The Foot xxx (xxxx) xxx-xxx

Contents lists available at ScienceDirect

The Foot

journal homepage: http://ees.elsevier.com

Journal Cover Image

Original Article

Posterior approaches to the ankle – an analysis of 3 approaches for access to the posterior malleolar fracture

Matthew D.G. Philpott [a], Malwattage Lara Tania Jayatilaka [a], Graham Millward [a], Andrew Molloy [a,b], Lyndon Mason [a,b,*]

[a] *Liverpool Hospitals NHS Foundation Trust, UK*
[b] *University of Liverpool, Liverpool, UK*

ARTICLE INFO

Keywords
Ankle fracture
Posterior malleolus
Approaches
Posterolateral
Posteromedial
CT

ABSTRACT

Background: We conducted an anatomical study to determine what degree of access to the posterior distal tibia could be gained by using 3 different approaches; the posterolateral, the posteromedial and the medial posteromedial approaches.
Methods: We conducted a comparison study, between the anatomical dissection of 7 fresh frozen cadaveric lower legs and image analysis of CT data of posterior malleolar fractures from a prospectively collected database. All fractures have been classified using the Mason and Molloy classification.
Results: In comparing the posterior malleolar fracture fragment width to distal tibia width, the posterolateral fragment encompasses 60.1% (95% CI 56.8, 63.3) of the total width of the tibia. If the posteromedial fragment is included the fragments encompass the entire distal tibia (100%). In type 3 fractures, 81.4% (95% CI 75.5, 87.1) of the distal tibia width is involved.When comparing the fracture width to the approach, no approach achieves a complete exposure of the type 2B or 3 fracture patterns. The overall surface area of the type 2B and 3 fractures, is significantly greater than all the approaches. Considering the lateral to medial extent of the fracture, the posterolateral fragment mean width is 33% greater than what can be exposed by the posterolateral approach (mean 24.9 vs 16.8 mm). In type 2B and 3 fractures, the horizontal exposure reduces to 39.8% and 47.6% respectively. In comparison, the PM approach exposes 47.6% of the type 2B fracture pattern and 57.1% of the type 3 fracture pattern and allows a preferable angle for hardware insertion. The MPM approach does not expose any of the posterolateral fragments in this study, however it does expose 92% (mean 21.9 vs. 23.8 mm) of the medial to lateral width of a posteromedial fragment of a type 2B fracture.
Conclusion: We conclude that each approach will allow access to different parts and amounts of the posterior tibia and we feel that an understanding of and utilisation of these approaches can lead to adequate exposure for fixation of most posterior malleolus fracture patterns seen.

1. Introduction

Injuries to the ankle involving the posterior malleolus have been demonstrated by several authors to lead to a poorer outcome for patients [1–3]. As a result, the management of these injuries has been subject of much research and debate in the current literature. Most agree that posterior malleolar factures are not homogenous. Mason and Molloy developed a classification of posterior malleolar fractures based on the CT appearance and proposed mechanism, categorising the fracture patterns into 3 main categories based on the pathomechanism [4]. Further work has produced recommendations on differing approaches and fixation methods for the different fracture patterns based on this classification [5,6].

A number of authors have illustrated improved clinical outcomes following open reduction and internal fixation of posterior malleolar fractures [5,7–10]. Three studies have demonstrated outcomes to be more predicatable and superior in patients undergoing posterior fixation of posterior malleolar fractures as compared to fixation with anteroposterior screws [9,11,12]. Miller et al. also demonstrated that syndesmotic stability was greatly improved when patients were positioned prone and posterior malleolus fractures were directly fixed compared to those fixed in the supine position. The on-going debate on the optimal fracture fixation technique for these fractures is beyond the scope of this paper.

Gandham et al. conducted a CT study on 141 posterior malleolar fractures of varying types, concluding that to fully expose each sub-

* Corresponding author at: Trauma and Orthopaedic Department, Aintree University Hospital, Lower Lane, Liverpool, UK.
E-mail address: lyndon.mason@liverpool.ac.uk (L. Mason)

https://doi.org/10.1016/j.foot.2020.101725
Received 13 March 2020; Received in revised form 18 June 2020; Accepted 4 August 2020
Available online xxx
0958-2592/© 2020.

type, differing incisions were necessary [6]. The anatomy of the three posterior approaches to the posterior ankle as advocated by Mason et al. for managing posterior malleolus fractures has not been explored previously [4,6]. Our aim in this study was to assess the extent of the distal posterior tibia that can be exposed through each approach advocated by Mason et al., in order to help guide the choice of surgical approach to be taken when dealing with the non-homogenous posterior malleolus fractures of the ankle.

2. Materials and methods

This study was undertaken at Keele University under the auspices of the Human Tissue Authority license held by the Keele Anatomy and Surgical Training Centre at the University of Keele Medical School. Cadaveric images used were taken with permission. We examined 7 fresh frozen cadaveric lower limbs that had been amputated at the level of the mid tibia. No specimen had any signs of premortem surgical intervention or scars about the ankle and were morphologically normal.

The specimens were positioned prone to replicate normal surgical practice. Three posterior ankle approaches (posterolateral (PL), posteromedial (PM) and medial posteromedial (MPM) approaches were performed, using a consistent repeatable incision of 7 cm extended proximal from a line drawn from the palpable distal extent of the medial and lateral malleoli (Fig. 1). The order of the incisions was randomly chosen to reduce the bias of each incision mobilising the soft tissue and impacting on the subsequent incisions. Incision length of 7 cm was chosen to ensure the largest reported posterior malleolar fractures, as reported by Jayatilaka et al., would be included in the scope of the incision [13].

In both the PL and PM approaches, the flexor hallucis longus (FHL) was taken medially. In the MPM approach, the access was anterior to tibialis posterior (TP). Kirchner wires were then placed parallel to one another at the 4 extremities of the approach (proximal, distal, medial and lateral) without significant tension on the soft tissues (Fig. 2). The ankles were imaged using an image intensifier and the distances measured between the Kirchner wires. For the posterolateral approach the sural nerve was identified within the incision. The points at which it entered the incision proximally and distally were measured.

2.1. Dissection/approaches

Three surgical approaches were utilised in this study; posterolateral (PL), posteromedial (PM) and medial posteromedial (MPM). Each approach contains a repeatable sequence of the investing fascia, the muscular fascia overlying the muscle compartment, and then the periosteum. For the posterolateral approach (PL) the skin incision was marked out half-way between the posterior edge of the fibular and the lateral edge of the Achilles tendon, extending 7 cm proximal from the intermalleolar axis (the line drawn between the distal tips of the medial and lateral malleoli). The sural nerve and short saphenous vein were identified and protected superficial to the investing fascia. The investing fascia was then opened revealing the fascia superficial to the flexor hallucis longus (FHL) and peroneal compartment. To expose the distal tibia and posterior incisura, the deep fascia was incised over the FHL and the FHL muscle was mobilised medially. The next layer reveals the periosteum, PITFL and intermalleolar ligament. Care was taken to elevate the periosteum and leave the posterior syndesmotic ligaments intact.

For the posteromedial approach (PM) the skin incision was made immediately medial to and parallel with the Achilles tendon, and was extended 7 cm proximally from the intermalleolar axis. After going through the skin, care was taken to avoid the Achilles tendon paratenon, then the investing fascia was opened revealing the fascia superficial to the FHL. The fascia over the FHL was opened as lateral as is allowed by the incision. The FHL muscle belly was elevated off the posterior aspect of the tibia from lateral to medial and retracted medially. The same periosteal precautions were taken as with the posterolateral approach.

The medial posteromedial approach (MPM) was marked out along the posteromedial edge of the tibia, starting from the intermalleolar axis and extending 7 cm proximally. The investing fascia was opened longitudinally exposing the tibialis posterior tendon sheath. The tibialis posterior tendon sheath was opened longitudinally, and the exposed tendon was protected and retracted laterally. The periosteum was then elevated to expose the posteromedial tibia.

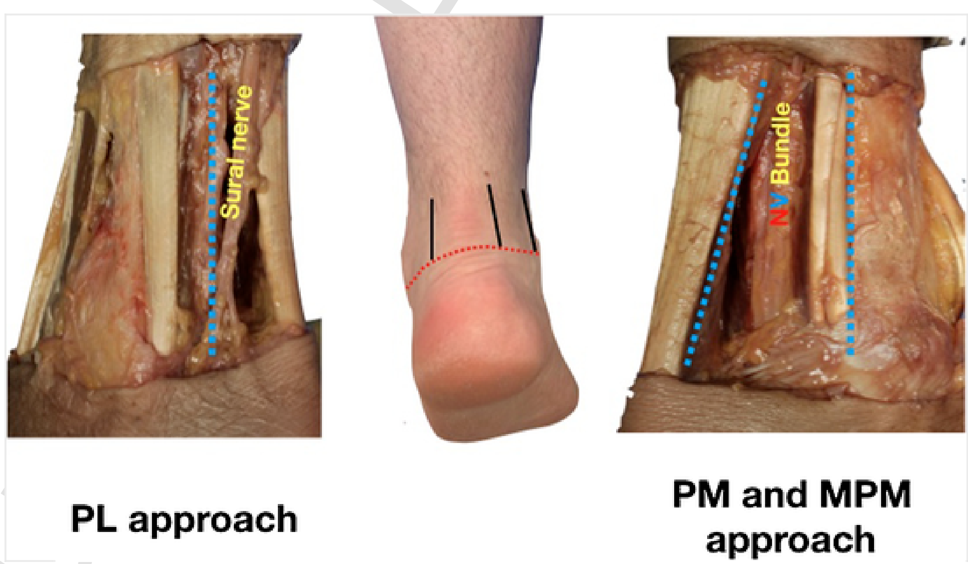

Fig. 1. The central picture illustrates the 3 approaches that were undertaken for this study. Skin incisions for PL, PM and MPM approaches marked out – 7cm proximal from line between distal tips of medial and lateral malleoli. The picture on the left is an anatomical dissection with a superimposed PL approach. The sural nerve clearly crosses the approach distally. The picture on the right illustrates an anatomical dissection with a superimposed PM and MPM approaches. The neurovascular bundle is protected by the FHL in the PM approach and tibialis posterior in the MPM approach.

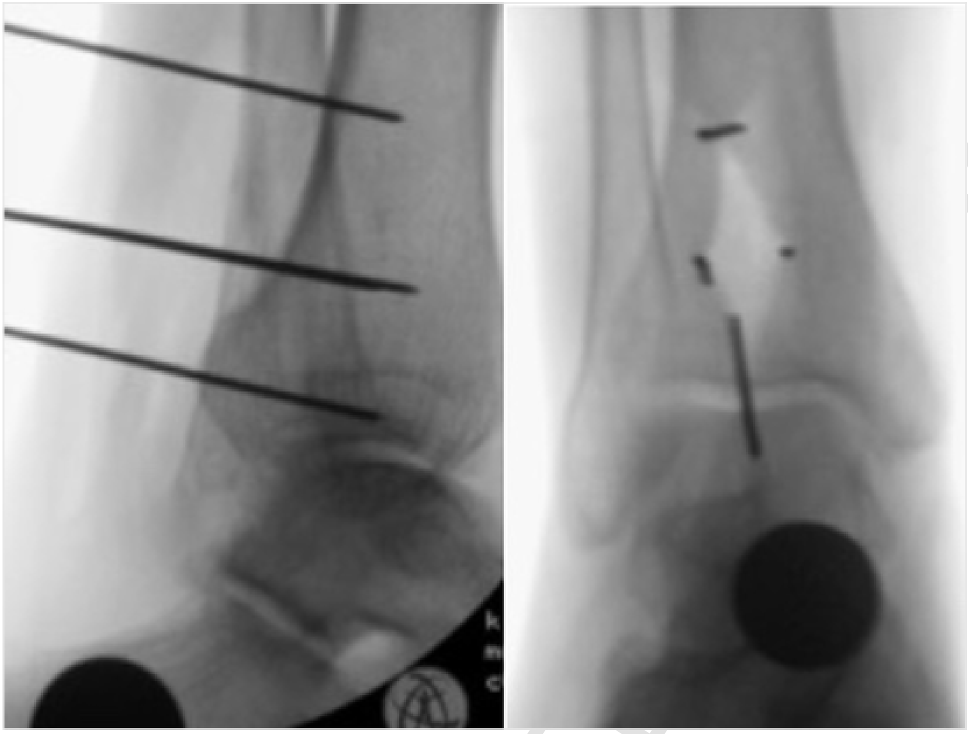

Fig. 2. Lateral and anteroposterior radiographs of 4 parallel K-wires inserted through a PM incision at the apex, base, medial and lateral extremities. A marker was used in all cases to ensure accurate measurements. The soft tissue shadow indicating the exposure is clearly illustrated on the anteroposterior radiograph.

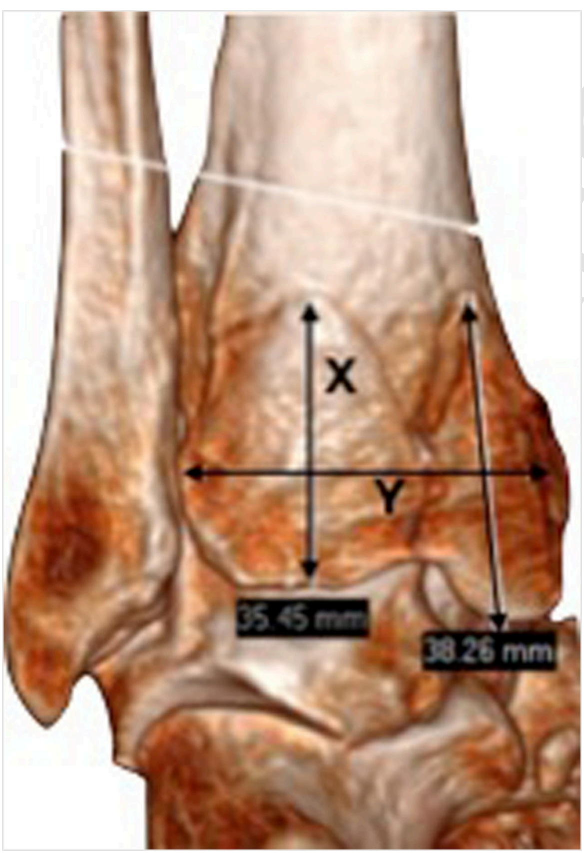

Fig. 3. 3D surface rendering of a Mason and Molloy 2B Posterior Malleolar Fracture with the illustration of the measurements taken. Measurements were also taken for the distal tibia width in every fracture.

2.2. Radiographic measurement

Our prospectively collected ankle fracture database was accessed to collect all posterior malleolar fractures attending between December 2014 and July 2018. CT scans, with 3D reconstruction images, were performed on all patients. The posterior malleolar fracture fragments were assessed using the departmental digital imaging software (Vue PACS, Carestream, Version 11.4.1.0324) as described by Jayatilaka et al. [13] Maximum length of posteromedial and posterolateral fragments in 2 axes (X, Y) were reported by reviewing axial, coronal, sagittal and 3D surface rendering of all fractures. X axis was classed as the proximal to distal length measured on sagittal, and the Y was medial to lateral on axial sections (Fig. 4).

2.3. Statistics

Descriptive statistics were analysed using IBM SPSS software version 25 for Windows (IBM Corp., USA). The surface area of each approach and fracture fragment were calculated by the area of a rhombus (1/2XY). The differences were considered statistically significant when p value was less than 0.05.

3. Results

The fluoroscopic images taken in the cadaveric anatomy lab were analysed and measurements were taken for each approach. The areas calculated for each approach are approximations based on the horizontal and vertical limits of the approaches. These measurements are illustrated in Table 1. Using the Kruskal–Wallis test there was no statistically significant difference between the groups ($P = 0.41$). The surface area of each approach is given in Table 1, illustrating a significantly greater exposure in the posteromedial and medial posteromedial approach as compared to the posterolateral approach ($P = 0.05$).

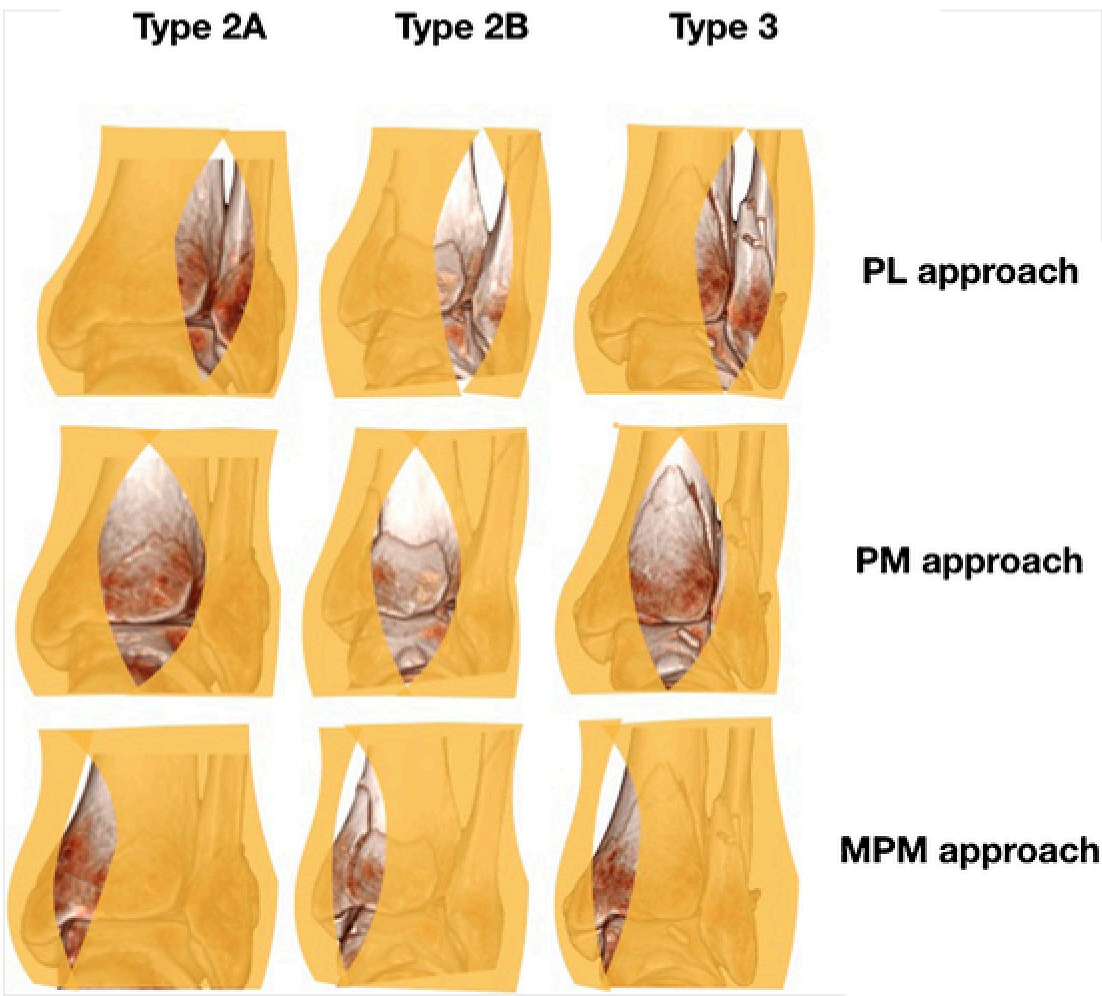

Fig. 4. Pictorial representation of Mason and Molloy types 2A, 2B and 3 with the differing approaches superimposed. As each picture represents a prone position, the width of the approach will appear smaller in the PL and MPM due to the differing orientation. This illustrates the easier access to the type 3 fracture patterns in the PM approach and the medial fracture fragment of a type 2B fracture using a MPM approach.

Table 1
Dimensions between K wires, measured of the 3 approaches. Surface area calculated as stated in methods.

Specimen number	Posterolateral		Posteromedial		Medial Posteromedial	
	Vertical (mm)	Horizontal (mm)	Vertical (mm)	Horizontal (mm)	Vertical (mm)	Horizontal (mm)
1	50.0	18.0	50.0	20.0	51.7	25.0
2	52.4	16.5	52.3	23.0	57.5	26.0
3	46.4	15.0	71.0	16.7	45.6	16.7
4	35.7	15.7	60.7	25.0	53.9	23.3
5	46.4	15.6	50.0	12.2	66.7	16.7
6	40.6	17.1	55.7	21.5	54.7	22.0
7	42.4	19.5	53.7	20.0	59.6	23.5
Mean average distances	44.8	16.8	56.2	19.8	55.7	21.9
Surface area	367.3 mm^2		556.4 mm^2		609.9 mm^3	

In the posterolateral approach, the sural nerve was found crossing the incision from posterior to anterior. The nerve was measured at the point at which the sural nerve entered the approach distally and how long it was present in the approach. These measurements are illustrated in Table 2. On average the sural nerve is present in 40 mm of the approach and appears 13 mm from the distal end of the approach as it crosses from posterior to anterior.

Our prospectively collected database of surgically treated posterior malleolar fractures contained 172 cases. Using the Mason and Molloy classification, there were 86 type 2 and 3 posterior malleolar fractures that could be included in the study. The dimensions of these fractures are illustrated in Table 3. In comparing the posterior malleolar fracture fragment width to distal tibia width, the posterolateral fragment encompasses 60.1% (95% CI 56.8, 63.3) of the total width of the tibia. If the posteromedial fragment is included the frag-

Table 2
Sural nerve position in the posterolateral approach.

	1	2	3	4	5	6	7
Length of nerve within approach	35 mm	50 mm	34.8 mm	50 mm	36.5 mm	38.1 mm	36.3 mm
Most distal aspect of the sural nerve	14 mm	13 mm	12.6 mm	13 mm	12.4 mm	12.3 mm	16.2 mm

Table 3
Dimensions of the posterior malleolar fracture as measured on the 3D surface rendering of the preoperative CT scans obtained in our department. The measurements taken are illustrated in Fig. 3.

	Dimensions	*Y*	*X*	Area
Mason and Molloy Classification	Number	Mean (mm)	Mean (mm)	Mean (mm ^{2})
		95% Confidence intervals in brackets		
Type 2A	33	27.6 (25.9, 29.3)	23.8 (22.5, 25.1)	334.1 (298.8, 369.6)
Type 2B	34	25.0 (21.8, 28.1)	47.8 (44.7, 50.9)	613.5 (503.7, 723.2)
Type 3	19	33.7 (30.7, 36.7)	46.0 (39.3, 52.7)	799.9 (626.8, 973.1)
Distal tibia width		43.3 (41.8, 44.8)		

ments encompass the entire distal tibia (100%). In type 3 fractures, 81.4% (95% CI 75.5, 87.1) of the distal tibia width is involved.

When comparing the fracture width to the approach, no approach achieves a complete exposure of the type 2B or 3 fracture patterns. As reported in Tables 1 and 3, the overall surface area of the type 2B and 3 fractures, is significantly greater than all the approaches. Considering the lateral to medial extent of the fracture, the posterolateral fragment mean width is 33% greater than what can be exposed by the posterolateral approach (mean 24.9 vs 16.8 mm). In type 2B and 3 fractures, the horizontal exposure reduces to 39.8% and 47.6% respectively. In comparison, the PM approach exposes 47.6% of the type 2B fracture pattern and 57.1% of the type 3 fracture pattern and allows a preferable angle for hardware insertion. The MPM approach does not expose any of the posterolateral fragments in this study, however it does expose 92% (mean 21.9 vs. 23.8 mm) of the medial to lateral width of a posteromedial fragment of a type 2B fracture.

4. Discussion

Our cadaveric study has outlined three approaches to the distal posterior tibia through safe corridors and provided evidence of how much each approach can expose of the distal tibia. The posterolateral approach is most commonly utilised for fixation of the posterior distal tibia as it also allows access to the distal fibula in the same approach and it gives access to type 2A and lateral fragments of type 2 B fractures. When the cadaveric data is compared to our institutions database of surgically managed posterior malleolar fractures, only 65% of fractures could be adequately exposed using the posterolateral (PL) approach. This is similar to Gandham et al. study who identified 56% of posterior malleolar fractures were accessible through a solitary posterolateral incision. The PL incision also allows the smallest amount of exposure to the distal posterior tibia. The sural nerve is a structure at risk during this approach and we have shown where it enters and exits the incision in our described approach. This is in agreement with a cadaveric study from Jowett et al. who examined the course of the sural nerve in a similar posterolateral approach [15].

Our current study identified that 78% of the Mason and Molloy type 2 and 3 fractures could be exposed using the PM incision, although Gandham et al. noted only 26% of fractures would undergo posteromedial approach, due to other factors like fibular access. The MPM approach gave the greatest area of exposure of the distal posterior tibia. However, this approach did not allow access to the posterolateral corner of the distal tibia, which is the site of the constant posterolateral (Volkmann) fragment [6,16]. Of the cases in the database managed by open reduction and internal fixation, 35% had posteromedial fractures that could be dealt with using the MPM incision. Therefore, we advocate that this approach is used as a supplementary approach in conjunction with the posterolateral incision. This is a similar strategy to that described by Bois et al, however the posteromedial approach they describe is similar to the MPM approach in our study, but they use an interval between tibialis posterior and FDL instead of tibia and tibialis posterior [17].

Each approach had anatomical limitations in certain directions. The posterolateral approach was limited proximally by the muscle belly of FHL and medially by the Achilles tendon. This is similar in the posteromedial approach but the Achilles tendon limits lateral exposure. It is important to note that the peroneal artery lies in the fascia between the FHL and peroneal compartments, and therefore this fascia should be preserved. Lidder et al. in a cadaveric study described that when mobilising the FHL medially from its attachment to the fibula, the peroneal perforating vessels were present. They also showed that the bifurcation of the peroneal artery into the anterior perforating artery and lateral calcaneal branch may be as little as 41 mm proximal from the tibial plafond and thus meticulous tissue handling is necessary [18]. The posteromedial approach is less affected by the constraints of the muscle belly of FHL, as it decreases in size as it crosses medially past the midline and thus one is able to expose more of the tibia in this plane. However, the muscle belly of the FHL can limit this approach more proximally. The medial posteromedial approach was limited laterally due to tibialis posterior muscle and tendon especially at the point the tibialis posterior tendon fully enters its groove [19]. Access becomes difficult distally in this incision, unless the tibialis posterior tendon is mobilised out of its groove. Proximally however, the MPM approach is the most extensive approach, as it follows the medial fasciotomy line.

Previous papers have described approaches to posterior malleolus fractures in relation to other classification systems such as those described by Haraguchi et al. [20] or Bartonicek et al. [21]. The Mason and Molloy classification was used for our study as we feel it progresses in severity and also helps indicate the pathomechanics of the injuries, which can help one to decide an appropriate surgical fixation strategy [22,23]. Other studies have described two approaches to the posterior malleolus for specific fracture patterns such as Bartonicek et al. [24] and Zhong et al. [19], however this study was only based on fixation of posterior malleolar fractures using screws. A similar cadaveric study by Assal et al. described 3 approaches to the posterior malleolus. The posterolateral approach they described, involved elevating the peroneal musculature off the fibula in the same plane when exposing the distal tibia. We are concerned that this approach may compromise the blood supply to the lateral skin due to peroneal artery compromise.

The medial approaches described by Assal et al. are different to the ones used in the current study. The modified posterior medial approaches used by Assal et al. utilised the interval between FHL and FDL, with FHL being taken laterally, exposing the neurovascular bundle to compression from retractors using their posteromedial approach [25]. Other posteromedial approaches to the ankle have been well described by a number of authors [26–29]. In relation to the posterior malleolar fracture management, Bali et al. described good results with a posteromedial approach based midway between the medial malleolus and medial border of the Achilles tendon. This involves mobilising the deep posterior neurovascular bundle to allow access to the tibia either side of this [30]. Our concerns with this approach and the medial approaches described by Assal et al. are the potential for complications when exposing the deep posterior neurovascular bundle. In comparison, the posteromedial approach described in this study goes lateral to FHL and allows FHL to be retracted medially to protect the neurovascular bundle and medial posteromedial approach is anterior to tibialis posterior and FDL, which are retracted laterally to protect the neurovascular bundle. We would not advocate approaches that expose the deep posterior neurovascular bundle as utility approaches for surgeons inexperienced in approaches to the distal posterior tibia. This strategy was demonstrated to improve Olerud-Molander Ankle scores in a recent series from our department [22].

We acknowledge limitations to this study. We used a small approach to ensure comparable data between the approaches with minimal soft tissue disruption. We have not explored the proximal extension possible for each incision, due to the aim in providing comparable data between each incision. However, the MPM approach is the most extensive as it can be extended along the medial fasciotomy line. The other incisions are limited due to the lateral to medial crossing of the posterior neurovascular bundle and the FHL. The number of specimens were limited, however the number of fractures analysed was very large as compared to current literature.

5. Conclusion

From this cadaveric anatomical study, we conclude that each approach will allow access to different parts and amounts of the posterior tibia and we feel that an understanding of and utilisation of these approaches can lead to adequate exposure for fixation of most posterior malleolus fracture patterns seen, that require operative fixation. Posterior malleolar fracture patterns are not homogenous and limiting oneself to one utility incision for access to these fractures will not allow adequate exposure of all fracture patterns. The results of this study can be used to help guide the choice of approach to be used when managing different types of posterior malleolus fractures, via open reduction and internal fixation.

Conflict of interest

Mr. Lyndon Mason and Mr. Andrew Molloy are paid consultants for Stryker and Orthosolutions. Mr. Andrew Molloy is a paid consultant for Arthrex. The anatomical component of this study was completed on a course funded by Orthosolutions.

Acknowledgements

The anatomical dissection component of this study was undertaken on a course run by Orthosolutions (Essex, UK).

References

[1] S Odak, et al. Management of posterior malleolar fractures: a systematic review. J Foot Ankle Surg 2016;55(1):140–145.
[2] R A Jaskulka, G Ittner, R Schedl Fractures of the posterior tibial margin: their role in the prognosis of malleolar fractures. J Trauma 1989;29(11):1565–1570.
[3] N C Tejwani, B Pahk, K A Egol Effect of posterior malleolus fracture on outcome after unstable ankle fracture. J Trauma 2010;69(3):666–669.
[4] L W Mason, et al. Pathoanatomy and associated injuries of posterior malleolus fracture of the ankle. Foot Ankle Int 2017. p. 1071100717719533.
[5] L W Mason, et al. Posterior malleolar ankle fractures. An effort in improving outcomes. Foot Ankle Int 2018;3(3).
[6] S Gandham, et al. Posterior malleolar fractures: a CT guided incision analysis. Foot (Edinb) 2019;43:101662.
[7] A E Levack, et al. Comparing functional outcomes after injury-specific fixation of posterior malleolar fractures and equivalent ligamentous injuries in rotational ankle fractures. J Orthop Trauma 2018;32(4):e123–e128.
[8] M Kalem, et al. Comparison of three posterior malleolar fixation methods in trimalleolar ankle fractures. Acta Orthop Belg 2018;84(2):203–212.
[9] B Tosun, et al. Posterior malleolus fractures in trimalleolar ankle fractures: malleolus versus transyndesmal fixation. Indian J Orthop 2018;52(3):309–314.
[10] S M Verhage, et al. Persistent postoperative step-off of the posterior malleolus leads to higher incidence of post-traumatic osteoarthritis in trimalleolar fractures. Arch Orthop Trauma Surg 2018.
[11] T J O'Connor, et al. "A to p" screw versus posterolateral plate for posterior malleolus fixation in trimalleolar ankle fractures. J Orthop Trauma 2015;29(4):e151–e156.
[12] H Shi, et al. Comparison of the direct and indirect reduction techniques during the surgical management of posterior malleolar fractures. BMC Musculoskelet Disord 2017;18:1–8.
[13] M L T Jayatilaka, et al. Anatomy of the insertion of the posterior inferior tibiofibular ligament and the posterior malleolar fracture. Foot Ankle Int 2019;40(11):1319–1324.
[14] J Forberger, et al. Posterolateral approach to the displaced posterior malleolus: functional outcome and local morbidity. Foot Ankle Int 2009;30(4):309–314.
[15] A J Jowett, et al. Location of the sural nerve during posterolateral approach to the ankle. Foot Ankle Int 2010;31(10):880–883.
[16] R Volkmann Centralblatt für Chirurgie. Leipzig; 1875.
[17] A J Bois, W Dust Posterior fracture dislocation of the ankle: technique and clinical experience using a posteromedial surgical approach. J Orthop Trauma 2008;22(9):629–636.
[18] S Lidder, et al. The risk of injury to the peroneal artery in the posterolateral approach to the distal tibia: a cadaver study 2014;28.
[19] S Zhong, et al. Comparison of posteromedial versus posterolateral approach for posterior malleolus fixation in trimalleolar ankle fractures. Orthop Surg 2017;(9):69–76.
[20] N Haraguchi, et al. Pathoanatomy of posterior malleolar fractures of the ankle. J Bone Joint Surg 2006;88(5):1085–1092.
[21] J Bartonicek, et al. Anatomy and classification of the posterior tibial fragment in ankle fractures. Arch Orthop Trauma Surg 2015;135(4):505–516.
[22] L W Mason, et al. Posterior malleolar ankle fractures: an effort at improving outcomes. JBJS Open Access 2019. Latest articles.
[23] L W Mason, et al. Pathoanatomy and associated injuries of posterior malleolus fracture of the ankle. Foot Ankle Int 2017;38(11):1229–1235.
[24] J Bartonicek, S Rammelt, M Tucek Posterior malleolar fractures: changing concepts and recent developments. Foot Ankle Clin 2017;22(1):125–145.
[25] M Assal, et al. How to get to the distal posterior tibial malleolus? A cadaveric anatomic study defining the access corridors through 3 different approaches. J Orthop Trauma 2017;31(4):e127–e129.
[26] S Hoppenfeld, P DeBoer, R Buckley Surgical exposures in orthopaedics: the anatomic approach. 4th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2009.
[27] L F Amorosa, G D Brown, J Greisberg A surgical approach to posterior pilon fractures. J Orthop Trauma 2010;24(3):188–193.
[28] M D Hammit, E R Hobgood, T A Tarquinio Midline posterior approach to the ankle and hindfoot. Foot Ankle Int 2006;27(9):711–715.
[29] Y Wang, J Wang, CfJ B M D Luo Modified posteromedial approach for treatment of posterior pilon variant fracture 2016;17(1):328.
[30] N Bali, et al. An evolution in the management of fractures of the ankle: safety and efficacy of posteromedial approach for Haraguchi type 2 posterior malleolar fractures. Bone Joint J 2017;99–B(11):1496–1501.