AUCTORES
Globalize your Research

Journal of Clinical Research and Reports
Jike Lu*

Open Access

Review Article

Differences between Posterior Malleolus and Posterior Pilon Fractures-A Review

Yao Feng[1], Jing Niu[1], Yaozong Di[1], Jun Jiang[1], and Jike Lu[1]*

Departments of Orthopaedics1, Beijing United Family Hospital, No 2 Jiangtai Road, Chaoyang District, Beijing, 100016, China.

***Corresponding Author:** Jike Lu, Department of Orthopedic Surgery, Beijing united family hospital, Beijing China.

Received date: January 11, 2025; **Accepted date:** January 26, 2025; **Published date:** January 31, 2025

Citation: Yao Feng, Jing Niu, Yaozong Di, Jun Jiang, and Jike Lu, (2025), Differences between Posterior Malleolus and Posterior Pilon Fractures-A Review, *J Clinical Research and Reports*, 18(2); **DOI:10.31579/2690-1919/477**

Abstract

Based on the database of 98 consecutive trimalleolar ankle fractures collected over the past 7 years (2015-2022), we did a review of literature review trying to elucidate the differences between posterior malleolus fractures and posterior Pilon fractures. Posterior malleolus fractures are commonly caused by rotational forces on the ankle joint with foot in different positions, leading to different injuries from tearing of the posterior inferior tibiofibular ligament (PITFL) to an avulsion fracture of the posterior malleolus (PM). This is generally a low-energy injury and actually does not involve the joint articular surface. Posterior Pilon fractures result from a combination of rotational and vertical compression forces on the ankle joint, causing an intra-articular fracture of the distal posterior tibia. This type of fracture is commonly missed on plain gradiographs and often misdiagnosed. This review aims to provide an overview of the differences between posterior malleolus fractures and posterior Pilon fractures and some issues of clinical concerns such as how to make correct diagnosis for planning managements.

Keywords: posterior malleolus; posterior pilon; ankle fracture; intra articular fracture; internal fixation

Introduction

Posterior Pilon fractures are distinct entity of intra-articular fractures caused by rotational and axial forces, differing from typical Pilon fractures [1]. Posterior Pilon fractures are uncommon and generally have poorer outcomes if managed non-surgically or inappropriately [2]. In high-energy injuries caused by motor vehicle accidents or falls from height, the mechanism of the injury is usually placed ankle in a plantar flexed position, and the foot is in an inverted position. When the ankle is subjected to forward, downward, and outward forces from the body's inertia, it results in fractures of the lateral malleolus and posterior malleolus in the coronal plane [3]. The characteristics of posterior Pilon fractures were considered as a special type of trimalleolar fracture fragment, given a name of the posterior Pilon fracture [1]. Posterior Pilon fractures differ from most of the posterior malleolar fractures in terms of the severity of the force, injury mechanism, fracture pattern, soft tissue damage, management options, diagnostic complexity, and prognosis [4]. The characteristics of posterior Pilon fractures include joint surface depression and sagittal plane transfer of the fractured fragments close to medial malleolus and talar body (Fig 1). These characteristics determine the radiological features, surgical approach, choice of the fixation, and clinical outcomes that are significantly different between typical posterior malleolar fractures and Pilon fractures [5, 6]. Accurate diagnosis, appropriate surgical approach, and choice of the fixation significantly influenced on surgical outcomes and prognosis, as evidenced by Gao et al.'s research data [7]. Misdiagnosis and inappropriate treatment can lead to postoperative complications, including ankle joint dysfunction and post traumatic arthritis, therefore, it is important to distinguish posterior Pilon fractures from other ankle fractures and to guide our clinical managements.

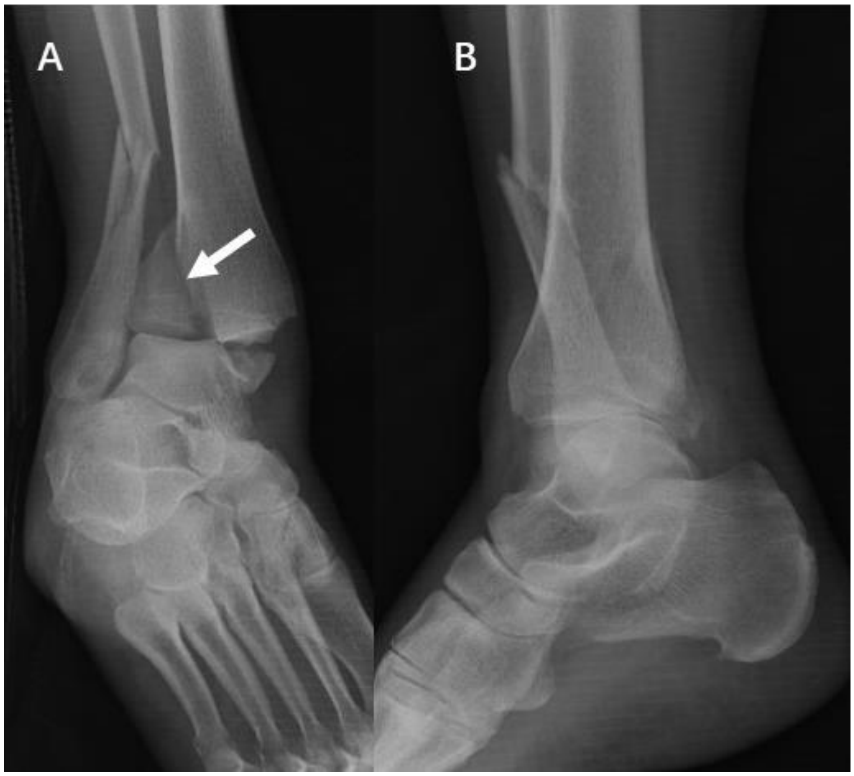

Figure 1: 39 years old female, had a fall accidently on the web ground, fractures ankle with talus subluxation

Figure 1-1: AP and lateral radiographs showed talus subluxed posteriorly in B, however posterior malleolus fracture was difficult to be seen (an arrow).

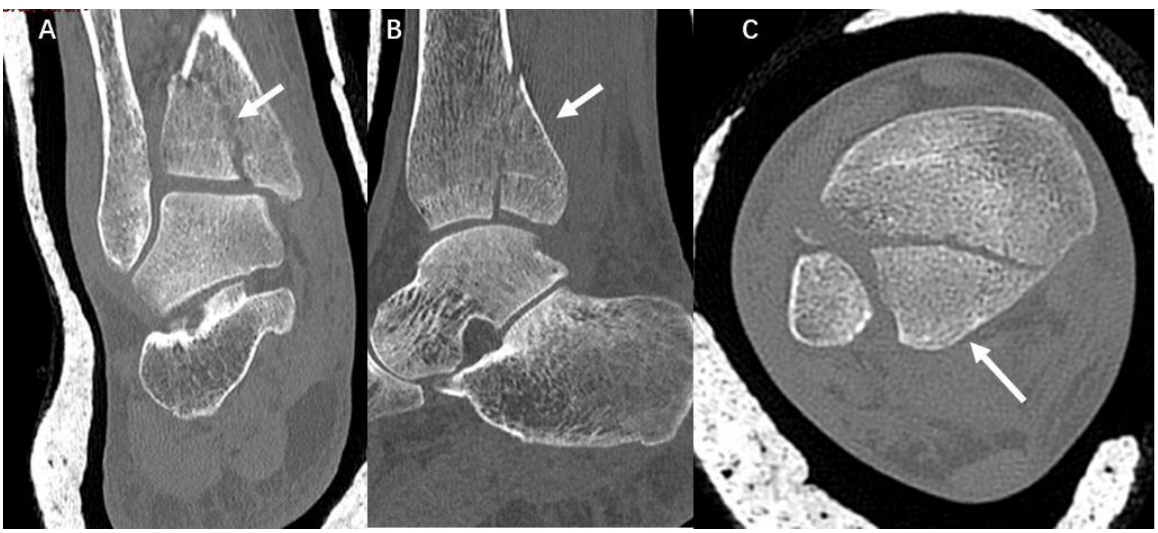

Figure 1-2: CT scans clearly showed PM fracture (arrows) on coronal and sagittal plane reconstruction views (A and B) and 3-D reconstruction AP and lateral views (C and D).

Discussion

The posterior malleolus plays an integral role in ankle joint stability (Figure 2) through its anatomical relationship with the posterior inferior tibiofibular ligament (PITFL), which has been demonstrated through cadaver studies to contribute to 42% of syndesmotic stability [8,9]. Ankle fractures involving the posterior malleolus if managed inappropriately are believed to have worse clinical outcomes, proposed around incongruity and the resultant development of posttraumatic arthrosis [8, 10].

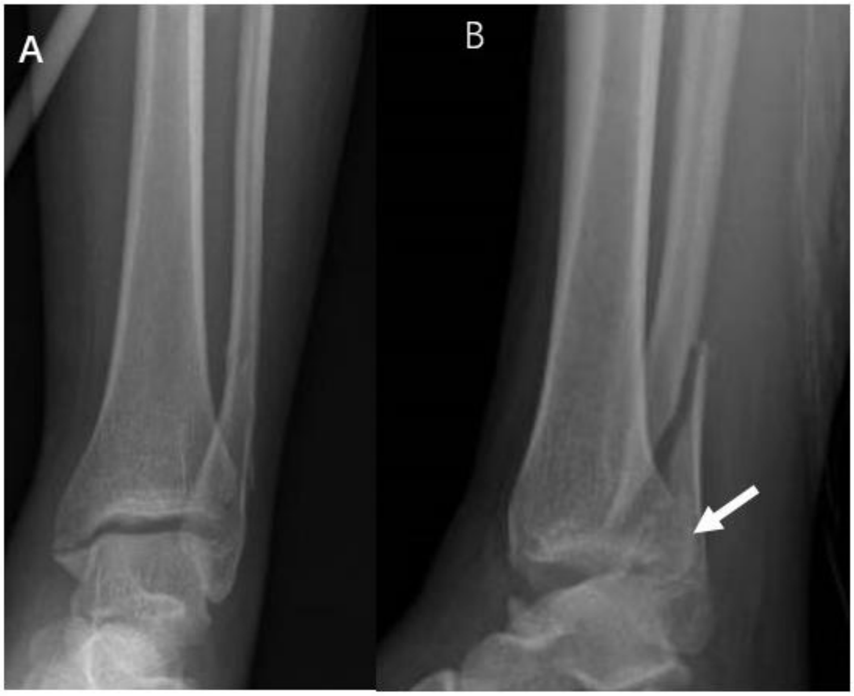

Figure 2: 68 years old female, fell off steps, ankle fracture/dislocation
Figure 2-1: Initial injury radiographs showed posterior pilon fracture with syndesmosis diastasis (an arrow on B).

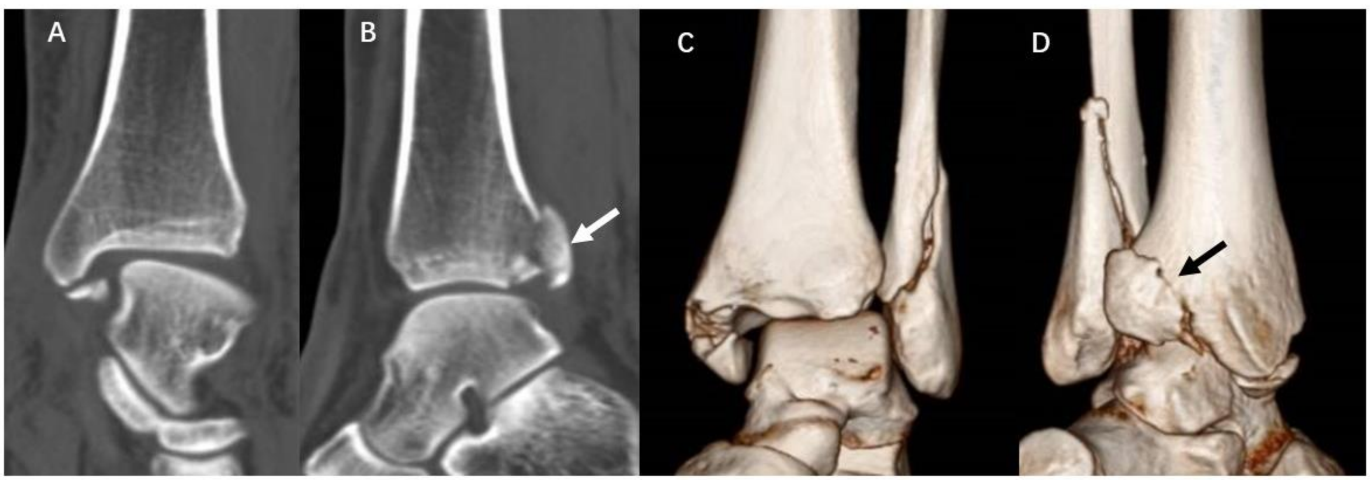

Figure 2-2: CT reconstruction images displayed posterior pilon large intra articular fractures with articular surface depression and step-off and syndesmosis diastasis significantly (arrows)

The tools for diagnosis of the ankle injuries include x-rays, CT and MRI. The posterior malleolus fragment ranges in size from a small extra-articular fragment to whole PM fragment sometimes involving less than 20 percent articular surface. Conventional plain radiography (i.e. AP, mortise, lateral) is still necessary in the primary diagnosis and estimation of the fragment size, with a fracture of the dorsal tibial margin possibly seen in the standard lateral view [11]. Given the variables in size and location diagnosis can be difficult, resulting in many PMFs being underestimated or missed [12]. An external rotation-lateral view of the ankle may help increase diagnostic yield [13]. Plain radiographs of the ankle may underestimate the size of the fragment and the percentage of the joint surface affected in addition to difficult to reveal occult posterior malleolus fragments, due to high fracture line variability and lack of consistency in fracture patterns [14, 15]. This can lead to worse clinical outcomes through delayed even appropriate operative management is carried out. CT scan does not have images overlapping and show greater accuracy for detection of occult fractures [16, 17], which provides more appropriate assessment and visualization of PMFs; it can detect varied fracture lines that usually missed on plain radiographs. Therefore, CT scan is recommended in combination with plain radiography for the diagnosis and estimation of fragment size, articular impaction and comminution [12].

X-ray is one of options for patients with posterior Pilon fractures. On plain radiographs, posterior malleolar fractures extend to the posteromedial portion of the distal tibia and are accompanied by compression of the ankle joint surface. "Double-contour sign" is a relatively specific radiological feature of posterior Pilon fractures on anteroposterior radiographs [18], which presents as a specific double-layer cortex shadow in the posteromedial region. However, this sign is not the primary feature of all posterior Pilon fractures, so other features should be used to increase its accuracy for diagnosis when necessary. Yang, et al recommend performing lateral X-rays in plantarflexion of the ankle to determine whether there is posterior dislocation of the talus [19]. Due to particular requirements of X-ray imaging for Pilon or PM fractures and the complexity of local anatomy of posterior Pilon, it is insufficient to judge the size and displacement of the fracture fragments solely from simple X-rays to develop the corresponding treatment plan might be difficult. Therefore, CT or other imaging modalities must be used for diagnosis of the Pilon or PM fractures [20]. If the X-ray including external rotation view shows continuous cortical bone of the ankle without obvious fractures, extensive examinations are not necessary, thereby saving the patient's time and cost. If fractures are detected on X-rays, the preliminary classification of the fracture type and early choice of treatment can be made based on orthogonal views of the radiographs [13].

CT scans can accurately determine the specifics of posterior Pilon fractures and identify whether there is injury to the syndesmosis and indirect signs of the injuries of the surrounding ligaments and tendons. CT clearly defines the extension of the posterior malleolar fracture lines, the size of the fracture fragments, and the specific damage to the joint surface, providing important references for fracture classification, patient positioning, surgical approach, and management options [21]. In some cases, three-dimensional CT reconstructions may reveal soft tissue interposed between the fracture fragments, such as the tibial nerve, posterior tibial artery, and flexor hallucis longus tendon. With its high resolution, low cost, and simplicity of procedure, CT is widely used in the routine diagnosis and treatment of posterior Pilon fractures, playing an important role for diagnosis and preoperative planning. As CT technology continues to innovate, preoperative assessment of the local anatomy, the size and position of fragments, and soft tissue interpostioned in posterior Pilon fractures is essential for planning the surgical approach, choice of implant selection, and fixation techniques [22].

Gardner et al [23] proposed that evaluating the stability of the ankle joint solely based on the fracture patterns seen on X-rays and CT may not be comprehensive. Utilizing MRI images are more sensitive to local soft tissues, it can be used to detect injuries to the medial and lateral ankle ligaments, anterior and posterior tibiofibular syndesmotic ligaments, interosseous membrane, and deltoid ligaments, and the extent, severity of these injuries. This can help determine the surgical approach and improve the patient's long-term outcomes [23, 24, and 25]. However, due to the relatively high cost of MRI, it is not widely accepted by patients, especially in private clinics or hospitals.

Classification is very important for guiding management. Currently, there are four main classification systems for posterior Pilon fractures which is proposed by Klammer, Yu Guangrong, Zhang Jianzheng, and Wang Lei [27, 29]. Each system provides some guidance for the treatment of posterior Pilon fractures, but they also have their limitations. Klammer classification [26] is based on the morphology and the number of fracture fragments; Type I is a single posteromedial fragment, Type II is posteromedial and posterolateral fragments, and Type III involves the medial malleolus; Yu Guangrong classification [27], is based on the CT scan results and the morphology of the posterior fragments, dividing them into three types: Type I is lateral oblique, Type II is a single posterior fragment, and Type III is a double fragment. Zhang Jianzheng and Wang Lei [29], also classify posterior Pilon fractures based on the location of the fracture lines and the size of the fracture fragments. However, these classification systems cannot cover all types, leading to limitations in clinical guidance for managements of the posterior Pilon fractures, and they do not fully covering the mechanism and extent of the fractures. Therefore, a new optimized classification system is needed to display the injury mechanisms and severity of different Pilon fractures to provide better evidence for guiding individualized managements and more accurate prognosis [30].

Traditional views claim that the size of the fracture fragments plays a decisive role in the integrity of the joint surface and the stability of the ankle joint, and fragment accounting for more than 25% of the total ankle articular surface are considered absolute indications for surgical treatment [28]. Traditional views rely solely on the size of the fracture fragments and the damage to the joint surface when considering surgical indications for posterior Pilon fractures, without considering ankle soft tissue injuries and stability. The latest points of view indicate that combining biomechanical research and preoperative X-ray and CT imaging results, that conservative treatment is unlikely to achieve satisfactory outcomes when the fracture affects more than 10% of the articular joint surface. The posterior malleolus plays a crucial role in load transfer between the distal tibia and the talar dome and in posterior stability, especially when the lateral checkrein is damaged. Reduction in joint surface area due to fractures can lead to increased peak stresses and changes in joint biomechanics. Fitzpatrick et al [43], evaluated the effects of anatomical reduction, 2 mm gap, or 2 mm step-off in a simulated posterior Pilon fracture accounting for 50% of the joint surface in cadaveric models. They did not find any impact on ankle kinematics, but observed anterior displacement of contacting stress. Therefore, the authors recommend direct visualization for open reduction and fixation. Jaskulka et al [25], found that the prognosis for patients with posterior Pilon fractures was significantly worse, even when the fragments were small. Additionally, the size of the posterior fragments affects the development of post-traumatic arthritis; large fragments are better to be fixed and reduced than small fragments. Unfortunately, in many of these studies, X-ray was used to determine the size of the fragments, which was inaccurate. Furthermore, patient outcome measures were unjustified, not all surgical cases were anatomically reduced and securely fixed, and the treatment of associated ankle fractures was variable. In a recent systematic review of the literature, biomechanical study [9], found no consensus on the size of the fragments as an indication for fixation and noted the lack of standardized long term outcome assessment in the currently available literature; but generally agreed that anatomical reduction, secured fixation, and early functional rehabilitation to maximize ankle joint function are recommended and reduce postoperative complications such as post-traumatic arthritis, thereby improving long-term patient outcomes [30,31]. At the same time, while emphasizing the importance of the size of the posterior Pilon fracture fragments on the prognosis, the evaluation and management of soft tissue injuries in patients with posterior Pilon fractures should not be ignored. Early external fixation and calcaneal traction have been increasingly recognized by surgeons for improving patient outcomes, and performing surgery after local soft tissue swelling has subsided and skin wrinkles visible can reduce the impact of secondary injuries and skin necrosis.

Harper's [28], cadaveric study has shown that if the fibula is in a stable anatomic position, no posterior talar subluxation would occur and therefore PM fragments may not necessarily be fixed. The way of reduction did not always include internal fixation, showing the mechanism of ligamentotaxis could be effective in maintaining syndesmotic joint congruity [31]. Most avulsion fractures can be treated non-operatively successfully. However, taking into account the biomechanics of the syndesmosis, Weening and Bhandari [35], recommended the fixation of all posterior malleolus fragments. This may be due to superior syndesmotic stability obtained through fixation of the posterior malleolus over the use of transsydesmotic screw fixation, demonstrated by Gardner et al's cadaveric study where fixation of the PM fragments restored 70% of syndesmotic stability compared with 40% through syndesmotic screw fixation [31, 32, and 33]. Syndesmotic reduction plays a significant role of functional outcome; even minimal displacement may lead to posttraumatic arthritis [34, 35, and 36], suggesting that anatomic reduction of all displaced PM fragments can prevent posterior talar subluxation and restore articular congruency to minimize posttraumatic osteoarthritis and improve the outcomes of trimalleolar fractures [37]. Therefore, direct posterior malleolus fixation is suitable for stabilizing syndesmotic injuries. Anatomic reduction and fixation of a posterior malleolus fracture can restore syndesmotic stability by restoring the length and tension of the intact PITFL and by preventing posterior and/or lateral translation of the fibula.

Although syndesmotic injury can be fixed by standard transsyndesmotic fixation, which has a high rate of syndesmotic mal-reduction (52%) [35]. Fixation of the posterior malleolus was biomechanically superior to syndesmotic screw fixation in Ogilvie-Harris et al. [9] cadaveric study. While Miller et al [11] compared the functional outcomes of three groups with open posterior malleolus fixation, syndesmotic screws and combined fixation; concluding that the posterior malleolus fixation is at least equivalent to syndesmotic screw stabilization. Patients who receive a syndesmotic screw may undergo additional fixation of the posterior malleolus fragment showing that 16-36% of syndesmotic screws may be unnecessary [36]. We believe posterior malleolus fixation is more accurate and more stable than syndesmotic screw fixation. Therefore, anatomic reduction and fixation of the posterior malleolar fragment without syndesmotic transfixation is recommended by some authors [37].

Surgical approach was determined by preoperative detailed image studies. Preoperative X-ray, CT, and other imaging examinations, which are used to determine the size, location, and rotation of the fracture fragments and are combined with the patient's soft tissue injury status, play a crucial role in choosing the surgical approach. Many studies have shown that the traditional anterior, medial, and posterior approaches cannot fully expose the fracture site, limiting the effectiveness of treating posterior Pilon fractures and making it difficult to fully expose the fracture site and small posterior impaction fragments, increasing the difficulty of surgery [38, 39]. Currently, the surgical approaches for posterior Pilon fractures are primarily the posterolateral approach, posteromedial approach, and combined posterolateral and posteromedial approaches. These approaches can provide clear exposure of the fracture site, offering the surgeon a good surgical field visualization [40]. However, each approach has its unique advantages and limitations.

The posteromedial approach allows a small joint incision to directly view the joint surface. Since the fibula is located posterior to tibia, the posterolateral approach cannot display the joint surface [41]. The posteromedial approach enables visualization and reduction of the medial fragment, and the indirect reduction of some lateral ankle fracture fragments using lateral tendon manipulation can reduce the stripping and damage of posterior lateral tendons and avoid postoperative soft tissue irritation from the posterior fixation implants. The modified posteromedial approach further provides a larger operative field and operating space, allowing direct observation of the distal tibiotalar joint surface and tibiofibular syndesmosis for reduction of the syndesmotic fragments [42]. However, special attention must be paid to the deep neurovascular bundle of the posterior tibial artery and tibial nerve to avoid postoperative complications caused by vascular and nerve injuries.

The posterolateral approach is a longitudinal incision between the lateral border of the Achilles tendon and the posterior border of the fibula, which exposes the fracture fragments through the short and long fibular muscles and the extensor hallucis longus tendon for reduction and fixation. Klammer et al [18], suggested that using the posterolateral approach alone provides excellent exposure, improves soft tissue coverage of the internal fixation, can also be used for reduction and fixation of fibular fractures and repair of posterior tibiofibular ligaments, and basically meets the exposure requirements for posterior malleolar fractures. Additionally, not cutting the lateral compartment can reduce irritation of the peroneal tendons, aiming to minimize related symptoms [41]. This approach has a good effect in reducing most posterior Pilon fractures. Unlike the posteromedial approach, which can indirectly reduce using the lateral anatomical ligament tension i.e. ligamentotaxis mechanism, the medial side of the posterior malleolus lacks strong ligamentous attachments, making indirect reduction through ligamentotaxis less likely. Moreover, the posteromedial fragment and tibialis posterior tendon sheath are interposed in fracture fragments, so for complex posterior Pilon fractures, especially those with posteromedial fragments, the pure posterolateral approach has significant limitations in intraoperative fracture reduction and fixation, leading to poor postoperative outcomes and even resulting postoperative complications [42].

Due to the special anatomical structure of the posterior malleolus, the pure posteromedial or posterolateral approach alone have their own limitations and is not ideal for complex or old posterior Pilon fractures, making it difficult to achieve anatomical reduction and rigid fixation. Therefore, the combined approach can compensate for the limitations of the pure posteromedial or posterolateral approach [43]. With continuous exploration and practice in clinical settings, the combined approach has been continuously improved, providing the surgeon with a clearer surgical field and significantly improving the quality of reduction and fixation. Current literature data indicate that the combined posterolateral and posteromedial approach has good clinical outcomes in treating posterior Pilon fractures, minimizing the incidence of complications such as traumatic arthritis, alleviating local tissue tension, reducing fracture healing time, and significantly improving patient long-term satisfaction [44].

Previous common surgical fixation methods for posterior Pilon fractures included anterior-to-posterior screws, posterior-to-anterior screws, and posterior buttress plate fixation. However, due to its poor stability, postoperative effects, and poor long-term prognosis of anterior-to-posterior screw fixation is less popular [45]. Early open reduction and internal fixation with screws or supporting plates is currently the main treatment approach when local soft tissue conditions of the ankle allow it. With the development of orthopedic endoscopy, posterior ankle arthroscopy-assisted reduction and internal fixation has emerged as a new method with significant advantages in the clinical setting. In short, due to the diversity and particularity of posterior Pilon fractures, the surgical approach should be comprehensively considered based on the patient's age, general health condition, fracture location and severity, and soft tissue injury.

The anterior-to-posterior compression screw fixation was found to have poor fixation effects, making intraoperative fixation difficult, leading to poor postoperative stability, and thus is no longer used. Amorosa, Wang, and Wang Hao et al. suggest that posterior-to-anterior multi-screw internal fixation for posterior Pilon fractures is widely used and has achieved good outcomes. Posterior-to-anterior screw fixation can reduce soft tissue stripping, avoid irritation of the tibialis posterior tendon, reduce local tension, achieve anatomical reduction of fractures, and good fracture healing. However, posterior-to-anterior screw fixation has the disadvantage of low fixation strength [46], so postoperative immobilization with a splint for 6 to 8 weeks is required, which delays ankle functional recovery.

Posterior support plate internal fixation is currently the main surgical method for posterior Pilon fractures. The posterior support plate solves the problem of insufficient fixation strength and unsatisfactory fixation results of single posterior compression screws, and the strong fixation allows the patient to perform functional exercises as early as possible, avoiding the series of issues caused by splint fixation [42]. Posterior support buttress plate fixation has been proven to effectively shorten the postoperative rehabilitation period of posterior Pilon fractures, improve the speed of ankle joint function recovery, and improve the long-term outcomes of patients, with high safety and widely clinical applications [47].

With the development of endoscopy technology and the series of issues faced in surgical treatment of posterior Pilon fractures, posterior arthroscopy-assisted reduction and internal fixation has become a new method for treating posterior malleolar fractures [48,49] . This technique allows direct visualization of fracture reduction while avoiding extensive soft tissue stripping and wound healing problems. Posterior arthroscopy can directly observe the reduction of the joint, and simultaneously washout inflammatory cytokines known to cause joint destruction. The posterior approach also allows maximization of the biomechanical strength of the posterior-to-anterior screws. Additionally, posterior arthroscopy-assisted reduction and internal fixation can address the issue of tibiofibular syndesmosis instability by restoring the tension of the posterior tibiofibular ligaments, thereby restoring the strength of the syndesmosis [48]. Although the clinical data for this approach in treating posterior Pilon fractures is still limited, early experiences have greatly recognized the safety and biomechanical stability of this treatment method, although there is still some controversy regarding the surgical indications [49].

In summary, posterior Pilon fractures are a challenging injury. To achieve good clinical outcomes, a comprehensive evaluation of the patient's injury mechanism, imaging findings, and identification of soft tissue damage is necessary to choose an appropriate surgical approach, surgical technique, and proper postoperative rehabilitation regimes. Regardless of the surgical approach or technique chosen, an individualized surgical plan should be made based on the patient's specific general health and local soft tissue conditions, aiming to restore the complex anatomical structure and joint surface integrity with minimal soft tissue injury. The endoscopy assisted technology in Pilon fracture reduction has led to significant progress in the diagnosis and treatment of posterior Pilon fractures. Even emerging a lot new technology, post-traumatic arthritis remains more prevalent in posterior Pilon fractures compared to other ankle injuries.

In summary, PM fracture is caused by torsion injuries leading to PITFL avulsion fractures, a low energy injury with no articular surface involved, but posterior Pilon fractures are caused by torsion combined with vertical forces leading to intra-articular fractures. The order of fixation for trimalleolus fracture is critical for surgical management. For a trimalleolus fracture, first, reduction of the lateral malleolus fractures then posterior malleolus, and finally medial malleolus fractures. For posterior Pilon fractures, reduce the articular depression first, then reduction and fixation of the posterior lateral fragment then posterior medial fragment, and then lateral malleolus fractures, and the last, medial malleolus fractures.

References

1. Leslie, K. (2000). Functional Reconstruction of the Foot and Ankle. The Journal of Bone and Joint Surgery. British Volume, 82:1208-1209.
2. Chen, D.W., Li, B., Yang, Y.F., and Yu, G.R. (2013). Posterior Pilon Fractures. Foot & Ankle International, 34:766-767.
3. Klammer, G., Kadakia, A.R., Joos, D.A., and Seybold, J.D. (2013). Posterior Pilon Fractures: A Retrospective Case Series and Proposed Classification System. Foot and Ankle International, 34:189-199.
4. Yang, M.G., Liu, Y., Chen, Y.C., Yang, Y.X., and Wu, D. (2021). Current Status and Progress in the Diagnosis and Treatment of Posterior Pilon Fractures. Trauma Surgery Journal, 23(7):551-554.
5. Zhang, J.Z., et al. (2022). Characteristics and Proposed Classification System of Posterior Pilon Fractures. Chinese Journal of Traumatology, 25:7.
6. Forberger, J., Sabandal, P.V., et al. (2009). Posterolateral Approach to the Displaced Posterior Malleolus: Functional Outcome and Local Morbidity. Foot & Ankle International, 30:309-314.
7. Gao, M., Liu, N.C., Cheng, Y., Shi, W.D., and Yang, H.L. (2019). Treatment Outcomes of the Posterolateral Approach of Plate Fixation for Posterior Pilon Fractures. Experimental Therapeutic Medicine, 17:4267-4272.
8. Haraguchi N, Haruyama H, Irwin TA, Lien J and Kadakia AR. (2013). Posterior malleolus fracture. The Journal of the American Academy of Orthopaedic Surgeons, 21:32-40.
9. Ogilvie-Harris DJ, Reed SC and Hedman TP. (1994). Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association, 10: 558-560.
10. Drijfhout van Hooff CC, Verhage SM and Hoogendoorn JM. (2015). Influence of Fragment Size and Postoperative Joint Congruency on Long-Term Outcome of Posterior Malleolar Fractures. Foot & ankle international, 36(6):673-678.
11. Miller AN, Carroll EA, Parker RJ, Helfet DL and Lorich DG. (2010). Posterior malleolar stabilization of syndesmotic injuries is equivalent to screw fixation. Clinical orthopedics and related research, 468: 1129-1135.

12. Neumaier Probst E, Maas R and Meenen NM. (1997). Isolated fracture of the posterolateral tibial lip (Volkmann's triangle). Acta radiologica, 38: 359-362.
13. Ebraheim NA, Mekhail AO and Haman SP. (1999). External rotation-lateral view of the ankle in the assessment of the posterior malleolus. Foot & ankle international, 20: 379-383.
14. Papachristou G, Efstathopoulos N, Levidiotis C and Chronopoulos E. (2003). Early weight bearing after posterior malleolar fractures: an experimental and prospective clinical study. The Journal of foot and ankle surgery: official publication of the American College of Foot and Ankle Surgeons, 42: 99-104.
15. Katioz H, Bombaci H and Gorgec M. (2003). Treatment of trimalleolar fractures. Is osteosynthesis needed in posterior malleolar fractures measuring less than 25% of the joint surface? Acta orthopaedica et traumatologica turcica, 37: 299-303.
16. Katioz H. (2012). A spiral tibial shaft fracture. European journal of radiology, 81: 594-597.
17. Hou Z, Zhang L, Zhang Q, et al. (2012). The "communication line" suggests occult posterior malleolar fracture associated with a spiral tibial shaft fracture. European journal of radiology, 81: 594-597.
18. Switaj PJ, et al. (2014). Evaluation of Posterior Malleolar Fractures and the Posterior Pilon Variant in Operatively Treated Ankle Fractures. Foot & Ankle International, 35: 886-895.
19. Goodman, S.M., Figgie, M.P., and Mackenzie, C.R. (2011). Peri-operative Management of Patients with Connective Tissue Disease. HSS Journal, 7: 72-79.
20. Zawadowski, M., Gjevre, J.A., Nair, B.V., and Taylor-Gjevre, R.M. (2011). Management of Rheumatoid Arthritis in the Perioperative Period. Canadian Journal of Surgery, 54: 6-7.
21. Qiu, S.W. and Xu, L. (2021). Comparison of Treatment Outcomes of Posterior Pilon Fractures with Support Plates and Screws. Zhejiang Trauma Surgery, 26(3): 426-427.
22. Bian, L. and Liu, P. (2019). Stereo Information of Skeletal Data Based on CT Sequence Medical Images. Journal of Infection Public Health, 13:2049-2054.
23. Gardner, M.J., Boraiah, S., and Hentel, K.D. (2007). The Hyper plantarflexion Ankle Fracture Variant. Journal of Foot Ankle Surgery: Official Publication of the American College of Foot Ankle Surgeons, 46: 256-260.
24. Macko VW, Matthews LS, Zwirkoski P and Goldstein SA. (1991) The joint-contact area of the ankle. The contribution of the posterior malleolus. The Journal of bone and joint surgery American volume, 73: 347-351.
25. Jaskulka RA, Ittner G and Schedl R. (1989). Fractures of the posterior tibial margin: their role in the prognosis of malleolar fractures. The Journal of trauma, 29: 1565-1570.
26. Klammer, G., Kadakia, A.R., Joos, D.A., Seybold, J.D., and Espinosa, N. (2013). Posterior Pilon Fractures: A Retrospective Case Series and Proposed Classification System. Foot & Ankle International, 34:189-199.
27. Yu Guangrong, et al. (2013). Efficacy Analysis of Support Plate Fixation for Posterior Pilon Fractures. Chinese Journal of Trauma, 29(3):243-248.
28. Harper MC. (1989). Posterior instability of the talus: an anatomic evaluation. Foot & ankle, 10: 36-39.
29. Lei, W., Si, Z.M., Zhang, C.Q., and Zeng, B.F. (2011) Trimalleolar Fracture with Involvement of the Entire Posterior Plafond. Foot & Ankle International, 32:774-781.
30. Li, Y.Q., Luo, R., and Yang, Y.F. (2022). Research Progress on Classification of Posterior Malleolar and Posterior Pilon Fractures. Chinese Journal of Bone and Joint Surgery, 15(3):234-240.
31. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL and Lorich DG. (2006). Malreduction of the tibiofibular syndesmosis in ankle fractures. Foot & ankle international, 27: 788-792.
32. Langenhuijsen JF, Heetveld MJ, Ultee JM, Steller EP and Butzelaar RM. (2002). Results of ankle fractures with involvement of the posterior tibial margin. The Journal of trauma, 53: 55-60.
33. Gardner, M.J., Streubel, P.N., Mccormick, J.J., and Klein, S.E. (2011). Surgeon Practices regarding Operative Treatment of Posterior Malleolus Fractures. Foot & Ankle International, 32:385-393.
34. Amorosa, L.F., Brown, G.D., and Greisberg, J. (2010). A Surgical Approach to Posterior Pilon Fractures. Journal of Orthopaedic Trauma, 24:188-193.
35. Weening B and Bhandari M. (2005). Predictors of functional outcome following transsyndesmotic screw fixation of ankle fractures. Journal of orthopedic trauma, 19: 102-108.
36. Di Giorgio, L., Touloupakis, G., Theodorakis, E., and Sodano, L. (2013). A Two-Choice Strategy through a Medial Tibial Approach for the Treatment of Pilon Fractures with Posterior or Anterior Fragmentation. Chinese Journal of Traumatology, 16:272-276.
37. Mehul Mayank, Jike Lu, Jac Trappel & Murray Hyde-Page. (2016) Modified Classification of Posterior Malleolus Fracture of Ankle. Imperial Journal of Interdisciplinary Research (IJIR), 2(4):377-384.
38. Hebert-Davies, J., Kleweno, C.P., and Nork, S.E. (2020) Contemporary Strategies in Pilon Fixation. Journal of Orthopaedic Trauma, 34:14-20.
39. Cho, J.W., et al. (2017). Approaches and Fixation of the Posterolateral Fracture Fragment in Tibial Plateau Fractures: A Review with an Emphasis on Rim Plating via Modified Anterolateral Approach. International Orthopaedics, 41:1887-1897.
40. Liu, C.F., Zhang, W., Liu, S.T., Li, H.D., Wei, D., Xu, W.J., and Li, Y. (2020). Posterior Medial Approach for Reduction and Fixation with Plate and Screws in Posterior Pilon Fractures. Chinese Journal of Bone and Joint Injury, 35(4):422-424.
41. Qin, Y. (2021) Clinical Diagnosis and Treatment Research Progress of Posterior Pilon Fractures. Popular Science Technology, 23(7):70-73.
42. Weening B and Bhandari M. (2005) Predictors of functional outcome following transsyndesmotic screw fixation of ankle fractures. Journal of orthopaedic trauma, 19: 102-108.
43. Fitzpatrick, E., et al. (2018) Effect of Posterior Malleolus Fracture on Syndesmotic Reduction: A Cadaveric Study. The Journal of Bone and Joint Surgery. American Volume, 100:243-248.

44. Bear, J., Rollick, N., and Helfet, D. (2018). Evolution in Management of Tibial Pilon Fractures. Current Reviews in Musculoskeletal Medicine, 11:537-545.
45. Zhang, J., et al. (2019). Comparison of Treatment Outcomes of Posterior Pilon Fractures with Posterior-to-Anterior Screws and Support Plates. Chinese Journal of Bone and Joint Injury, 34(10):1037-1040.
46. Shaw, M. and Mandell, B.F. (1999). Perioperative Management of Selected Problems in Patients with Rheumatic Diseases. Rheumatic Diseases Clinics of North America, 25:623-638.
47. Ming, X.F., Wang, Z., Wang, S.Y., Liu, Q., Yu, G.R., and Li, X.Y. (2022). Efficacy Analysis of Posteromedial Approach Combined with Lateral Approach for Open Reduction and Internal Fixation in Posterior Pilon Fractures. Chinese Journal of Bone and Joint Injury, 37(8):869-871.
48. Martin, K.D. (2019) Posterior Arthroscopic Reduction and Internal Fixation for Treatment of Posterior Malleolus Fractures. Foot & Ankle International, 41:115-120.
49. Chen, G., Du, W., Shi, K.Q., and Dai, T. (2019). Arthroscopic-Assisted Closed Reduction and Internal Fixation for Pilon Fractures. Chinese Journal of Orthopedic Surgery, 27(24):2237-2241.

DOI:10.31579/2690-1919/477