Posterior malleolar fractures

Diagnostic accuracy, morphology and clinical outcome

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OUTLINE OF THE CURRENT ISSUES AND AIMS OF THIS THESIS
The ankle is a complex joint that acquires its stability through a combination of bony and ligamentous structures. The osteology of the ankle joint consists of three bones: the tibia, fibula and talus. The predominant ankle articulation is between the tibia and the talus. The distal part of the fibula is known as the lateral malleolus. The medial malleolus is a tubercle of the distal tibia that curves down and articulates with the medial side of the talus. The posterior malleolus, to which the present thesis relates, is also part of the tibia at the posterior side.

In the sagittal plane, the tibial plafond is concave, with the posterior lip of the plafond extending distally. H. Earl, (1789–1838, England) was the first to describe a fracture-dislocation of the posterior edge of the tibia in 1828. Notwithstanding the fact that H. Earl described this type of fracture in 1828, F.J. Cotton (1869–1938, America) wrote about a ‘new’ type of ankle fracture named after himself in 1915. E. Destot (1864–1918, France) later introduced the term ‘malléole postérieure’ (posterior malleolus) in 1911. In 1932, M.S. Henderson introduced the term ‘trimalleolar fracture’.

The posterior malleolus is also known as the posterior rim, the posterior edge, the posterior fragment of the distal tibia, the tertius fragment or the Volkmann fracture (Figure 1).

To date, there is an ongoing debate in the orthopaedic trauma community whether or not to fix this fragment, and if so, which size or types of posterior malleolar fractures require fixation in association with rotational type ankle fractures.

The ligamentous structures, which are of great importance to syndesmotic stability and associated with the posterior malleolus is the distal tibiofibular syndesmotic complex. This complex consists of the anterior inferior tibiofibular ligament (AITFL), the posterior inferior tibiofibular ligament (PITFL) and the interosseous ligament. The PITFL runs from the posterior malleolus to the posterior side of the fibula. It consists of a superficial component and a deep component. A fracture of the posterior malleolus leads to the loss of a part of the syndesmotic stability.

Ankle fractures are common injuries in the emergency room, with an incidence of 1-2 per 1000 patients, accounting for up to 32,000 cases annually in the Netherlands and are described as the third most common Orthopaedic Trauma presentation. We consider an ankle fracture when one or more parts of the distal tibia or fibula are fractured. Seventy percent of ankle fractures are isolated malleolar fractures, predominantly fractures of the lateral malleolus. 23% are bimalleolar fractures, often involving the lateral and medial malleolus. Approximately 7-44% of these fractures present with a posterior malleolar fragment. Posterior malleolar ankle fractures occur most frequently in the setting of a rotational type ankle fracture, although they rarely occur in isolation.

Fractures of the posterior malleolus have been the subject of interest for more than 200 years and are one of the most controversial issues in the treatment of ankle fractures. In general, patients with an ankle fracture involving the posterior malleolar fragment have worse clinical outcome compared to uni or bimalleolar ankle fractures. This may be due to the high energy trauma needed to fracture the posterior malleolus, the fact that a posterior malleolar fracture is not often anatomically reduced, or even less often fixed and maybe because of the high complications rate which even amputation includes. In a systematic review of 1822 ankle fractures, Stufkens et al. concluded that, only 58% of the ankle fractures involving a posterior malleolus achieved good to excellent result four years postoperatively.
Retrospective studies compared operative and conservative treatment options with different thresholds for articular involvement of the posterior malleolar fragment. Besides, differing operation techniques and varying protocols are used to address the posterior malleolus. The results of the studies are conflicting and inconsistent. As a result, the authors of the most recent reviews were still unable to recommend level-1 evidence-based treatment and outcome for posterior malleolar fractures. Historically, and even today, the reason that is most frequently mentioned as decisive on whether or not to address the posterior malleolus is the size of the fragment. Several authors recommend internal fixation of the posterior malleolus for fragments within the range of 25% to 33% of the tibial plafond. Several retrospective studies and reviews still support this threshold. The work presented in this thesis seeks to further elucidate posterior malleolar diagnostic accuracy, morphology and clinical outcome.

**Part I** of this thesis comprises of three chapters describing the diagnostic accuracy of plain lateral radiographs and Computed Tomography (CT) scans for identification of posterior malleolar fragments and the 3D morphology of posterior malleolar fragments.

**Part II** examines two long-term follow-up studies on ankle fractures including a posterior malleolus, based on psychosocial aspects of the patients and fracture characteristics.

**Part III** entails three chapters in which the authors analyzed whether posterior malleolar fragment morphology and use of postoperative Quantitative 3 Dimensional Computed Tomography (Q3DCT) measurement techniques influence the clinical outcome of patients with a posterior malleolar fracture.

**PART I— DIAGNOSTIC ACCURACY AND POSTERIOR MALLEOLAR FRACURE CHARACTERISTICS**

Chapter 1: Guesstimation of posterior malleolar fractures on lateral plain radiographs

V. Chaput was the first who demonstrated (in ‘Société de Chirurgie’ in 1899) a roentgenogram of a posterior malleolar fragment. The initial radiographic examination includes anterior posterior (AP), mortise and lateral plain radiographs for evaluation and diagnosis of ankle fractures. The percentage of articular involvement of the posterior malleolar fracture that benefits from anatomical reduction and fixation remains the subject of ongoing debate in Orthopaedic and Trauma Surgery. In 1940, M.C. Nelson introduced a new interpretation of posterior malleolar fractures. He described two different fragments, the ‘classical’ trimalleolar fragment and the ‘minimal’ fragment. By ‘classical’, he meant a posterior fragment that involved one-third or more of the articular surface of the distal end of the tibia. By ‘minimal’ he sought to indicate the involvement of less than one-third of the tibial articular surface. This cut-off point is based on only one patient treated by Nelson, as well as a small number of biomechanical studies.

The guideline of 25% - 33% of the articular surface of the posterior malleolar fragment seems arbitrary since the measurements have all been made on plain lateral radiographs. Moreover, accuracy of plain lateral radiographs have yet to be investigated as to date the literature lacks a reference standard. Also, clinical decision-making is highly variable, as demonstrated through a dedicated survey. 29% of the surgeons used fragment size of 25% or larger as an indication for surgical fixation of...
the posterior malleolar fracture. If size of posterior fragments is important in decision-making it
seems foolish to rely on questionable diagnostics.

This chapter presents a study of diagnostic accuracy. The objective was to measure articular
involvement of posterior fragments in ankle fractures on plain radiographs using Q3DCT
reconstructions as a reference standard. A second objective is to assess the reliability of decision-
making when determining whether or not to fix the posterior malleolar fragment.

The primary hypothesis is that surgeons overestimate articular involvement of posterior
malleolar fragments measured on plain radiographs. However, our secondary hypothesis, it is
expected that there would be agreement in clinical decision-making on whether or not to address
the posterior malleolar fragment.

Chapter 2: Diagnostic accuracy of 2-Dimensional computed tomography for articular involvement and fracture pattern of posterior malleolar fractures

2D-CT is expected to enhance surgeons’ ability to estimate size and morphology of posterior
malleolar fragments more accurate. Many studies to date lack 2D-CT. Despite the fact that the three most recent reviews advice to use 2D-CT to guide treatment of posterior
malleolar fragments, accuracy of 2D-CT is never clarified. This chapter evaluates the diagnostic accuracy of 2D-CT in the assessment of posterior malleolar fragment size according to Q3DCT as a reference standard. Also the value of 2D-CT imaging in preoperative planning and the degree of variation in surgical management is assessed. Finally, the diagnostic accuracy of 2D-CT to the accuracy of plain radiographs as measured in chapter three is compared.

The primary hypothesis is that surgeons measure the articular involvement more accurately
on 2D-CT in comparison to plain radiographs. Secondary hypothesis, it is assumed that surgeons
would agree on the value of 2D-CT for preoperative planning, but not on the management of
addressing posterior malleolar fractures.

Chapter 3: Posterior malleolar fracture patterns

Much controversy exists around the question whether fracture size correlates with management
and clinical outcome. Knowledge of the characteristics of posterior malleolar fragments will
contribute to the general understanding of ankle fracture patterns. Haraguchi et al. were the first to
explore the pathoanatomy of the posterior malleolus based on 2D-CT instead of size. They described three types, based on 57 cases (Figure 3):

- Type- I: fracture of the posterior malleolus (67%), with a triangular fragment involving
  the posterolateral corner of the tibial plafond.
- Type- II: fracture of the posterior malleolus, with extension of the fracture line to the anterior
  part of the medial malleolus (19%).
- Type- III: fracture of the posterior malleolus, with small shell-shaped fragments at
  the posterior lip of the tibial plafond (14%).

It has been suggested that 3-dimensional (3D) morphology of the posterior malleolar fragment
might be more important than fracture size. However, 3D pathoanatomy was never clarified.

Chapter 3 seeks to characterize posterior malleolar fracture morphology by using the Cole
fracture mapping technique. Subsequently the reliability of Q3DCT-modeling for posterior malleolar
fractures is examined, and posterior malleolar fracture pathoanatomy is correlated to the Cole
fracture map, as well as to 3DCT quantification of posterior fragment size and articular involvement.

The primary hypothesis is that Haraguchi type I and type III fractures are part of a continuous
spectrum. A secondary hypothesis is that Q3DCT is a reproducible technique for posterior
malleolar fractures to measure fragment size and articular involvement. Haraguchi type I and III
differ from type II fractures in terms of fracture mapping, but not significantly with respect to
articular involvement according to Q3DCT.

PART II – POSTERIOR MALLEOLAR FRACTURES: LONG-TERM
CLINICAL OUTCOME

In part II, subdivided in chapter 4 and chapter 5, retrospective studies of more than 100 ankle
fractures, including a posterior malleolar fragment after more than 20 years of follow-up
are described.

Chapter 4: What factors are associated with outcomes scores after surgical
treatment of ankle fractures with a posterior malleolar fragment?

Psychological aspects of recovery from musculoskeletal injury merit greater attention. In general,
patients with upper extremity trauma, measurements of depression and pain catastrophic thinking
are known predictors of disability. To the best of our knowledge, it is unknown if psychological
aspects accounts for the variability in unsatisfactory outcomes after rotational type ankle fractures
in long-term.

This chapter evaluates which factors are associated with better or worse scores on validated
lower-extremity outcomes instruments after surgical treatment for rotational type ankle fractures
including a posterior malleolar fragment at long-term follow-up.

The primary hypothesis is that patient-reported outcome measure scores have little to do with
pathophysiology; they mostly reflect impairment and depression symptoms.
Chapter 5: Twenty-four year follow-up of 128 surgically treated ankle fractures with a posterior malleolar fragment: A retrospective cohort study
As stated before, 58% of the ankle fractures involving a posterior malleolus achieved good to excellent results four years postoperatively. Precise prediction of the long-term outcome on ankle fractures including a posterior malleolar fragment remains impossible. This is because lack of up to date long-term follow-up studies regarding fracture characteristics, objective outcome scores, subjective outcome scores and osteoarthritis scores. All retrospective studies are outdated or have a limited follow-up period of less than 10 years.

This chapter evaluates and reports long-term patient- and physician based functional outcomes of ankle fractures including a posterior malleolar fragment after 24 years follow up. Secondly, this study analyses, which fracture characteristics, are predictors for long-term outcomes in rotational type ankle fractures including a posterior malleolar fragment.

The hypothesis is that Weber C-type fractures, Lauge-Hansen SER4, medial malleolus fractures and open trauma tend to have worse clinical outcomes.

PART III – EVALUATION OF POSTERIOR MALLEOLAR FRACTURES

Chapter 6: Posterior malleolar fracture morphology determines outcome in rotational type ankle fractures.
In elbow fractures, O’Driscoll et al. revealed that the morphology of a coronoid fracture is a more important consideration than coronoid fracture height in guiding clinical decision-making. Three specific types of coronoid fractures are associated strongly with three specific overall patterns of traumatic elbow instability. Although some authors still debate the size of the posterior malleolar fragment that requires fixation, we concur with recent review articles: fragment morphology may be more important than size. Unfortunately, since the publication on fragment morphology of Haraguchi in 2006, there is no evidence to support recommending specific treatment choices for the different types of posterior malleolar fractures.

Chapter 6 analyzes whether the morphology of posterior malleolar fragments is associated with functional outcome of patients.

The hypothesis is that there is no difference in patient-based outcome between Haraguchi type II versus the spectrum of Haraguchi Type I and III.

Chapter 7: Articular gap and step-off revisited: 3D quantification of operative reduction for posterior malleolar fragments
Despite advanced imaging techniques, classic measurements of postoperative fracture reduction of posterior malleolar fractures have not been revisited to date. With the development of 3D technology we expand our understanding of reduction postoperatively but we need innovative and reliable postoperative measurements of reduction before it might be a promising adjunct.

Chapter 8: Quantification of post-operative posterior malleolar fragment reduction using three-dimensional computed tomography (Q3DCT) determines outcome of patients with rotational type ankle fractures
The Swiss AO (Arbeitsgemeinschaft für Osteosynthesefragen) group coined the principles of restoration of the articular surface as one of the basic prerequisite for good long-term outcome. For a long period, the decisive factors for indication to surgery was the size of the articular surface carried by the posterior malleolar fragment and its displacement. In 1922, B.F. Lounsbury and A.R. Metz were the first to describe open reduction and internal fixation of the posterior malleolar fracture as a consequence of conservative treatment achieving unsatisfying outcomes.

Articular congruity is an important factor to consider in deciding whether operational fixation would be appropriate. There is a lack of evidence-based quantified cut-off points for acceptable articular step-off and gap-size in ankle fractures, as they do emerge in other fractures. In 1974 Joy et al. introduced the 2 mm displacement rule as acceptable for posterior malleolar fractures. Orthopaedic and Trauma surgeons continued to use this rule after Jupiter’s ‘classic’ 2 mm step-off for distal radius fractures. In 1971 Osteoarthritis occurred more frequently when postoperative step-off was 1 mm or more, regardless of whether this was fixed, as concluded by Drijfhout and Langenhuijsen. Unfortunately, the measurements were made on unreliable plain lateral radiographs.

Recent reviews advised Orthopaedic Trauma surgeons to focus on restoring articular congruity, correct posterior talar translations, address articular impaction, removing osteochondral debris and achieve syndesmotic stability. Despite advanced imaging techniques, quantification of posterior malleolar fragment size, step-off and gap have not been revisited clinically.

Chapter 8 seeks to clarify the role of posterior fragment reduction by using our new techniques as described in chapter 7, with the objective of correlating these Q3DCT measures of multidirectional displacement, fracture gap and step-off with patient and physician based outcome of the patient after one-year follow-up.

The hypothesis is that step-off and fragment size correlate with osteoarthritis and patient-based clinical outcome.
REFERENCES


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