rates, and complications associated with each technique.

Methods

This study is an epidemiological analysis based on a systematic review of the literature in scientific databases. The systematic review is chosen to ensure a comprehensive and objective evaluation of the existing evidence on fixation methods for osteosynthesis of ankle fractures.

The PubMed, Scopus, Web of Science, Cochrane Library, and Virtual Health Library (VHL) databases were used. The inclusion criteria were studies published in the last 10 years and available in full text that compared the postoperative outcomes of different fixation methods for osteosynthesis of ankle fractures.

A structured search was performed in the aforementioned databases using a combination of keywords and MeSH terms, such as "ankle fracture osteosynthesis," "fixation methods," "clinical outcomes," "bone healing rates," osteossíntese de fratura de tornozelo," and "métodos de fixação." The search strategy was adapted for each database, and the search terms were combined with Boolean operators to improve sensitivity and specificity.

The study selection was conducted in two stages: the initial screening, which included two independent reviewers who examined the titles and abstracts of articles identified in the initial search to exclude studies that did not meet the inclusion criteria, and the evaluation of potentially relevant articles in full.

Both reviewers independently decided on the inclusion or exclusion of the studies. In case of disagreements, a third reviewer was consulted to resolve the disagreements.

Data were extracted from each selected study, including information on methodology, study population, interventions, results, and conclusions.

Extracted data were synthesized and analyzed to identify trends, common outcomes, and discrepancies between studies.

The inclusion criteria included studies published over the last 10 years (2014 - 2024), studies available in full text, studies published in English, Portuguese, or Spanish, patients with ankle fractures, without restriction of age, sex or other demographic characteristics, studies that directly compared different fixation methods for osteosynthesis of ankle fractures, patients with ankle fractures, without restriction of age, sex or other demographic characteristics, and postoperative clinical outcomes, including complication rates, bone consolidation rates, functional recovery time, and health-related quality of life.

Through this systematic review, it was hoped to achieve a comprehensive and detailed understanding of the comparative effectiveness of the different fixation methods used in the osteosynthesis of ankle fractures. Expected results included:

- It is expected to identify which fixation method—whether internal fixation with plates and screws, intramedullary nails, or external fixators—offers the best outcomes in terms of bone consolidation and functional recovery. This includes assessing which technique promotes faster recovery, reduces immobilization time, and facilitates early return to daily and occupational activities.
- One of the main objectives is to compare complication rates across fixation methods. Complications such as infections, fixation failures, pseudarthrosis, and the need for surgical revisions will be analyzed. It is expected to determine whether any method has a superior safety profile, especially in at-risk populations such as patients with diabetes or older patients.

- It is expected to identify whether certain fixation methods are more effective in specific subgroups of patients, such as those with more complex fractures (e.g., bimalleolar and trimalleolar fractures), those with comorbidities (such as diabetes), or those in different age groups. This analysis may reveal whether certain patient characteristics influence the choice of the most appropriate fixation method.
- The review should provide detailed information on the functional outcomes associated with each fixation method, including assessment of range of motion, joint stability, and the incidence of chronic pain or discomfort. The expectation is to identify which technique provides the best long-term quality of life and minimizes the incidence of permanent sequelae.
- In addition to clinical and functional outcomes, it is expected to obtain data on the quality of life of patients undergoing different fixation methods. This includes assessing subjective measures of well-being, satisfaction with treatment, and psychological impact. This aspect is particularly relevant to understanding the overall success of treatment from patients' perspective.
- By compiling and synthesizing data from existing studies, this systematic review is expected to provide a solid evidence base to guide clinical practice. The results may inform the development of guidelines and clinical protocols to help orthopedic surgeons select the most appropriate fixation method for each case.
- In addition to practical insights, the study is expected to identify gaps in the existing literature, highlighting areas where there is a lack of robust evidence or where more research is needed. This may include the need for better-designed studies, research in underrepresented populations, or investigations into new attachment technologies that are emerging in the field.
- Finally, the results of this review are expected to help advance toward personalization of ankle fracture treatment, allowing surgeons to adjust their approaches based on individual patient characteristics such as fracture severity, coexisting medical conditions, and personal preferences, thereby ensuring the best possible outcomes.

Results and discussions

The analysis covers studies published in the last 10 years and includes a variety of methodologies and patient populations.

It is important to note that the less favorable results associated with fixation with plates and external fixators are largely related to the complexity of the fracture patterns and the associated injuries that required such techniques. Therefore, the severity of the fracture must be considered a determining factor in the choice of fixation method and the interpretation of outcomes.

Determination of the most suitable fixation method

The effectiveness of fixation methods for ankle fractures varies considerably depending on the type of fracture, patients' clinical conditions, and potential complications. This section explores in detail the main findings of each fixation technique, with an emphasis on evidence from specific articles.

Intramedullary fixation (IF)

Intramedullary fixation is widely adopted for fractures of the distal tibia, especially in fractures of the lateral malleolus. Peng et al. [6] showed that IF provides greater stability, resulting in lower postoperative complication rates than plate fixation (PF), particularly in less complex fractures. The study highlighted that the less invasive approach to IF reduces surgical trauma, favoring faster functional recovery and a lower incidence of infections.

Alcelik et al.[4] corroborate the efficacy of IF in patients at high risk of infectious complications, such as those with diabetes. Due to the lower soft tissue impairment, IF proved to be superior in preventing severe infectious complications, making it a preferable option for patients with significant comorbidities.

Another relevant point about IF is its application to simpler fractures that do not require the robust stabilization offered by PF. In distal tibia fractures, IF stood out for maintaining necessary stability while reducing recovery time and associated complication rates[6].

Plate fixation

Plate fixation is generally the technique of choice for complex ankle fractures such as bimalleolar and trimalleolar fractures. Chen et al.[8] demonstrated that PF provides excellent joint stability, which is crucial in fractures where joint integrity is severely compromised. Plate fixation's ability to resist multidirectional forces makes it the technique of choice in fractures that require a strong attachment to prevent loss of alignment during the healing process.

However, PF is not risk-free. Pearce et al.[2] identified that the use of PF is associated with a higher incidence of complications in older patients, such as surgical site infections and fixation-related problems. This study suggests that while PF is effective for stability, its use should be carefully considered in vulnerable populations, where the risks of complications may outweigh the benefits.

Chan et al.[9] also directly compared IF and PF, concluding that despite the complications associated with PF, it remains the preferred technique for fractures requiring robust, durable fixation. This is particularly relevant in trimalleolar fractures, where FP ensures that all gait-related forces are properly distributed across the fixation, minimizing the risk of implant failure.

Fixation with external pins

Fixation with external pins is often used in situations with extensive soft-tissue damage or a high risk of infection, making immediate internal fixation impossible. Chen et al.[8] showed that external fixation can be an effective solution when temporary stabilization is required until soft-tissue conditions improve.

However, this technique is not without problems. Alcelik et al.[4] pointed out that complications such as pin migration and superficial infections are common. While these complications are generally manageable, they require constant vigilance and a rigorous postoperative care protocol to prevent more serious infections.

External fixation may also be used as a temporary method prior to conversion to definitive internal fixation. In highly unstable fractures with significant soft-tissue compromise, external fixation allows the surgeon to gain time until a definitive intervention can be safely performed[8].

Comparison among methods

The comparison between IF and PF is central in many of the reviewed studies. Chan et al.[9] noted that while IF may be preferred for less complex fractures due to lower complication rates, PF remains the ideal option for fractures requiring more robust stabilization, such as trimalleolar fractures. The choice between these techniques should therefore be based not only on the complexity of the fracture but also on the patient's individual characteristics, including age, soft-tissue quality, and comorbidities.

Assessment of complication rates

The complications associated with the different fixation methods vary considerably, as described in the reviewed articles.

Intramedullary fixation: Chan et al.[9] reported that IF is associated with lower rates of infection and wound-related complications compared with FP. However, in patients with comorbidities such as diabetes, Gougoulias et al.[5] reported a higher incidence of non-bone consolidation and late complications, suggesting that although IF is less invasive, its limitations in certain patient groups should be considered.

Plaque fixation: Pearce et al.[2] documented higher complication rates in older patients undergoing PF, including surgical site infections and the need for secondary interventions. This indicates that PF may be less recommended in patients with additional risk factors, such as advanced age and comorbidities, such as osteoporosis.

External pins: Although effective for temporary stabilization, they are associated with complications such as pin migration and superficial infections[8]. These complications, while manageable, require close monitoring to prevent progression to more serious infections that could compromise the treatment outcome.

Subgroup analysis

Subgroup analysis offers detailed insights into how different fixation methods behave in specific patient populations.

Bimalleolar and trimalleolar fractures: Chen et al.[8] reported that PF is superior for postoperative joint stability in complex fractures. However, in certain cases, the combination of FI and PF has been considered, especially in trimalleolar fractures, to improve stability without significantly increasing the risk of complications.

Patients with comorbidities (such as diabetes): IF showed better bone consolidation rates in diabetic patients, as reported by Gougoulias et al.[5]. However, when the risk of infectious complications is high, external pin fixation may be a viable option, allowing a safer intervention until internal fixation can be performed.

Patients of different age groups: Woo et al. (2021) showed that PF is associated with a higher complication rate in older patients, whereas IF is more favorable because of its lower invasiveness. This suggests that patient age should be a critical factor in choosing the fixation method, with a possible preference for IF in elderly populations to minimize the risk of postoperative complications.

Functional outcomes

Functional outcomes are crucial in evaluating the success of different fixation techniques. These include range of motion, joint stability, and the incidence of chronic pain:

Range of motion: Peng et al.[6] observed that patients treated with IF demonstrated a faster recovery of range of motion, especially in simple fractures. This is due to the lower invasiveness of the procedure, which preserves the integrity of soft tissues and facilitates a more efficient rehabilitation.

Joint stability: In complex fractures, PF was superior in providing joint stability, as demonstrated by Chen et al.[8]. However, complete functional recovery may be slower than IF due to the greater invasiveness of PF and the higher risk of postoperative complications.

Chronic pain and discomfort: The incidence of chronic pain was lower among patients treated with IF, possibly due to the procedure's lower invasiveness and faster recovery. In contrast, PF was associated with greater postoperative discomfort, particularly in older patients, as described by Pearce et al.[2].

Impact on postoperative quality of life

Quality of life after surgery is an essential aspect in evaluating the success of different fixation techniques. Chan et al.[9] reported that quality of life was significantly better in patients treated with IF, due to faster recovery and lower complication rates. The lower invasiveness of the procedure contributes to a faster return to daily activities and reduced chronic pain, which significantly improves patients' quality of life.

On the other hand, patients treated with PF, especially those with complex fractures, reported higher levels of discomfort and a longer recovery, which negatively impacts their quality of life in the postoperative period. This suggests that, despite the superior stability offered by PF, its choice should be carefully weighed, especially in patients with high sensitivity to pain or comorbidities that may complicate recovery[2].

Summary of evidence for clinical practice

This systematic review brings together the available evidence to guide clinical practices in choosing the most appropriate fixation method for ankle fractures:

- Intramedullary fixation: Recommended for simple fractures and in patients at high risk of infectious complications. Intramedullary fixation is less invasive and facilitates faster recovery with fewer complications.
- Plate fixation: More suitable for complex fractures, such as trimalleolar, where a robust fixation is required. However, caution is warranted in older or comorbid patients due to the increased risk of complications.
- External pins: Mainly used in cases of significant soft tissue injuries or as temporary stabilization. Although effective, they require close monitoring to prevent complications.

Gaps in the literature

Despite significant advances in understanding fixation methods for ankle fractures, the review identifies several gaps in the literature that warrant attention. There is a lack of longitudinal studies examining functional outcomes and quality of life after surgery in the long term, especially in high-risk populations. The need for studies that address outcomes in specific subgroups, such as patients with multiple comorbidities or older patients, is evident. These studies would help further personalize treatment by providing specific data for different patient groups.

Considerations

The choice of fixation method for ankle fractures should be based on the patient's individual characteristics and the fracture's complexity. Intramedullary fixation has been shown to be superior in many cases, particularly in simple fractures and in patients at high risk of infectious complications. Plaque fixation, although effective in complex fractures, has been associated with a higher incidence of complications in patients with comorbidities and the older population. These findings highlight the importance of a personalized approach in the treatment of ankle fractures.

These conclusions reinforce the need for an individualized approach in the treatment of ankle fractures, considering factors such as age, comorbidities, and the complexity of the fracture. Ongoing development of fixation techniques and more specific studies across diverse subgroups is essential to optimize clinical outcomes and improve patients' quality of life.

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