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Systematic Review

Osteochondral lesions of the talus: diagnostic and therapeutic approaches in orthopedics

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Abstract

Objective: Evaluate the diagnostic and therapeutic approaches currently employed in the management of osteochondral lesions of the talus, with an emphasis on technological advances and regenerative therapies.

Methods: This review was conducted based on the PRISMA guidelines and included 16 studies published between 2010 and 2024, selected from the PubMed, Scopus, Web of Science, and Embase databases.

Results: Advanced imaging techniques, such as magnetic resonance imaging with T2 mapping and three-dimensional computed tomography, are fundamental for early diagnosis and surgical planning. Conservative approaches, such as immobilization and physiotherapy rehabilitation, have demonstrated efficacy in providing symptomatic relief for minor lesions; however, they present limitations in tissue regeneration and the long-term maintenance of joint function. Conventional surgical procedures, including microfractures and subchondral perforation, were associated with initial functional improvements but with a risk of progressive degeneration of the reparative fibrocartilage. Regenerative therapies, such as autologous and allogeneic osteochondral transplantation, as well as the use of mesenchymal stem cells and bioactive scaffolds, have shown potential in restoring hyaline cartilage and preserving the joint, particularly in complex and refractory lesions. Despite technological and therapeutic advances, challenges persist, including the standardization of protocols, high costs, and limited accessibility to emerging therapies. Additionally, a meta-analysis was not possible to perform due to the heterogeneity of the included studies, which encompassed both randomized clinical trials and observational studies.

Conclusion: Integrated and individualized therapeutic strategies are crucial for optimizing clinical outcomes, preserving joint functionality, and enhancing the quality of life for patients with osteochondral lesions of the talus.

Level of evidence I; Systematic Review.

Keywords: Lesion; Talus; Diagnostic imaging; Technological development.

Introduction

Osteochondral lesions of the talus (OLT) represent a significant diagnostic and therapeutic challenge in orthopedic practice, given their complexity and the functional role of the talus in the ankle joint. These lesions, often related to acute trauma or repetitive microtrauma, compromise the integrity of the cartilage and the underlying bone, which can progress to chronic pain, joint instability, and progressive degeneration. Although they are more prevalent in young and active individuals, the functional impact of these lesions can be severe in any age group, making it difficult to restore joint mobility fully[1].

An early and accurate diagnosis is essential to prevent the progression of osteochondral damage. Clinical examination, although relevant, is often insufficient to determine the extent of lesions, requiring the use of advanced imaging tests. Imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) have distinguished

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themselves for their ability to characterize the depth, stability, and impairment of adjacent structures, thereby assisting in therapeutic planning. However, gaps remain in the standardization of diagnostic criteria and the evaluation of response to treatment[2].

Therapeutic approaches vary widely, ranging from conservative strategies such as immobilization and rehabilitation to surgical interventions, which may include microfractures, autologous osteochondral transplantation, and tissue engineering techniques. Choosing the optimal technique is influenced by multiple factors, including the patient's age, the extent of injury, the level of physical activity, and the presence of biomechanical changes in the ankle. Despite recent advances in surgical technologies and biomaterials, the literature reports varied results, with success rates that depend on rigorous treatment selection and adherence to rehabilitation[3].

In addition, OLTs are often associated with joint comorbidities, including ligament instability and reactive synovitis, which can complicate clinical management. Such conditions require a multidisciplinary approach to ensure functional recovery and minimize the risk of recurrences. In this context, research in regenerative therapies, such as the use of mesenchymal stem cells and bioactive scaffolds, has shown promising potential in restoring osteochondral tissue and improving long-term clinical outcomes[4].

Given the clinical relevance and functional impact of OLT, healthcare professionals must understand the diagnostic and therapeutic nuances associated with these lesions. The integration of technological advances and ongoing scientific research are indispensable for optimizing management protocols, improving patient outcomes, and reducing the burden associated with long-term complications.

The objective of this study is to evaluate the diagnostic and therapeutic approaches currently employed in the management of osteochondral lesions of the talus, with an emphasis on technological advances and regenerative therapies. In addition, identify the clinical and radiological factors that influence the choice of treatment, as well as discuss the outcomes related to different orthopedic management strategies.

Methods

This systematic literature review adhered to the principles established for systematic reviews, as outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, prioritizing the scope and relevance of the included sources.

The search was conducted in the PubMed, Scopus, Web of Science, and Embase databases, covering publications between 2010 and 2024, with the inclusion of studies without language restriction. The descriptors used were selected based on Health Sciences Descriptors (DeCS) and Medical Subject Headings (MeSH), including the terms "osteochondral lesions of the talus," "diagnostic imaging," "therapeutic approaches," "ankle injuries" and "orthopedic management." The combination of terms was performed using Boolean operators ("AND" and "OR") to ensure a comprehensive and specific search.

Original articles, systematic reviews, meta-analyses, and relevant clinical studies addressing the diagnosis and treatment of OLT were included. Inclusion criteria were: (i) studies involving patients with a confirmed diagnosis of OLT; (ii) articles describing imaging techniques used in the diagnosis (MRI and CT); and (iii) research that presented therapeutic interventions, both conservative and surgical. Studies focusing exclusively on lesions of other joints, isolated case reports, and articles that did not provide full text were excluded (Figure 1).

The screening process was performed in two stages. Initially, two independent reviewers evaluated the titles and abstracts of the retrieved articles to verify their eligibility based on the defined criteria. Subsequently, the full texts of the selected studies were analyzed to confirm their inclusion. Disagreements were resolved by consensus or by consultation with a third reviewer.

Data from the included articles were extracted and organized. The analysis was qualitative, focusing on the identification of technological advances, limitations of current methods, and gaps in the literature that require further investigation. Whenever possible, the levels of evidence and the methodological quality of the studies were highlighted, using the GRADE system for critical evaluation.

As a limitation, it was not possible to perform a meta-analysis due to the inclusion of observational studies and randomized and non-randomized clinical trials. However, the findings of this systematic review make a significant contribution to the understanding of best practices in the management of OLT and provide support for future clinical research.

Results and Discussion

The 16 studies included in this qualitative analysis address a range of therapeutic strategies and techniques for the treatment of OLT, reflecting the diversity of clinical and surgical approaches available[5-20]. Investigations range from comparisons between conservative and surgical treatments, such as the study by Acar and Çevik (2025)[7], to the evaluation of new techniques, including the use of autologous osteochondral transplants and minimally invasive therapies (Wei et al., 2023)[11]. In addition, several studies evaluate the effectiveness of techniques such as bone marrow stimulation by arthroscopy (Arshad et al., 2022)[17], the induced matrix of chondrogenesis (Migliorini et al., 2022)[15], and the retrograde approach to OLT (Faldini et al., 2023)[13]. The analysis also includes research investigating the role of imaging in injury management (Khan et al., 2024)[9], the evaluation of healing indicators (Kim et al., 2022)[21], and the impact of chronic ankle instability on osteochondral lesions (Feng et al., 2022)[18]. Evidence extracted from these studies will be detailed below, providing critical insights into the effectiveness of treatments and future directions for managing OLT.

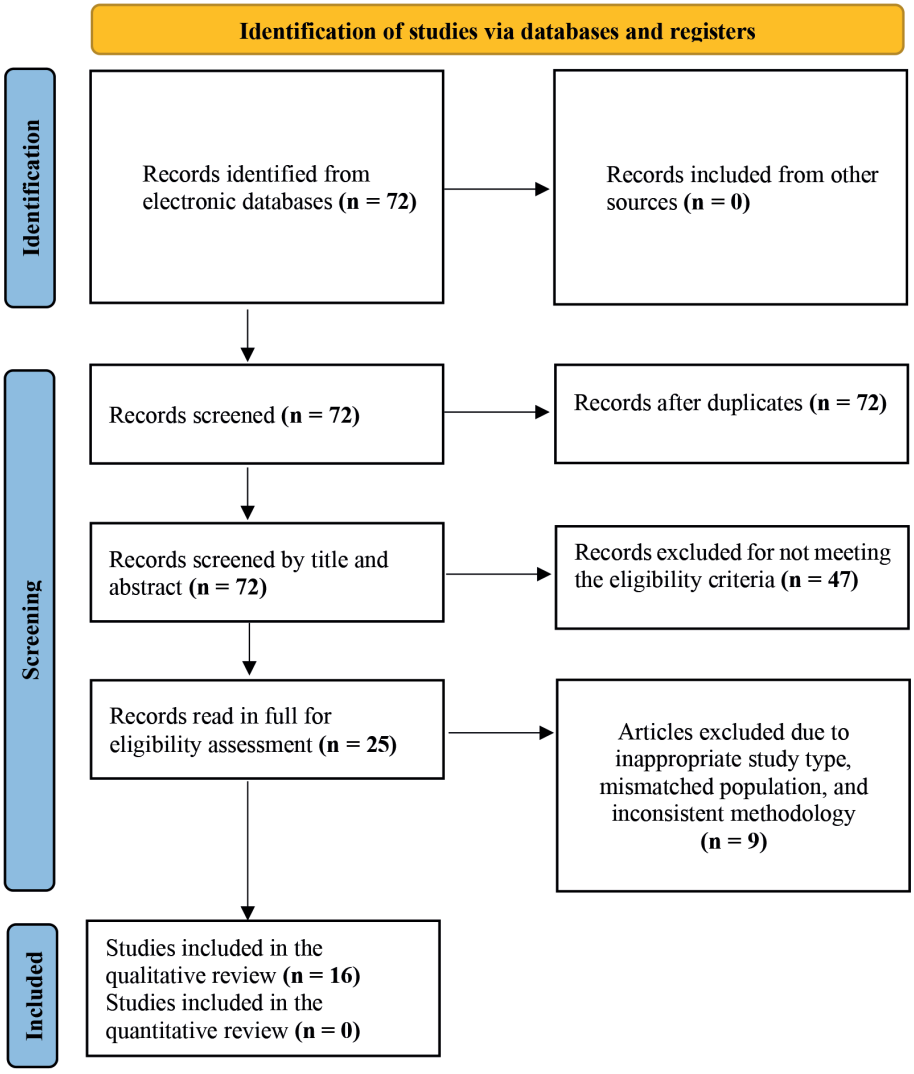

Figure 1. PRISMA flow diagram.

Advances in diagnostic imaging methods

Imaging diagnostic techniques have played a crucial role in the identification and characterization of OLT, enabling an accurate and personalized approach. Magnetic resonance imaging was highlighted as the gold standard tool due to its high sensitivity and specificity in evaluating osteochondral structures. Studies such as Khan et al. (2024)[9] have described the importance of MRI in the diagnosis, planning, and management of OLT, emphasizing its superiority in differentiating affected structures. Butler et al. (2024)[8] reinforced this perspective by associating the presence of a hypertrophic distal fascicle of the anterior tibiofibular ligament with a high rate of osteochondral lesions, demonstrating the relevance of imaging in the evaluation of predisposing anatomical factors.

Computed tomography remains an essential tool, especially for the analysis of subchondral bone and lesion morphology. Wei et al. (2023)[11] highlighted its role in the detailed evaluation of cystic lesions, favoring the selection of appropriate surgical interventions. Likewise, Walther et al. (2023)[12] analyzed its application in the classification and conservative diagnosis of OLT, highlighting the need for multimodal approaches. Migliorini et al. (2022)[15] have explored MRI using advanced techniques, including T2 mapping and T1-weighted images with specific contrast (dGEMRIC), which enable the early quantification of cartilaginous changes, promoting more accurate detection before significant clinical manifestations.

Regarding minimally invasive treatments, virtual arthroscopy emerges as a promising innovation. Arshad et al. (2022)[17] described its effectiveness in simulating direct arthroscopic

vision, optimizing the assessment of joint integrity without the need for invasive procedures. In addition, ultrasound has emerged as a complementary method in post-treatment follow-up, enabling the dynamic monitoring of changes in the soft tissue around the joint, as reported by Feng et al. (2022) [18] in cases of chronic ankle instability.

Advances in imaging technology have also facilitated the development of automated artificial intelligence systems, which assist in the detection and classification of OLT, optimizing diagnosis and reducing subjectivity in medical interpretation. Weber et al. (2021)[20] discussed the impact of these tools on therapeutic planning, emphasizing the need for large-scale clinical validation to consolidate their routine use. Kim et al. (2021)[21] showed the benefit of MRI in the evaluation of postoperative outcomes, confirming its applicability in the follow-up of intraarticular treatments.

Overall, advances in diagnostic imaging methods have allowed not only a deeper understanding of the pathogenesis of OLT but also greater accuracy in diagnosis and therapeutic planning, especially in complex and refractory cases. The integration of these technologies into clinical practice has the potential to enhance patients' functional outcomes and overall quality of life.

Performance of conservative interventions

Conservative interventions for the management of OLTs are often indicated in cases of lesser severity, especially in stable and limited-sized lesions. These strategies aim to relieve symptoms, reduce the progression of joint damage, and restore ankle function without the need for surgical intervention. Among the main approaches are temporary immobilization, the use of orthoses, modification of activities, and physiotherapy rehabilitation programs focused on muscle strengthening and biomechanical rebalancing.

The reviewed studies indicated that immobilization and joint load reduction are effective in alleviating pain and controlling initial inflammation, particularly in patients with a recent history of trauma. Kim et al. (2022)[14] reported that immobilization may provide initial symptomatic relief in young patients with osteochondritis dissecans of the talus; however, its long-term effectiveness remains a subject of debate. Walther et al. (2023)[12] reviewed conservative treatment modalities and highlighted that, although immobilization can alleviate initial symptoms, its effectiveness is limited in cases involving larger lesions.

Physiotherapy, when performed in a structured and personalized manner, has shown improvement in ankle mobility and muscle strength, contributing to more consistent functional recovery. Walther et al. (2023)[12] discussed the role of physical therapy in functional ankle stabilization, indicating that targeted protocols can optimize joint biomechanics and reduce overload in vulnerable areas. In addition, Faldini et al. (2023)[13] reported that conservative approaches are more effective when combined with measures that promote joint rebalancing and muscle strengthening.

Although conservative approaches are often effective for symptom relief, their ability to promote significant tissue regeneration is limited. Wei et al. (2023)[11] suggest that, in the absence of regenerative or surgical treatment, degenerative changes may progress, especially in lesions involving the subchondral bone. In addition, biomechanical factors such as ankle misalignment and ligament instability can compromise results, highlighting the importance of a comprehensive diagnosis before opting for this approach.

More recent conservative approaches include intraarticular infiltration of hyaluronic acid and corticosteroids, which have shown positive results in pain control and short-term functional improvement. Weber et al. (2021)[20] reported that these therapies may provide temporary symptomatic relief, but evidence of their impact on the long-term preservation of articular cartilage remains inconclusive.

In summary, conservative interventions represent an initial approach in selected cases of OLT, particularly when lesions are small and joint instability is absent. However, it is important to highlight that there is no robust scientific evidence to prove the effectiveness of these modalities in tissue repair or prevention of lesion progression. Thus, its use is primarily aimed at symptomatic control, with limited prognostic impact. The unpredictability of the clinical evolution of patients treated exclusively with conservative approaches requires caution when selecting this approach and reinforces the need for continuous monitoring through clinical and imaging reassessments.

Effectiveness of conventional surgical techniques

Conventional surgical techniques remain widely used in the management of OLT, especially in cases refractory to conservative treatment or in unstable and symptomatic lesions. Among the most used procedures are microfractures, subchondral perforation, and curettage, whose objective is to promote the formation of repair tissue in an attempt to restore, albeit partially, joint function. Migliorini et al. (2022)[15] highlighted that the microfracture technique, by inducing the migration of mesenchymal cells to the lesion site, presented satisfactory results in small lesions, usually less than 1.5 cm^2, providing significant pain relief and functional recovery in the short-term.

However, the limitation of fibrocartilage formation, which has biomechanical properties inferior to those of hyaline cartilage, has been identified as a critical factor that can compromise the durability of results, especially in young or physically active patients. Arshad et al. (2022)[17] reinforced this limitation, indicating that progressive degeneration can occur over time, leading to the need for complementary treatments.

Subchondral perforation, a technique similar to microfractures, has shown comparable effectiveness in relieving symptoms; however, it is associated with a higher risk of thermal injury during the procedure, unlike microfractures, which do not involve this type of complication, as highlighted

by Feng et al. (2022)[18]. Curettage, in turn, has been used as a complement in cases involving loose osteochondral fragments, allowing the removal of devitalized tissues and the preparation of the articular bed for additional interventions, as reported by Kim et al. (2021)[21].

Another limitation of conventional techniques is their reduced effectiveness in larger lesions or cases of significant subchondral bone involvement. In such situations, progression to advanced techniques, such as osteochondral transplants or the use of biological matrices, is often necessary to enhance clinical and functional outcomes. Wei et al. (2023)[11] described that, in lesions greater than 1.5 cm^2, the conventional approach had a lower long-term success rate, while more advanced techniques showed additional benefits in tissue regeneration.

In summary, conventional surgical techniques remain a valid and widely accessible therapeutic approach for the initial management of OLT. Despite the limitations regarding tissue regeneration, these techniques have a favorable profile of safety, simplicity, and effectiveness in the short-term and are widely used in less complex lesions. Currently, these interventions, such as microfractures, subchondral perforations, and curettages, are performed almost exclusively arthroscopically, as the open approach is no longer recommended in modern orthopedic practice due to the higher risk of morbidity and poorer functional recovery. The choice of technique should be based on criteria such as lesion size, joint stability, and the patient's clinical profile, ensuring a personalized and effective approach.

Advances in regenerative therapies and osteochondral transplants

Regenerative therapies and osteochondral transplants represent significant advances in the management of OLT, especially in cases refractory to conservative and conventional approaches. These strategies aim to restore joint integrity through regeneration of hyaline cartilage or direct replacement of injured tissue, offering more lasting and effective solutions for extensive or complex lesions. Wei et al. (2023)[11] highlighted that these approaches improve joint functionality by reducing the progression of osteochondral degeneration.

Autologous osteochondral transplantation (mosaicplasty) is a promising technique in which osteochondral cylinders are removed from non-supportive areas of the joint and transferred to the lesion site. Migliorini et al. (2022)[15] indicated that this approach provides excellent tissue integration, with hyaline cartilage formation and sustained long-term clinical improvement. However, challenges such as limitations in graft size and the potential for morbidity at the donor site still need to be considered.

Allogeneic osteochondral transplantation, in turn, has emerged as a valuable option due to its potential for treating larger lesions without the restrictions associated with donor sites. This technique maintains the preservation of joint congruency and enables the replacement of viable osteochondral tissue, especially in lesions involving large areas of the talus. Weber et al. (2021)[20] described advances in graft preservation techniques to increase cell viability. However, success rates remain unsatisfactory, and the indication of this type of procedure continues to be widely questioned in the literature. Additionally, the risks of immune rejection and the limited availability of viable donors represent significant challenges to their adoption in clinical practice.

Regenerative therapies, including the use of mesenchymal stem cells and growth factors, have shown promise in stimulating tissue regeneration. Clinical trials analyzed by Arshad et al. (2022)[17] demonstrated that intraarticular application of stem cells derived from bone marrow or adipose tissue can promote the formation of hyaline cartilage, in addition to improving functional parameters and reducing pain. Similarly, the use of three-dimensional bioactive matrices, such as collagen scaffolds or biomaterials, is effective in supporting tissue repair, promoting cell organization and structural regeneration.

Although advances in regenerative therapies and osteochondral transplants represent a milestone in the approach to OLT, challenges remain, including the standardization of protocols, high costs, and the need for long-term studies to assess the durability of results. However, these strategies offer promising prospects for significantly improving patients' clinical outcomes and quality of life, especially in cases where traditional approaches are insufficient[21].

Functional outcomes and quality of life

The functional outcomes and quality of life of patients with OLT are directly related to the choice and effectiveness of the therapeutic approach, as well as to the initial severity of the lesion. Recent studies demonstrate that successful interventions, whether conservative, conventional surgical, or advanced, are associated with significant improvements in joint mobility, pain relief, and recovery from daily activities. Walther et al. (2023)[12] reviewed the effects of conservative interventions, showing initial functional improvement but highlighting the limitations in the long-term preservation of the joint.

Patients treated with conservative interventions, such as physical therapy and joint infiltrations, often report short-term functional improvement, especially in cases of minor lesions. However, the absence of effective tissue repair may limit long-term gains, with recurrence of symptoms and progressive joint impairment in some cases. Feng et al. (2022)[18] reported that although physiotherapy can improve mobility and muscle strengthening, patients with extensive lesions have higher rates of failure in conservative treatment. On the other hand, conventional surgical treatments, such as microfractures and subchondral perforations, are more effective in relieving pain and restoring joint function, although results may be inferior in patients with extensive lesions. Migliorini et al. (2022)[15] showed that patients undergoing microfractures had

significant improvement in joint function scores but had an increased risk of fibrocartilage degeneration over time.

Advances in regenerative techniques and osteochondral transplants have shown a positive impact on functional outcomes, particularly in patients with complex lesions. Osteochondral transplantation, both autologous and allogeneic, has been associated with the restoration of normal biomechanical patterns in the ankle, resulting in a significant reduction in pain and an improvement in the ability to perform physical activities. Studies indicate that autologous osteochondral transplantation has success rates greater than 85% in the long term; however, minor symptoms may persist, and late deterioration may occur. Similarly, the use of bioactive stem cells and scaffolds has demonstrated potential for regenerating hyaline cartilage, promoting superior functional outcomes and greater long-term preservation of the joint, as noted by Arshad et al. (2022)[17].

Regarding quality of life, standardized assessment instruments, such as the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot score and the Short Form 36 Health Survey Questionnaire (SF-36), indicate that most patients experience considerable improvement following successful interventions. For example, studies have shown that patients undergoing arthroscopy-assisted micro-perforations had a mean increase of 22.5 points in the AOFAS score after the surgical procedure. This improvement is associated not only with symptom relief but also with the re-establishment of functional independence and the resumption of leisure and work activities. Kim et al. (2021) [21] reinforced that patients undergoing regenerative therapies demonstrated higher scores in these instruments compared to conventional approaches.

Despite therapeutic advances, certain factors continue to negatively impact functional outcomes and quality of life, including advanced age, large lesions, and associated comorbidities. Weber et al. (2021)[20] emphasized that individualization of treatment, longitudinal follow-up, and the use of multimodal approaches are essential to optimize clinical outcomes and provide broader functional and psychosocial recovery for patients with OLT.

Final considerations

Osteochondral lesions of the talus represent a significant challenge in orthopedic practice due to their anatomical location, wide clinical variability, and functional impact. Proper management of these lesions depends on a multidisciplinary approach that integrates advanced diagnostic methods, therapeutic interventions, and careful longitudinal follow-up.

Advances in imaging methods, such as high-resolution MRI and CT with three-dimensional reconstruction, have enhanced diagnostic accuracy, enabling the earlier identification of lesions and more detailed surgical planning. These advances have contributed to more accurate stratification of patients and the selection of personalized therapeutic strategies.

In the therapeutic field, although conservative approaches are still used in specific contexts, they are not considered effective pillars in the management of OLT. They are most often employed as transitional strategies in situations where more definitive interventions are not feasible. Conventional surgical techniques, on the other hand, remain a reference in cases of less complex lesions. On the other hand, advances in regenerative therapies and osteochondral transplants offer more promising prospects, with the potential to at least partially restore articular cartilage and improve functional outcomes and quality of life, particularly in cases of extensive or refractory lesions. Still, the widespread adoption of these techniques faces significant limitations, including high costs, resource scarcity, and a lack of standardization in protocols.

Despite significant advances, gaps remain in understanding the evolution of OLT, particularly regarding the progression of joint degeneration and the factors that influence long-term therapeutic outcomes. Future research should focus on optimizing treatment protocols, benchmarking different techniques, and developing biomaterials and cell therapies that promote tissue regeneration more efficiently.

We believe that the integrated approach of OLT, combining early diagnosis, innovative therapies, and personalized care, is fundamental to minimizing the functional impact and improving the quality of life for patients. Continued advancement in clinical and scientific knowledge is essential to develop more effective, safe, and accessible strategies for managing these complex lesions.

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