Posterior Malleolus Exposure Map and Screw Trajectory: A Cadaveric Study

Specific Aims

Exposure and fixation of fractures of the posterior malleolus is a challenging aspect of ankle fracture surgery. Haraguchi et al. classified these fractures into three distinct patterns[1]. Haraguchi type 2 fractures extend from the fibular incisura to the posteromedial aspect of the plafond, often including the posterior colliculus of the medial malleolus and deep deltoid ligament. These fracture fragments often exhibit a central split, necessitating independent fixation. These are typical in hyperplantarflexion ankle fracture variants and present challenges in deciding on optimal patient positioning, surgical approach and fixation[2]. Specifically, it has not been demonstrated if the posterolateral and posteromedial fracture fragments can be reliable exposed and fixed via a single approach, or if dual approaches are needed.

The aims of this study are 1. To investigate the maximal surface area exposure of the posterior malleolus through both the posterolateral and posteromedial approaches, and 2. To identify how far across the posterior malleolus can be instrumented through either exposure.

Null Hypothesis: The posterior malleolus may be completely exposed and instrumented through either the posterolateral or posteromedial approaches.

Background and Significance

Posterior malleolus fractures occur in 44% of all rotational ankle injuries[3]. These fractures have been shown to have inferior clinical outcomes compared to simpler ankle fractures[4]. Traditional guidelines recommend fixation for fractures involving greater than 25-33% of the articular surface, based on biomechanical and cadaveric studies [5,6,7] without clinical basis.

Recent literature challenges this dogma for several reasons. First, reliability of estimating fragment size based on X-ray has been refuted[8]. Haraguchi's CT study determined that posterior malleolus fractures consist of three distinct patterns[1] (figure 1). Haraguchi type 2 fractures are of particular interest as they are often two separate fracture fragments with a common central fracture line. The lateral component contains the PITFL, whereas the medial fragment involves the posterior colliculus of the medial malleolus and deep deltoid ligament. With both structures disrupted, the ankle is unstable. These fractures have been likened to coronoid fractures as classified by O'Driscoll[9], with fracture morphology more relevant than fragment size.

Second, the role of the posterior malleolus with respect to the functional anatomy of the ankle has become clearer. It is the site of attachment of the posterior inferior tibiofibular ligament, providing 42% of syndesmotic stability[10]. Management of syndesmosis disruption is a source of much discussion. It has been proposed that anatomic fixation of the posterior malleolus or syndesmotic ligaments decrease syndesmotic malreduction rates[11]. Specifically, non-operatively managed fractures of the posterior mallelolus have been shown to lead to increased syndesmotic malreduction due to loss of the medial incisura buttress[12], allowing the fibula to slide posterior and externally rotate. Posterior malleolus fixation has also been shown to improve the strength of syndesmotic fixation compared to syndesmosis screws alone[13]. This provides an anatomic argument for direct fixation of posterior malleolus fractures.

One can access the posterior malleolus through either a posteromedial or posterolateral approach[14,15]. The posterolateral approach is most commonly used[16], however this approach limits both access, and more importantly fixation, to posteromedial fragments. The same is true for the posteromedial approach with respect to posterolateral fragments. Maximal exposure and instrumentation access through either approach has not been previously described and it has been suggested that dual posterolateral and posteriomedial approaches are needed to address Haraguchi type 2 fractures[2]. Our goal is to describe the maximal exposure and instrumentation potential to help guide patient set-up and management of these complex fracture patterns.

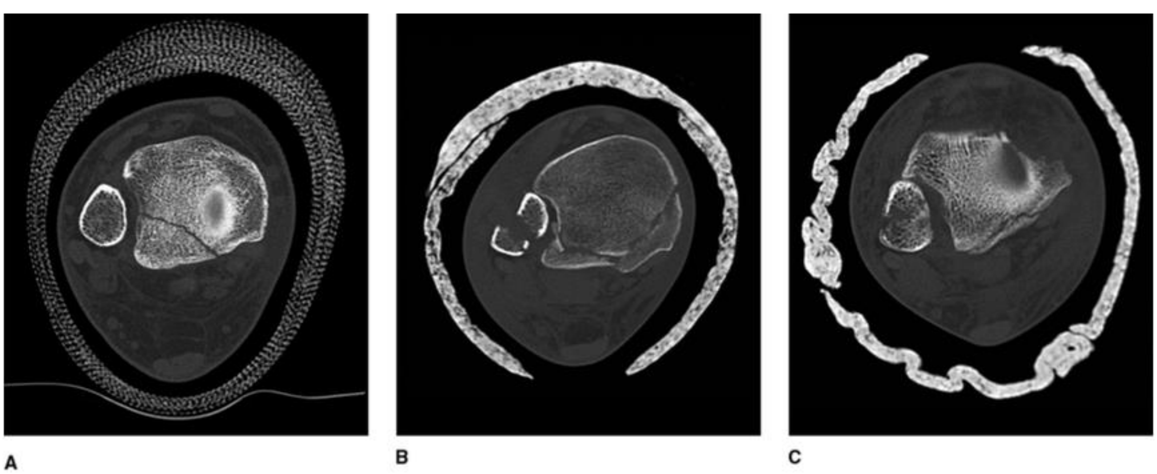

Figure 1: Harguchi Classification of Posterior Malleolus Fractures

Research Design and Methods

This will be a staged protocol to address both research questions.

Stage 1

Twelve fresh-frozen cadaveric legs will be used for surgical exposures. The knee and ankle will be included to simulate in vivo soft tissue excursion. Two will be allocated for pilot trials as needed. The legs will be thawed at room temperature. All dissections will be performed by the orthopaedic resident (BGM) under the supervision of the senior author (SP). Each approach will be performed on 5 limbs to avoid over-estimating exposure due to prior soft tissue mobilization.

The posterolateral approach will be performed as previously described[17]. The skin incision will be marked at the midpoint between the posterior border of the fibula and lateral border of the Achilles tendon, beginning at the distal tip of the fibula. The interval between the peroneal tendons and the flexor hallucis longus (FHL) will be bluntly dissected. The FHL will then be elevated from the interosseous membrane and posterior tibial surface by working lateral to medial, and retracted using a Hohman retractor to simulate in vivo technique. Dissection will continue proximally until as much posterior malleolus is visible as possible.

The posteromedial approach will be performed as previously described [15]. The incision will be marked in line with the posteriomedial border of the tibia. The distal extent will curve distally towards the talonavicular joint. The flexor retinaculum will be opened and the interval between the neurovascular bundle and FHL tendon will be exploited to prevent over retraction on the bundle when retracting laterally. The FHL tendon will then be bluntly elevated to the lateral side of the tibia and a Hohman retratctor will be placed. Proximal extension of the exposure will be extended until maximal visualization the posterior malleolus is achieved.

Following maximal exposure of the posterior malleolus with each approach, a burr will be used to score the extent of visualization. The foot will be brought into maximal plantarflexion and dorsiflexion to maximize overall exposure prior to etching with the burr.

Stage 2

The second stage of the study will involve obtaining a P-to-A screw at a point 1 cm proximal to the articular surface. The goal is to identify the range of possible screw trajectory from each approach performed. As such, through the posterolateral approach, the most medial screw trajectory possible will be assessed. Similarly, the most lateral screw trajectory attainable from the posteromedial approach will be assessed. To simulate fracture fixation, the goal is to aim towards the midline of the anterior tibia to ensure fixation perpendicular to the bone and ‘fracture line’.

Intraoperative conditions will be simulated with use of a Hohman retractor retracting the FHL to the far side of the tibia. A long 2.5 mm AO drillbit, with universal drill-guide will be used to help prevent soft tissue impingement. The screw hole will then be measured using an AO depth gauge and a 3.5 mm AO screw will be placed.

Screw Trajectory Assessment

All cadaver legs will be identified by surgical approach used by tagging the great toe. CT scans of each leg will be obtained to produce 1 mm axial cuts (Aquilion ONE; Toshiba Medical Systems, Tochigi, Japan). We will then employ the 'Cole Mapping Technique' to create overlay images, as has been previously described for the tibial plafond [18,19]. An axial cut at the level of the screw (1 cm proximal to the articular surface) will be digitally transferred to Gimp Photoshop software (GimpShop, Tampa, FL). The images will be standardized to side, and a grid will be overlaid to calibrate sizing and rotation. The fibula and incisura will be used as a control for rotation. Overlay images will then be created for both the posterolateral approach group, and the posteromedial approach group. This will give an overlay map of screw trajectory.

Screw trajectory will be assessed in two ways. The posterior malleolus will first be defined as the length from the posteromedial corner of the plafond to the posterolateral corner of the fibular incisura. The screw start point will be measured as a distance from the side of their respective approach, and expressed as a percentage of the distance across the plafond. The range of trajectories possible from each starting point will also be measured. This will be performed by measuring the angle between a line perpendicular to the trans-malleolar axis, and the most medial and lateral screws, respectively.

Surface Area Measurement

The methods for measuring the surface area exposure have been previously described[20]. The soft tissues overlying the ankle will be stripped for analysis. A laser-and-camera surface scanning system will be used to digitize the bones in order to quantify the exposed surface area. Each bone will be positioned within a calibration frame and scanned at multiple angles with use of a high-intensity linear laser. The scans from each bone will be referenced to the calibration frame and were recorded with a high-resolution video camera. The recordings will then be processed into surface maps by triangulating the projection of the laser line on the bone and reference frame with DAVID-Laserscanner software (DAVID Vision Systems, Koblenz, Germany). The generated surfaces will then be overlaid and merged to obtain a complete three-dimensional model with use of the Iterative Closest Point (ICP) algorithm in the scanning software. This reconstruction technique has been shown to be very accurate, with <0.4 mm RMS (root-mean-square) error[21]. This system has been internally validated with use of a precision-machined reference component and was shown to have a similarly high accuracy, with an RMS error of <0.3 mm.

Role of the Resident

This project has been the work of the resident from the stages of research idea and design to the present stages. The resident developed the project and approached the staff for mentorship and oversight involvement. The resident developed the study proposal and protocol, presented the proposal to the local biomechanics and anatomy lab, liaised with the lab for cadaver acquisition, and submitted for approval from the local Departmental Ethics Approval Board. The resident, under senior staff supervision, has performed this grant application.

Going forward, the resident will be responsible for cadaveric dissections and execution of the study protocol under supervision of the senior author. He will liaise with the biomechanics lab throughout the data collection phase, and with the local research methods center for the statistical analysis. Manuscript development will be done by the resident as well as abstract submission and presentation at the local Orthopedic Research day, Department of Surgery Research day, and at a future OTA meeting.

References

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OTA Resident Research Grant Budget Sheet

Budget cannot exceed $20,000

Submitting a budget over this amount disqualifies your application for consideration

- Salaries and Wages: Enter name, percentage of time on project and salary requested as well as fringe benefits charged to the grant. Please also state what each person will be doing.
- Permanent Equipment: Justification to be appended.
- Consumable Supplies: Excludes animals and animal care.
- Animals and Animal Care: Justify all requests where need is not apparent.
- All Other Expenses**:** Charges for overhead are not covered by OTA Grants. No indirect costs will be funded.

SALARIES AND WAGES (List all personnel for whom money is requested)	% Of Time on this project	Requested from OTA Funds (Omit Cents)
Research Engineer - 0.035 FTE (Study design, analysis, manuscript assistance)	3.5%	$ 4200
Technician/Student (TBD) - 0.1 FTE (Scanning, mesh workflow)	10 %	$ 4000
CT Technician (TBD) - 1X4 hours scanning session	4 hrs	$ 400
Statistics consultant (TBD) – 10hrs@ $75/hr	10 hrs	$ 750
Fringe Benefits _______% of Salaries and Wages Salaries and Wages plus Fringe Benefits	TOTAL	$ 9350

PERMANENT EQUIPMENT (Justification to be appended)		
Surface scanner maintenance/modification		$ 800
Surface scanner software Upgrade		$ 500
	Subtotal	$ 1300

CONSUMABLE SUPPLIES (Exclude animals and animal care)		
Cadaveric lower limbs (Above the Knee amputation)		$ 4800
Lab supplies		$ 100
Screws and power equipment		Donation
	Subtotal	$ 4900

ANIMALS AND ANIMAL CARE		
	Subtotal	

ALL OTHER EXPENSES		
Manuscript and poster development, publication fees		$ 500
Meeting / Conference Travel fees		$ 1000
	Subtotal	$ 1500

TOTAL DIRECT COSTS $17, 050